NORTH PACIFIC RESEARCH BOARD PROJECT FINAL REPORT

Ice Seal Bio-Monitoring in the Bering-Chukchi Sea Region

NPRB Project 312 Final Report

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Abstract

We collected tissue samples and recorded morphological measurements from more than 1,100 seals of four species from the subsistence harvest in eight Alaskan villages in 2000–2005. Our goal was to use these samples to develop indices of population status and health, such as age at first reproduction, pregnancy rate, growth rate, body condition, diet, contaminant levels, and genetic diversity. We have completed preliminary analyses for productivity, body condition, diet, contaminants, genetics and traditional knowledge. Both trace element and organochlorine levels were low compared to other places in the Arctic. Patterns in mitochondrial DNA do not indicate the presence of stock structure in any species. Current reproductive rates were similar to maximum documented rates. We are approaching sample sizes that will allow complete analyses of the above parameters. We will also be able to compare the current status of ice seal populations with several time periods in the past.

Key Words

Ringed seal, bearded seal, spotted seal, ribbon seal, *Phoca hispida, Erignathus barbatus, Phoca largha, Phoca fasciata*, Bering Sea, Chukchi Sea, stock structure, diet, productivity, contaminants

Citation

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Study Chronology

This study began in 2002 with funding from the National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries). North Pacific Research Board (NPRB) funding partially supported this study from 1 May 2005–30 April 2006. Although this is a 'final report' for NPRB, the study is continuing into 2007 with funding from NOAA Fisheries. In order to maximize sample sizes and produce the most meaningful results possible, we incorporated samples collected from Shishmaref between 2000 and 2002 with funding from Sea Grant and samples collected from Little Diomede between 2000 and 2005 with funding from the National Science Foundation.

Introduction

Bearded (*Erignathus barbatus*), ringed (*Phoca hispida*), spotted (*P. largha*), and ribbon (*P. fasciata*) seals are the species of Alaska's seals collectively called ice seals because they depend upon sea ice for feeding, resting, and pupping. Ice seals are an important component in maintaining the subsistence culture of Alaska Natives, because they are a source of food and clothing. Ice seals are also important components of the Bering, Chukchi, and Beaufort seas ecosystems, because they feed at several trophic levels (Shustov 1965, Frost and Lowry 1980, Lowry et al. 1980, Burns 1981, Lowry et al. 1981, Antonelis et al. 1994), may compete with some commercial fisheries (Lowry et al. 1978, Bukhtiyarov et al. 1984, Lowry 1984), and are eaten by polar bears (*Ursus maritimus*; Amstrup and DeMaster 1988). However, little is known about the biology or population dynamics of ice seals and they have received little attention compared with other Bering Sea species known to be in decline (NMFS 1995, Trites 1992). Population estimates for ice seals are not available and not easily attainable due to their wide distribution and the problems related to marine mammal surveys in remote, ice-covered waters. Although ice seals are harvested, declining abundance will likely go undetected by hunters until large declines have already occurred.

Although little is known about the population status of ice seals, there is cause for concern. Sea ice is changing in thickness, persistence, and distribution (Comiso 2002, 2006, Rigor and Wallace 2004). Evidence indicates that oceanographic conditions have been changing in the Bering Sea (Niebauer 1980, 1983, 1988; Ebbesmeyer et al. 1991; Trenberth 1990, Grebmeier et al. 2006), which suggests changes in the ecosystem may also occur. Oil and gas activities, increasing concentrations of contaminants in the Arctic, and large volume fish removals in the Bering Sea may also be affecting seal populations.

This project provides information that allows us to monitor changes in population status, availability to subsistence hunters, and contaminant concentrations in four species of ice seals in the Bering and Chukchi seas. We established a bio-monitoring program and have collected samples from more than 1,100 ice seals harvested in eight coastal Alaska villages (Barrow, Point Hope, Shishmaref, Diomede, Nome, Gambell, Savoonga, Hooper Bay; Fig. 1). These villages were chosen because historical data are available that will allow temporal comparisons. We have completed preliminary analyses on reproductive rate, body condition, diet, contaminants, and genetics.

Figure 1. Map of locations where seal samples were collected in Alaska, 2000–2005.

Objectives

To monitor for changes in the status of ice seal populations our objectives were to: 1) establish an ice seal bio-monitoring program in at least seven villages, 2) collect samples from ice seals harvested for subsistence, and 3) analyze samples for information about the health and status of the populations. Samples collected in 2000–2005 were analyzed for sex and age composition of the harvest, reproductive rate, growth, body condition, diet, contaminants, and genetics.

Methods

Collection and handling

The bio-monitoring project was approved in each village by one or more local governments or by the Ice Seal Committee before sampling began. A biologist then worked with each village to collect samples, answer questions, and provide results of the project. Biological information recorded included location, date harvested, date sampled, species, sex, and measurements (Appendix A). Seals were laid on their backs and the straight line distance was measured from nose to tip of tail (American Society of Mammalogists 1967). Blubber thickness was measured through an incision to the sternum between the front flippers (McLaren 1958). Axillary girth was measured with a soft tape placed under the foreflippers at the level of the axillae (McLaren 1958) and hip girth was measured at the level of the hip. Samples collected included a mandible (either left or right), the reproductive tract of females, the whole stomach, and pieces of liver, kidney, blubber, and skin. Samples were frozen in the field and shipped frozen to the Alaska Department of Fish and Game (ADF&G) in Fairbanks for processing. Samples not used in our analyses remain available upon request to other researchers and programs with compatible objectives and valid permits. Samples were also provided to the University of Alaska Museum for their frozen tissue archive and other collections.

Ageing

Mandibles were soaked in hot water for at least 1 hr before extracting a canine using a tooth extractor. Canines were sectioned and stained by Matson's Lab, Milltown, MT. The growth layer groups of cementum were counted for age determination according to Stewart et al. (1996) either by L. Dehn or by Matson's Lab. Age was used as a covariate for most analyses as age affects body size, contaminant concentrations, and reproductive history.

Productivity

Reproductive tracts were evaluated for status (nulliparous, primiparous, or multiparous)[1] and condition (e.g., pregnant, not pregnant) by sectioning ovaries, identifying *corpora lutea* and *corpora albicantia*, and examining the condition of uterine horns (McLaren 1958, Johnson et al. 1966, Smith 1973). In some cases (due to missing ovaries or uterine horns) pregnancy could not be determined. These reproductive tracts were omitted from the analysis. Due to the delay between conception and implantation in seals there are several months where pregnancy cannot be determined by the presence of a fetus. The presence of a *corpora lutea* indicates that the female ovulated but pregnancy can not be confirmed during this time period. We considered all females with a *corpora lutea* that were harvested from May to September to be pregnant. If some females ovulate, but do not conceive, the pregnancy rate will be inflated.

[1] Nulliparous females are reproductively immature, primiparous females have ovulated only once, and a multiparous females have ovulated more than once.

The best way to quantify the average age of first reproduction is to consider the proportion of reproductively active seals in each age class. The average age at first reproduction can then be estimated using the technique of DeMaster (1978) or a logistic regression. Currently, we only have ages for a sample of primiparous and multiparous females (i.e., we have few ages for young females). Therefore, to summarize the data, we quantified the average age at first reproduction by calculating the average age of primiparous females in our existing sample. Because this statistic may be biased relative to the true average age at first reproduction, we also present the range of ages for our sample of primiparous females. We plan to use better approaches to quantify the average age of reproduction when specimen ages are available.

Morphometrics

We examined age relative to asymptotic length, growth rate within the first year of life, and sternal blubber thickness as indices to population health for ringed and spotted seals. Sample sizes for bearded and ribbon seals were not sufficient for morphometric analyses. Estimation of asymptotic length depends upon having all age classes well represented and our samples of seals greater than one year of age included 121 spotted and 90 ringed seals, but only 44 bearded and 20 ribbon seals.

All morphometric analyses rely on knowing the age of individual seals. Ageing is accomplished by counting annuli in tooth cross-sections and can only classify a seal to a particular year. Seals less than 1 year old are simply classified as <1 year old. This is problematic for analyses of body length, because the rate of growth is greatest for seals during their first year. To allow grouping younger, shorter seals towards the beginning of their first year and older, longer seals towards the ending of their first year we assumed that all ringed and spotted seals were born on 1 April. This assumption seemed reasonable given that ringed seals generally whelp between mid-March to mid-April (Kelly 1988) and the peak of whelping for spotted seals occurs in mid-April (Quakenbush 1988).

Asymptotic length

We estimated asymptotic length using von Bertalanffy growth curves (e.g., Andersen 1999, McLaren 1993, Schnute 1981). The model is:

$$L_x = L_{\inf}\left(1 - e^{-a(x-x_0)}\right)^b,$$

where

L_x is the standard length of individual seals,
L_{inf} is the asymptotic or maximum length of individuals,
a and b are rate parameters that define the rate at which growth approaches asymptotic length,
x is the age of individuals, as determined from tooth age, and
x_0 is an adjustment for where the curve crosses the x-axis. Because of prenatal growth, individuals of age zero are not length zero. McLaren (1993) provides empirical values of x_0 for a variety of species and regions; x_0 =0.61 for ringed seals and 0.55 for spotted seals in both the Chukchi and Bering regions.

L_x, x, and x_0 are known parameters; L_{inf}, a, and b are random variables that must be estimated. We use Bayesian inference (e.g., Congdon 2003, Gelman et al. 2004) to estimate these parameters. We ran four chains, 40,000 iterations each, to confirm that all chains converged on the same solution. We discarded the first 20,000 iterations (i.e., the 'burn-in') to remove the effect of initial values on the posterior distribution. To confirm that our model was converging on a stable solution, we examined Gelman-Rubin plots (Gelman and Rubin 1992) and the iterative histories for L_{inf}, a, and b within each chain.

To determine how best to partition the data, we compared five alternative models using Deviance Information Criteria (DIC). The model with the lowest DIC was considered the best approximating model and was used for inference. In general, models within two DIC of the best approximating model receive some support. All models contained species specific estimates of x_0, but differed in how many growth curves were estimated. The least parameterized model assumed that one growth curve was shared by all seals. The most parameterized model assumed that there were four growth curves, one for each species and sex. Other models included varying combinations of species and sex effects.

First-year growth

Although growth rate is non-linear over the life of a seal, growth rate is approximately linear within a seal's first year. We estimated the growth rate of seals over their first year using simple linear regression. The data were not sufficient for complex analyses and we simply report the growth rate (i.e., slope) for each species and sex.

Blubber thickness

Previous analyses of blubber thickness indicated that blubber thickness cycles annually (Johnson et al. 1966, ADFG, unpublished data). In general, blubber is the thickest in the winter (November – March) and thinnest in the spring and summer (May – September).

To control for seasonal effects, we accounted for the effect of month. We first investigated the general shape of the relationship between blubber thickness and month by comparing three models. One model included only month, one included month squared, and one included month cubed. After determining the general relationshi4p between month and blubber thickness, we then examined six models that included different additive and multiplicative effects of species and sex (Table 5). We identified the best approximating model using Aikaike Information Criteria adjusted for sample size (AICc; Burnham and Anderson 2002). As with DIC, models within 2 AIC of the best approximating model receive some support. All models were fit using ProcMixed in SAS (SAS Institute 1999).

Diet

Stomachs were collected whole, frozen, and shipped to Fairbanks where contents were removed, weighed, and then rinsed with freshwater on a 1.0 mm sieve. Prey items were sorted into major taxonomic groups, and identified to the lowest taxonomic level. The frequency of occurrence of major prey types was calculated as the number of stomachs containing that prey divided by the total number of stomach that were examined. Identification of fish otoliths and invertebrate parts from stomachs collected between 2000 and 2002 were either identified by L. Lowry (ADF&G) or by professional laboratories. After 2002, W. Walker at the National Marine Mammal

Laboratory identified otoliths and cephalopod beaks to species and personnel at the University of Alaska Fairbanks (UAF), Institute of Marine Science identified other invertebrate prey.

Contaminants

Tissue preparation

Liver and blubber tissue from selected seals were clean-sampled at ADG&G following protocol established by the National Institute of Standards and Technology (Becker et al. 1991) and contaminants were quantified by TDI – Brooks International, Inc., B&B Laboratories, Inc., College Station, TX. Individual seals were used for contaminants analyses only if liver, kidney, and blubber tissue were available in quantities that would allow the required sample amount for testing after clean sampling each tissue. A tooth was also required so that age could be related to results. We also selected seals by species and sex so that our sample sizes per category would be useful.

Trace metals analysis

Liver samples were homogenized with a meat grinder. An aliquot of approximately 100 g was weighed and freeze-dried and then further homogenized using a blender prior to extraction. Percent moisture was calculated by comparing the weight of the wet sample with the weight of the dry samples before a 0.5 g sample was extracted and digested in a microwave wet ash procedure using, H_2O_2, and HCl. Microwave digestion was used for all metals except As and Se.

Samples analyzed for As and Se were digested using Magnesium dry ash digestion methods. This method uses methanol, HNO_3, HCl, and heat for digestion. After digestion As and Se were analyzed using Hydride Generation AA. Calibration was done at 0, 1.0, 5.0, 15.0 ppb and the QC check was 10.0 and a known Reference Sample. The 5.00 ppb standard was checked every 10^{th} sample and if the value differed by > 5% from 5.00 the instrument was recalibrated. If the value was > 10% different from 5.00 the last 10 samples were rerun. Pb was analyzed using Graphite Furnace AA. Calibration was done at 0 and 1.0 ppb and then 3–5 standards were run to check the calibration. All other metals were analyzed using ICP on a Perkin-Elmer 4300 DV.

For total mercury, a 10 ml aliquot was removed immediately after dilution, HCl was added and concentrations were determined using Cold Vapor AA. Calibration was done at 0, 1.0, 5.0, 30.0 ppb and the QC checks were 10.0, 20.0, and a known Reference Sample. The 5.00 ppb standard was checked every 10^{th} sample and if the value differed by > 5% from 5.00 the instrument was recalibrated. If the value was > 10% different from 5.00 the last 10 samples were rerun.

Methyl mercury

For analysis of methyl mercury, liver samples were delivered frozen to the UAF Wildlife Toxicology Laboratory. Samples were freeze dried before extraction to eliminate water and aid in the extraction process. Extraction of MeHg was initiated by the addition of 10 g 25% KOH in methanol and left overnight at room temperature (25 ^{0}C). The extraction procedure was continued over 24 hours with the addition of 15.6 g of methanol. The extraction process was complete when all tissues were solubilized in the KOH in methanol solution. Extracts were analyzed for MeHg using cold vapor atomic fluorescence spectrometry (CVAFS) using the BrooksRand Model III detection system (Seattle, WA) and following procedures modified from Woshner et al. (2001a, b), Dehn et al. (2005, 2006) and Method 1630 (EPA-821-R-01-020,

2001). In short, 0.050–1.00 mL of the extract was added to 100 mL of ultrapure water, adjusted to pH 4–5 with acetic acid buffer. Methylated forms of mercury in the sample were ethylated with a solution of 1.0% sodium tetraethyl borate ($NaBEt_4$) in 2% KOH in a closed bubbler for 20 minutes. Methyl ethyl mercury was subsequently separated from the solution by purging with nitrogen (N_2) gas onto Tenax® speciation traps. The methyl ethyl mercury was thermally desorbed from the traps and traveled via inert argon gas through a gas chromatography (GC) column heated to 105 ºC that further isolated the mercury species of interest. Mercury forms were next heated to 750 ºC with a pyrolytic coil that converted all organic mercury to elemental forms (Hg II), which can be detected by CVAFS. Three peaks emerge during the detection run, with the second (representing methyl ethyl mercury forms) used for calculation of MeHg in the sample. The amount of MeHg in each sample was compared to a 6 point calibration curve (calibration coefficient = 0.07; RSD = 14.3 %), calculated using Mercury Guru software (version 3.0.48; BrooksRand, Seattle, WA), and converted to ppb wet weight (ww). All samples were performed in duplicate with a coefficient of variation < 18 %. The detection limit for the sample run was 25 pg and recovery of quality control samples ranged from 88 to 136 %.

OC analysis

Liver tissue was analyzed for organochlorines (e.g., PCBs and pesticides) and trace elements (e.g., mercury, cadmium, lead, selenium); blubber was analyzed for organochlorines only. Tissue samples were homogenized using a stainless steel blender with titanium blades. Aliquots of approximately 15 g of wet tissue were chemically dried using Hydromatix® and extracted with 100% dichloromethane using a Dionex Accelerated Solvent Extractor (ASE200) operated at 100°C and 2,000 psi. The extracts are reduced to 3 mL by evaporative solvent reduction. A 100 µL aliquot is removed and weighed to determine lipid weight. The remaining sample portion is purified using alumina/silica gel column chromatography and gel permeation column (GPC)/high performance liquid chromatography (HPLC). After HPLC purification, the eluents were reduced to 0.5 mL and analyzed for PCBs and pesticides by either gas chromatography/mass spectrometry (GC/MS) or gas chromatography/electron capture detector (GC/ECD).

A GC/ECD, coupled to two capillary columns, was used to resolve and detect chlorinated hydrocarbons (polychlorinated biphenyls and pesticides) in tissues. Samples were injected into a temperature-programmed GC/ECD, operated in splitless mode. The capillary columns are DB-5 (30 m x 0.25 mm ID and 25 µm film thickness) and DB-17HT (30 m x 0.25 mm ID and 0.15 µm film thickness). The DB-17HT column is used for analyte confirmation. A data acquisition system continuously acquired and stored all data for quantitation. This method is capable of producing data at parts-per billion and parts-per trillion concentrations. The surrogate spiking solution includes 4,4'-dibromooctaflurobiphenyl (DBOFB), 2,2',4,5',6 pentachlorobiphenyl (PCB 103), and 2,2',3,3',4,5,5'6 octachlorobiphenyl (PCB 198). Surrogate solution (100 µL) is added to all samples and quality control samples prior to extraction. Surrogate compounds are resolved from, but elute in close proximity to, the analytes of interest. The recovery of PCB 103 is used to correct analyte concentrations. Spikes, duplicates, and blanks were analyzed for quality control with each batch of 20 samples or less.

Genetics
Skin samples were analyzed for mitochondrial DNA by Greg O'Corry-Crowe at NMFS, Southwest Fisheries Science Center to determine genetic diversity of bearded, ringed, and ribbon seals for an understanding of their population structure (for detailed methods see Kocher et al. 1989). A total of 564 base pairs (bp) of the mtDNA control region and adjacent proline tRNA gene were sequenced for ringed seals, 554 bp for bearded seals, and 600 bp for ribbon seals (O'Corry-Crowe et al. 2003, O'Corry-Crowe and Bonin 2004).

Traditional Ecological Knowledge
We developed a questionnaire to collect information from villages participating in the biomonitoring project. Questions included the importance of the different seal species, if changes had occurred in seal numbers, seal distribution, harvest methods, harvest timing, and local ice conditions (Appendix B). The results are important to understand whether changes observed in our sample collections are due to changes in seal numbers and behavior, or changes in harvest methods. Information collected from the questionnaires was compiled and summarized by village.

Questionnaires were made available at local government offices, at village meetings, and by biologists or trained samplers. Completing questionnaires was voluntary and could be anonymous. We compensated participants $10 for each completed form. We are still distributing questionnaires and have not yet determined the reporting rate for each village. To date, we have used the responses to help us understand seal hunting practices and to identify topics that may need further investigation. For example, if the majority of respondents in a village indicated that many ringed seals they harvested had tumors on the liver we would try to determine the cause of those abnormalities.

Composition of the Sampled Harvest
We were not able to determine the total annual seal harvest or its composition for the villages we worked with during this study; however we summarized the sampled harvest as a possible representation of species, sex, and age classes harvested. The sampled harvest may be biased because the samplers may collect from the same hunters each year and those hunters may have specific preferences, skills, or times of year that they are able to hunt.

Results

We established an ice seal bio-monitoring program and samples were collected in eight villages on the Bering and Chukchi seas. We collected samples from 1,118 seals of all four species (Table 1).

Table 1. Number of seals sampled by village and species. Percent total by species is in parentheses. Percent total by village is in brackets.

	Barrow	Point Hope	Shishmaref	Diomede	Nome	Gambell	Savoonga	Hooper Bay	Totals
Ringed	5 (1)	11 (3)	179 (48)	127 (34)	2 (<1)	16 (4)	6 (2)	30 (8)	376 (33)
Bearded	12 (4)	43 (14)	100 (32)	121 (39)	3 (1)	16 (5)	8 (3)	6 (2)	309 (28)
Spotted	2 (<1)	0	293 (76)	44 (11)	3 (<1)	23 (6)	11 (3)	11 (3)	387 (35)
Ribbon	0	1 (2)	0	40 (87)	0	1 (2)	1 (2)	3 (7)	46 (4)
Totals	19 [2]	55 [5]	572 [51]	332 [30]	8 [1]	56 [5]	26 [2]	50 [4]	1,118

Productivity

We analyzed the reproductive tracts from 206 females (Table 2). Pregnancy rates ranged from 86–91% for sexually mature females of all species. Ribbon seals had the highest pregnancy rate, followed by ringed, bearded, and spotted seals, in descending order (Table 2).

Table 2. Reproductive status by species of females sampled between 2000 and 2005.

	Nulliparous[1]	Primiparous[2]		Multiparous[3]		Unknown		No.	Total	Total
	No.	No.	% preg.	No.	% preg.	No.	% preg.	mature	% preg.	repros.
Ringed	47	8	75	4	100	6	100	18	89	**65**
Bearded	20	3	100	23	87	2	100	29	89	**48**
Spotted	58	6	50	13	100	2	100	21	86	**79**
Ribbon	8	5	80	6	100	0	0	11	91	**19**

[1] Nulliparous females are reproductively immature.
[2] Primiparous females have ovulated once.
[3] Multiparous females have ovulated more than once.

To determine age at first reproduction we looked at the ages of females of each species pregnant for the first time. Ribbon seals were the youngest to mature, followed by spotted, bearded, and ringed (Table 3).

Table 3. Average age of seals pregnant for the first time.

Species	n	Average age	Range of ages
Ringed	4	21.0	15-30
Bearded	3	11.7	8-19
Spotted	3	6.0	4-9
Ribbon	4	3.3	2-4

Morphometrics

Asymptotic length

Asymptotic length was estimated using 61 female and 106 male ringed seals, and 95 female and 144 male spotted seals. All models converged within 15,000 iterations and there was no sign of multiple modes or parameter instability. The data only supported estimating different growth curves for each species; sex specific growth curves (within species) were not supported (Table 4). The asymptotic length for ringed seals was 132.0 cm (95% CI = 119.2 to 157.0; Figure 2). The asymptotic length for spotted seals was 153.1 cm (95%CI = 147.4 to 160.1).

These results should be interpreted cautiously. Estimation of asymptotic growth requires a large sample of individuals in older age classes. For both species, asymptotic length was not reached until individuals were >15 years of age. Beyond this threshold, our sample includes only nine ringed seals and eight spotted seals. Hence, our estimates of asymptotic length are likely to change as sample sizes increase.

Table 4. Models used for Bayesian inference of asymptotic length for ringed and spotted seals. Models have a minimum of three estimated parameters, L_{inf}, a, and b. The best approximating model is that with the lowest DIC score and was used for inference.

Model	# growth curves	# parameters	DIC	Δ DIC
species	2	6	3248.47	0.00
sex*spotted+ringed	3	9	3348.14	99.67
spotted+sex*ringed	3	9	3350.81	102.34
sex*ringed+sex*spotted	4	12	3375.26	126.79
no sources of variation	1	3	3593.80	345.33

First year growth

The sample used to estimate first year growth rate consisted of 32 female and 52 male ringed seals, and 52 female and 77 male spotted seals. On average, female ringed seals grew 29.0 cm and male ringed seals grew 27.8 cm during their first year of life (Table 5). Estimated growth rates for spotted seals were very imprecise and 95% confidence limits included zero because samples were not evenly distributed throughout the calendar year. Virtually all spotted seals <1 year of age were sampled within 6 months of birth. Samples will need to be collected within the last 6 months of the first year of life to precisely estimate the growth rate.

Table 5. First year growth rate for ringed and spotted seals.

Species	Sex	n	Growth rate (cm)	5%	95%	P-value
Ringed	Female	32	29.0	5.42	52.61	0.02
	Male	52	27.8	10.24	45.36	<0.01
Spotted	Female	52	24.0	-6.76	54.76	0.12
	Male	77	8.4	-7.31	24.1	0.29

Sternal blubber thickness

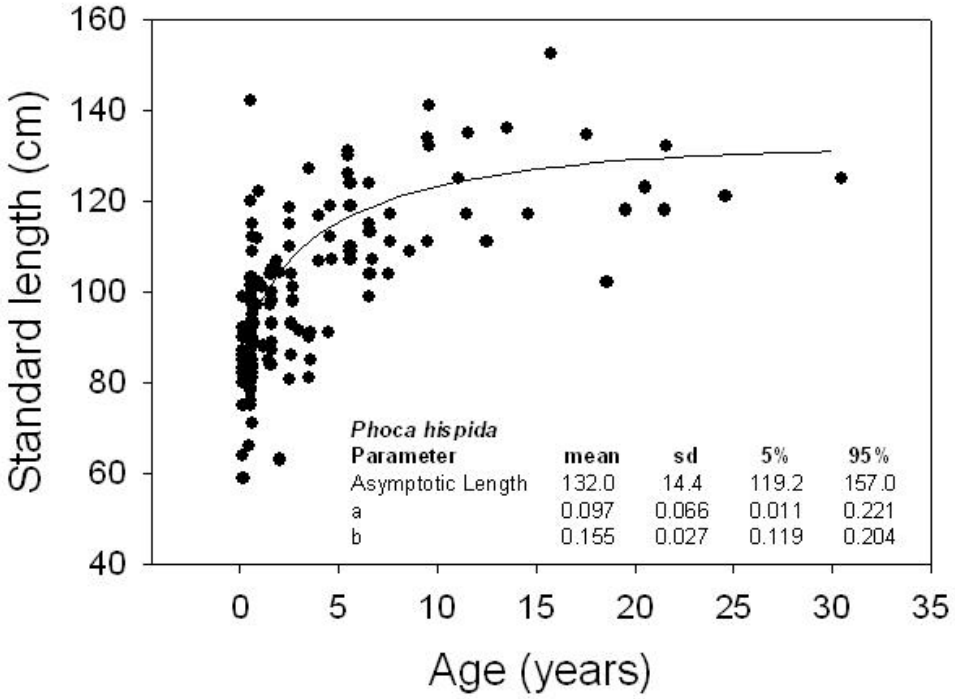
Sternal blubber thickness was estimated using 42 female and 87 male ringed seals, and 75 female and 114 male spotted seals. Blubber thickness ranged from 1.0 to 7.6 cm in ringed seals and 1.5 to 8.0 cm in spotted seals. Blubber thickness varied seasonally for all sexes and species in a similar fashion and the data only supported estimating one quadratic curve based on month of year (Table 6). Two other models that included species and species and sex specific effects were almost 2 AIC units away and therefore did not receive strong support. Also, visual inspection of the data indicated no consistent effects of sex or species. We plotted the empirical mean blubber thickness for each species in each month (Fig. 3).

These results should be interpreted with caution. Prior analyses with other data for ice seals indicated that blubber thickness did not vary seasonally until seals were mature (Ryg et al. 1990) or >6 years of age (ADFG, unpublished data). Because few seals in the current analysis are >6 years old (44 seals; 22 ringed and 22 spotted), we included all seals. The inclusion of immature seals in the sample may be confounding the relationship between blubber thickness, age, and sex.

Table 6. Models of sternal blubber thickness for ringed and spotted seals.

Models	# parameters	AICc	Δ AICc
month^2	3	992.30	0.00
month^2+species*sex	6	994.10	1.80
month^2+species	4	994.20	1.90
month^2+sex	4	994.30	2.01
month^2*species	5	996.80	4.50
month^2*sex	5	1001.10	8.80
month^3	4	1001.30	9.00
month^2*species*sex	9	1012.40	20.10
month	2	1044.90	52.60

Figure 2. Von Bertalanffy growth curves fit to ringed and spotted seal data.



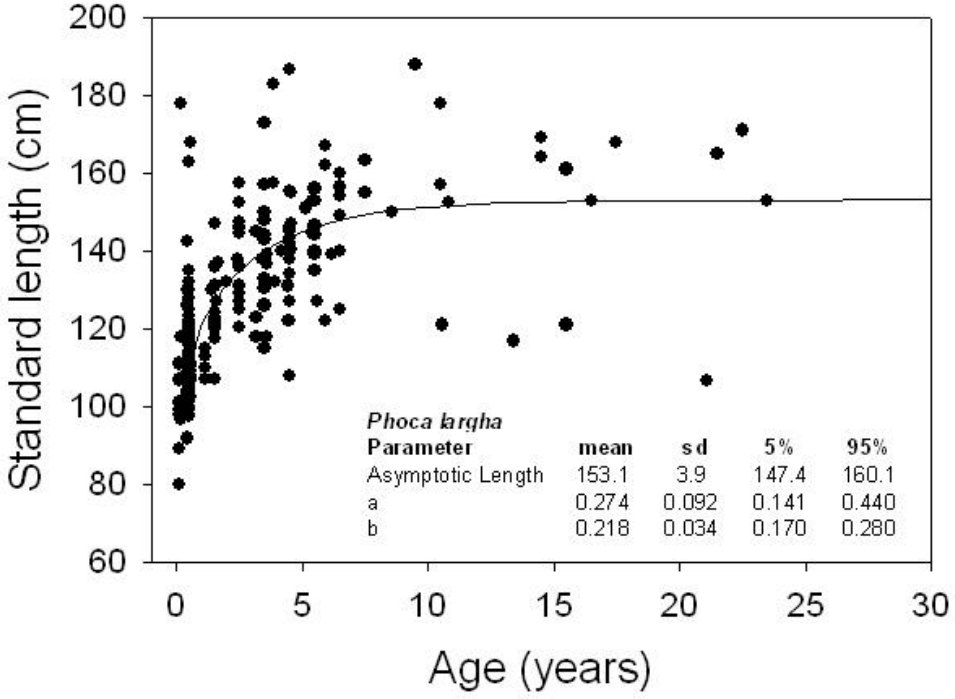
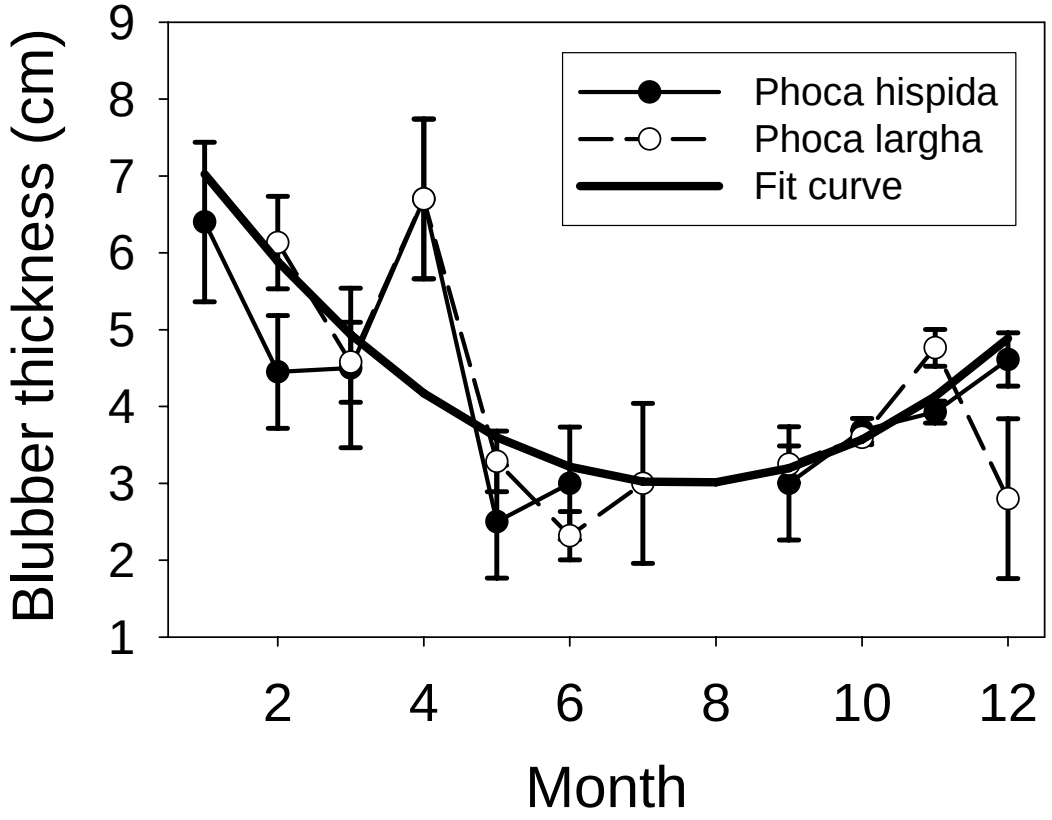


Figure 3. Empirical means and 95% confidence intervals for sternal blubber thickness of ringed and spotted seals. The curve is from the best approximating model for blubber thickness and does not include sex or species specific variation.



Diet

Stomachs from over 600 seals have been processed. Shishmaref had the largest sample size (n = 316) so we calculated the percent occurrence of the major prey items for the seals harvested there between 2000 and 2005 (Table 7). We will do the same for the other villages as sample sizes allow.

Table 7. Percent occurrence of major prey items from 316 ice seals harvested near Shishmaref during 2000–2005. Values are the percentage of stomachs containing the prey item. Prey categories are not mutually exclusive; hence, percentages do not add to 100.

	Spotted seals n=157	**Ringed seals** n=118	**Bearded seals** n=41
Invertebrates	**33**	**67**	**98**
Bryozoa	0	0	2
Polychaete	1	0	10
Snail	0	0	32
Clam	4	3	52
Cephalopod	0	0	8
Mysid	0	15	2
Isopod	0	1	15
Amphipod	16	36	17
Euphausiid	1	17	2
Echiurid	0	3	37
Shrimp	20	48	71
Crab	0	0	39
Fish	**96**	**99**	**80**
Herring	48	9	6
Cod	58	76	21
Smelt	47	40	6
Sculpin	3	13	55
Eelblenny	0	1	3
Eelpout	1	0	0
Poacher	1	0	3
Sandlance	8	5	6
Stickleback	0	1	0
Flatfish	7	7	64

Fish occurred in 80–99% of all stomachs yet the species of fish eaten differed by seal species. Herring, cod, and smelts occurred most frequently (47–58%) in the diet of spotted seals (Table 7). Cod (primarily *Boreogadus* sp.) occurred most frequently (76%) in the diet of ringed seals; flatfish (64%) and sculpin (55%) were most frequent in bearded seals, reflecting their benthic feeding habits.

Invertebrates were often detected in seal stomachs, most commonly in bearded seals (98%) and least commonly in spotted seals (33%). Of invertebrate prey types, shrimp (20%) and

amphipods (16%) were most commonly observed in spotted seal stomachs. In ringed seal stomachs, shrimp (48%) and amphipods (36%) were also commonly observed, in addition to euphausiids (17%) and mysids (15%). Bearded seals had the highest diversity of invertebrate prey types with most stomachs containing 71% shrimp and 61% molluscs (Table 7).

We are planning to use these data in retrospective comparisons with percent occurrence data from ice seal stomachs collected and analyzed during the 1970's. Percent occurrence of major prey identified from stomachs collected during 1975–1979 for ringed seals (n = 624), bearded seals (n = 257), and spotted seals (n = 50) have been compiled by village for future comparative analysis (see **Future Work**).

Contaminants

Metals and Other Elements

We quantified concentrations of 19 elements (metals and other elements) in liver samples of 61 seals including, 19 ringed, 24 bearded, 11 spotted, and seven ribbon seals (Table 8). Barium was the only element not detected in ringed, spotted, or ribbon seals. Of the elements that are potentially toxic at higher concentrations (i.e., cadmium, mercury, and lead), ribbon seals had the highest mean concentration of cadmium however a 16-yr-old male bearded seal had the highest concentration of any individual seal. All spotted seals sampled had low concentrations of cadmium. Bearded seals had the highest mean concentrations of mercury and the same individual that had the highest cadmium concentration also had the highest mercury concentration. Lead concentrations were very low and similar among species. Additional samples are needed in order to address contaminant levels by different sex and age classes.

Methyl mercury in liver tissue was analyzed for 12 bearded seals, four ringed seals, and two spotted seals. When methyl mercury is expressed as a percentage of total mercury, bearded seals had the lowest percentage of methyl mercury (geometric mean 1.82%, SD 2.2%, range 0.2–8.8%), spotted seals had the highest percentage (geometric mean 25.92%, SD 22.53%, range 14.49–46.35%) and ringed seals were in between (geometric mean 7.62%, SD 5.5%, range 2.94–14.32%).

Organochlorines

We quantified organochlorine (OC) concentrations in blubber (Figs. 4 and 5) and liver of 19 ringed, 19 bearded, 11 spotted, and seven ribbon seals. We examined total hexachlorocyclohexane (ΣHCH, four compounds), chlordane (ΣCHL, seven compounds), dichlorodiphenyltrichloroethane (ΣDDT, six compounds), and polychlorinated biphenyls (ΣPCB, 82 congeners and congener groups) from blubber. Spotted seals had the highest geometric mean concentration of ΣHCH (109.20 ng/g lipid wt), which was similar to that of ribbon seals. Ribbon seals had the highest mean concentrations of ΣCHL (355.29 ng/g lipid wt), ΣDDT (391.97 ng/g lipid wt), and ΣPCB (526.54 ng/g lipid wt). Bearded seals had the lowest concentrations of ΣHCH (14.68 ng/g lipid wt), ΣDDT (98.55 ng/g lipid wt), and ΣPCB (201.85 ng/g lipid wt). OC concentrations in liver tissue have not been analyzed but are lower than levels in blubber. Additional samples are necessary to attain sample sizes that will allow us to understand the effects of sex and age on contaminant concentrations.

Table 8. Geometric mean concentration and ranges (μg/g or ppm wet wt) for selected metals in liver from ice seals harvested in Alaska 2003–2005.

Metal		Species			
		Ringed	**Bearded**	**Spotted**	**Ribbon**
	n	19	24	11	7
Al	Mean	0.45	0.73	0.51	0.40
	SD	0.55	0.49	0.50	0.71
	Range	(0.30-2.69)	(0.29-1.91)	(0.28-1.67)	(0.29-2.17)
As	Mean	0.63	0.36	0.35	0.43
	SD	0.30	0.25	0.24	0.25
	Range	(0.13-1.29)	(0.04-1.15)	(0.21-0.98)	(0.20-0.96)
B	Mean	0.33	0.31	0.31	0.30
	SD	0.14	0.12	0.09	0.01
	Range	(0.27-0.91)	(0.27-0.89)	(0.28-0.59)	(0.29-0.32)
Ba	Mean	0.03	0.04	0.03	0.03
	SD	0.00	0.05	0.00	0.00
	Range	(0.03-0.03)	(0.03-0.03)	(0.03-0.03)	(0.03-0.03)
Be	Mean	0.02	0.01	0.01	0.02
	SD	0.00	0.00	0.00	0.00
	Range	(0.01-0.02)	(0.01-0.02)	(0.01-0.02)	(0.01-0.02)
Cd	Mean	1.51	2.20	0.35	2.48
	SD	4.51	8.74	1.03	4.46
	Range	(0.17-20.80)	(0.01-39.93)	(0.02-3.73)	(0.42-11.59)
Cr	Mean	0.05	0.07	0.08	0.12
	SD	0.03	0.15	0.04	0.26
	Range	(0.01-0.09)	(0.01-0.77)	(0.07-0.18)	(0.07-0.76)
Cu	Mean	10.40	25.31	9.47	7.29
	SD	12.29	15.16	5.35	3.2
	Range	(2.89-60.33)	(6.20-70.74)	(5.13-22.40)	(4.77-13.10)
Fe	Mean	403.14	595.61	693.03	1127.00
	SD	470.72	192.33	632.21	669.09
	Range	(100.76-1603.24)	(272.92-1078.7)	(355.7-2594.2)	(420.5-2198.5)
Hg	Mean	1.29	1.70	1.18	1.50
	SD	3.69	5.73	1.42	4.27
	Range	(0.18-12.88)	(0.13-28.31)	(0.20-4.85)	(0.41-10.27)

Table 8. Continued.

Metal		Species			
		Ringed	**Bearded**	**Spotted**	**Ribbon**
Mg	Mean	219.15	183.79	211.28	208.49
	SD	15.34	18.28	17.69	9.11
	Range	(185.65-255.34)	(127.88-218.73)	(190.58-242.20)	(199.04-222.13)
Mn	Mean	4.55	4.62	4.32	3.55
	SD	1.35	1.06	1.02	0.62
	Range	(2.47-8.24)	(2.67-6.78)	(2.83-6.17)	(2.92-4.49)
Mo	Mean	0.39	0.34	0.31	0.30
	SD	0.22	0.12	0.09	0.01
	Range	(0.27-1.00)	(0.27-0.61)	(0.28-0.58)	(0.29-0.32)
Ni	Mean	0.05	0.07	0.06	0.08
	SD	0.03	0.02	0.02	0.00
	Range	(0.03-0.09)	(0.03-0.14)	(0.03-0.08)	(0.07-0.08)
Pb	Mean	0.04	0.03	0.04	0.03
	SD	0.03	0.01	0.06	0.01
	Range	(0.03-0.12)	(0.03-0.09)	(0.03-0.22)	(0.03-0.06)
Se	Mean	2.96	3.79	2.16	2.84
	SD	3.09	3.60	1.06	2.17
	Range	(0.95-12.64)	(1.29-18.48)	(0.91-4.74)	(1.47-6.95)
Sr	Mean	0.09	0.20	0.10	0.09
	SD	0.15	0.28	0.22	0.05
	Range	(0.03-0.55)	(0.11-1.47)	(0.03-0.81)	(0.03-0.20)
V	Mean	0.15	0.29	0.10	0.19
	SD	0.25	0.60	0.09	0.2
	Range	(0.07-0.92)	(0.07-2.90)	(0.07-0.30)	(0.08-0.66)
Zn	Mean	34.93	60.94	47.46	48.49
	SD	13.08	17.83	9.47	5.26
	Range	(0.48-67.39)	(30.83-115.20)	(36.24-64.22)	(42.34-56.73)

Figure 4. Total concentration (ng/g or ppb lipid wt) of organochlorines (A) HCH and (B) CHL in blubber from ice seals harvested in Alaska 2003–2005. See text for number of compounds per category.

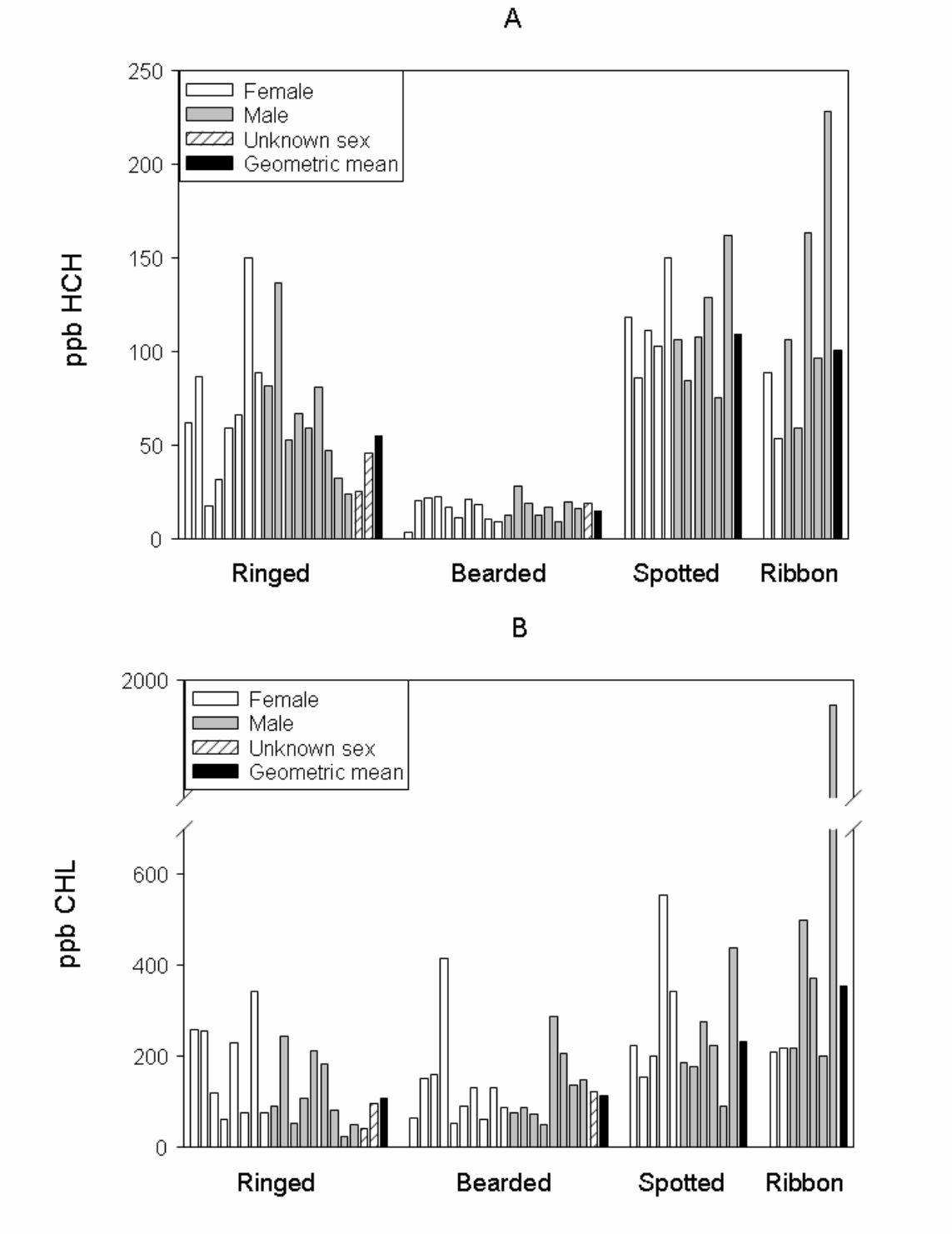
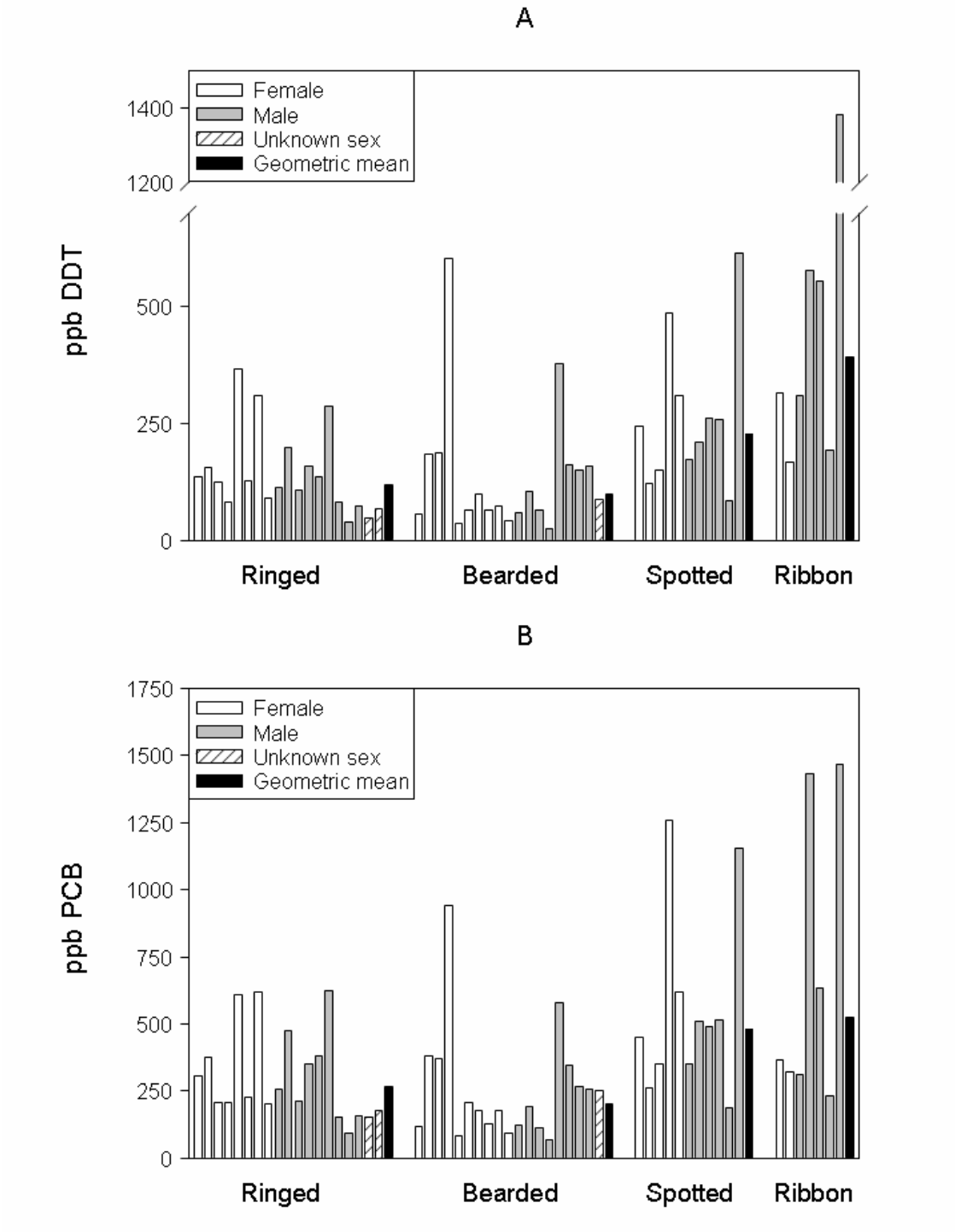


Figure 5. Total concentration (ng/g or ppb lipid wt) of organochlorines (A) DDT and (B) PCB in blubber from ice seals harvested in Alaska 2003–2005. See text for number of compounds per category.



Genetics
Variation in mitochondrial DNA (mtDNA) was examined using skin samples from 58 ringed, 65 bearded, and 24 ribbon seals collected during this project, along with samples previously archived at ADF&G. Samples represented all ages, sexes, and seasons from locations in the Bering and eastern Chukchi seas.

All species were found to posses very high levels of nucleotide and haplotype diversity. For example, all 58 ringed seals analyzed had unique haplotypes. This high level of haplotype diversity reduces the power of frequency-based statistical tests to detect population subdivision. Subdivisions within the population were not detectable, possibly due to the relatively short geographic distances separating sampling areas (100–200 km).

Additional skin samples from 214 bearded, 145 ringed, and 46 spotted seals have been sent to the Southwest Fisheries Science Center but have not yet been analyzed, therefore those results cannot be included here. In order to increase our ability to understand population structure, we have also expanded our samples to include individuals throughout the species' ranges.

Traditional Ecological Knowledge
A total of 70 questionnaires were analyzed from five Bering and Chukchi sea villages. Only the villages with eight or more respondents were summarized. In order to give an example of the type of information collected from the questionnaire (see Appendix B) we have summarized the responses of some of the questions by village (Table 9).

Responses regarding population status did not indicate decreases in any species at any location, except for Hooper Bay where 50% of the respondents thought that ringed and bearded seals had decreased. The majority of respondents from all villages reported that seals are found in the same locations as in the past and the timing of the hunts has not changed. The villages were most different in their preferences for different types of seals. Some tried for specific size, sex, or age classes of some species of seal and others did not. For example, Point Hope and Gambell tried for specific types of ringed seals although the types they preferred varied among hunters. Hunters from both villages avoided adult male ringed seals in spring because they smell and taste bad. Hooper Bay hunters tried for small, young spotted seals because they are tender and taste better.

In general, bearded seals alone or bearded seals combined with other species were most important for all villages. Hooper Bay was the only village that did not report bearded seals as the most important species. Most hunters do not encounter ribbon seals; therefore, they were of least importance and we received little information about them. Seals were used for meat, oil, boat skins, rope, clothing, and material for artwork. General concerns included noticeably longer ice-free periods resulting in a shorter hunting season and pollution (i.e., contaminants, garbage, oil spills).

Table 9. Summary of selected Traditional Ecological Knowledge (TEK) questions regarding seal harvest. Numbers are the percentage of respondents answering "yes" to a question. Responses of "don't know" are not included in this table. See Appendix B for the complete TEK questionnaire.

		Location				
		Point Hope	**Diomede**	**Shishmaref**	**Gambell**	**Hooper Bay**
Species	**Question**	n = 16	n =19	n = 14	n =13	n = 8
Ringed	Have numbers remained the same?	31	33	43	54	13
	Have numbers decreased?	31	44	36	31	50
	Have numbers increased?	13	0	7	15	0
	Are seals found in the same areas?	73	88	85	83	50
	Does the hunt occur at the same time?	71	89	71	85	71
	Do you try for certain types of this seal?	86	44	36	85	38
	What is the hunting season?	Jan-Aug	Sept-Jun	Jun; Sept-Nov	Aug-Mar; Jun	Oct-Apr
Bearded	Have numbers remained the same?	56	47	64	62	13
	Have numbers decreased?	19	11	7	8	50
	Have numbers increased?	13	5	21	23	13
	Are seals found in the same areas?	100	78	92	83	63
	Does the hunt occur at the same time?	100	100	71	100	88
	Do you try for certain types of this seal?	56	29	50	23	13
	What is the hunting season?	May-Jun	Apr-Jun; Oct-Dec	May-Jun	Sept-Jun	Mar-May; Aug
Spotted	Have numbers remained the same?	56	53	36	38	38
	Have numbers decreased?	13	26	36	38	38
	Have numbers increased?	0	5	21	15	25
	Are seals found in the same areas?	100	94	85	83	75
	Does the hunt occur at the same time?	94	100	100	100	80
	Do you try for certain types of this seal?	44	29	31	46	83
	What is the hunting season?	May-Aug	Sept-Nov	Jun; Sept-Nov	Aug-Dec	Year round
Ribbon	Have numbers remained the same?	15	42	40	54	14
	Have numbers decreased?	23	17	0	15	38
	Have numbers increased?	0	17	0	15	13
	Are seals found in the same areas?	55	82	43	83	50
	Do you try for certain types of this seal?	0	20	33	44	50
	Does the hunt occur at the same time?	89	92	80	60	100
	What is the hunting season?	May-Jun	May-Jun	May-Jun; Oct-Nov	May-Jun	Oct-Nov

We are continuing to distribute and collect questionnaires and as the proportion of respondents relative to the total number of hunters in each village increases, the results will allow us to understand potential biases created by hunting practices, which will allow us to better interpret our study results. The information gathered to date has been helpful in understanding aspects of the harvest. For example, fewer adult male ringed seals sampled in spring when they smell and taste bad is likely due to hunter preference and not availability. The questionnaires also provided local hunters an effective avenue for communicating concerns about seals and the environment.

Composition of the Sampled Harvest

We were not able to determine the total harvest or its composition in the villages where we collected samples. In some villages there were concerns regarding harvest information. People worry that the information may be used to develop hunting restrictions. In developing our biomonitoring protocols we realized that collecting harvest information simultaneously with sample collections would likely be detrimental to the biomonitoring study. Although we did not collect harvest information (i.e., number of each species harvested by sex and age) we do have some general information regarding harvest if the seals we sampled are representative of the harvest (Table 10).

Bearded seals were the most sampled species in Point Hope; however our sampling has coincided with the peak of the beaded seal hunting season (Table 10). Spotted seals were the most sampled species in Shishmaref, Gambell, and Savoonga. Ringed seals were the most sampled species in Diomede and Hooper Bay. The majority of our samples came from seals less than 4 years old (Table 11) for all species except ribbon seals.

Table 10. Species and sex composition of the sampled harvest by village during 2000–2005. Dominant species for each village is in bold.

Location/species	% of sample	% male	% female	% unknown
Point Hope	(n = 42)			
Ringed	23	45	36	18
Bearded	77	22	59	19
Spotted	0	0	0	0
Ribbon	0	0	0	0
Shishmaref	(n = 508)			
Ringed	31	60	35	5
Bearded	19	35	42	23
Spotted	50	60	32	8
Ribbon	0	0	0	0
Diomede	(n = 392)			
Ringed	38	59	33	9
Bearded	33	40	33	27
Spotted	18	57	4	9
Ribbon	10	44	49	7
Gambell	(n = 43)			
Ringed	23	60	20	20
Bearded	33	29	29	43
Spotted	44	26	47	26
Ribbon	0	0	0	0
Savoonga	(n = 28)			
Ringed	21	17	50	33
Bearded	29	50	38	13
Spotted	39	27	36	36
Ribbon	7	50	0	50
Hooper Bay	(n = 42)			
Ringed	55	52	48	0
Bearded	14	67	17	17
Spotted	24	60	30	10
Ribbon	7	33	67	0

Table 11. Age composition of the sampled harvest by village during 2000–2005. Percentage for the dominant age class for each species is in bold.

Location/species	% pup–4 yrs	% 5–10 yrs	% 11–19 yrs	% 20+ yrs	% unknown age
Point Hope	(n = 42)				
Ringed	0	**9**	0	0	91
Bearded	**35**	19	16	5	24
Spotted	0	0	0	0	0
Ribbon	0	0	0	0	0
Shishmaref	(n = 508)				
Ringed	**70**	14	5	5	6
Bearded	**59**	18	9	4	9
Spotted	**75**	9	4	3	10
Ribbon	0	0	0	0	0
Diomede	(n = 392)				
Ringed	**65**	12	5	0	19
Bearded	**53**	16	10	5	17
Spotted	**73**	10	1	3	13
Ribbon	**51**	32	5	5	7
Gambell	(n = 43)				
Ringed	**30**	0	0	0	70
Bearded	**36**	0	0	7	57
Spotted	**42**	0	0	0	58
Ribbon	0	0	0	0	0
Savoonga	(n = 28)				
Ringed	**83**	0	0	17	0
Bearded	**89**	11	0	0	0
Spotted	**91**	9	0	0	0
Ribbon	0	**50**	0	0	50
Hooper Bay	(n = 42)				
Ringed	**70**	13	4	0	13
Bearded	**100**	0	0	0	0
Spotted	**50**	40	0	0	10
Ribbon	33	0	0	**67**	0

Discussion

Productivity

Our sample sizes for sexually mature females were low for all species; however, our preliminary results show that reproductive rates were similar for all species (range 86–91%) and at a relatively high level (Table 2). Reproductive rates for ringed, spotted, and ribbon seals are capable of approaching 95% annually (McLaren 1958, Smith 1973, Burns 1981). Reproductive rates for bearded seals have been reported to be fairly consistent at around 85% in Alaskan waters (Burns 1967, Burns and Eley 1978, Burns 1981), which is lower than our finding of 89%. Recent (2004–2005) reproductive rates of ringed seals in the western Canadian Arctic were lower (74–76%) and blubber thickness of females that did not ovulate was significantly lower than that of ovulating females (Harwood 2005). Recent changes in the marine environment have

raised concerns about possible long-term affects on seal productivity (Harwood 2005). Reproductive rate is known to be affected by resource availability and can be an indicator of population status (Fowler and Siniff 1992).

Although our sample sizes of primiparous females were too small to be confident that we accurately estimated the age at first reproduction in all species, our data showed that ribbon seals matured at a younger age (2–3 yrs) than the other species. Consistent with an early age of reproduction, we also found multiparous ribbon seal females as young as 4–6 yrs. The age of maturation in ribbon seals was also consistent with estimates reported in the 1960s (Burns 1981) and 1980s (Fedoseev 2000). Primiparous spotted seals ranged from 4–9 yrs in our study, which was older than the range (3–4 yrs) found in the literature (Tikhomirov 1966, Burns 1978). Of only three primiparous bearded seals none were younger than 8 yrs while Burns (1981) reported the average to be about age six yrs. Our ringed seal results were the most extreme. In our sample, ringed seals that were pregnant for the first time were considerably older (range 15–30 yrs) than expected, as ringed seals typically begin breeding at 3–7 yrs (McLaren 1958, Smith 1973, Lydersen and Gjertz 1987). The current reproductive rate for ringed seals however indicates that females are still becoming pregnant at the expected rate, which does not fit with the much older age of first reproduction. We expect additional collections of sexually mature females to improve the reliability of our results.

Morphometrics

Body measurements can be used to compare growth rates and body condition among time periods (McLaren 1958, Pitcher 1986, Quakenbush et al. 1999). Low reproductive rates may correlate with low blubber thickness values and older age at asymptotic length, thereby providing evidence that the population has experienced nutritional stress. Although the total number of seals measured was large, when categorized by species, sex, age, and for some analyses time of year, sample sizes are limiting. Furthermore, our sample is mainly composed of younger age classes, limiting our ability to compare growth rates and body condition among time periods for all species. Once we acquire the necessary sample sizes our data can be compared to data from the same populations during earlier time periods (ADF&G unpubl., Johnson et al. 1966). Ringed seals collected in Alaska from 1975 to 1977 were much smaller and reached asymptotic length at approximately 117 cm (Frost and Lowry 1981) compared to our study where the asymptotic lengths was approximately 132 cm. Ringed seals in our study were larger at an earlier age indicating better nutritional status than in the 1970s. Monitoring this parameter through time for the same seal population can provide information about how the environment may be changing. Similarly monitoring first year growth rates can indicate stress related to ice stability or food availability. More samples are needed of spotted seal pups between 6–12 months of age to estimate first year growth rates for this species.

To compare blubber thickness we will need a larger sample size of fall-harvested adult seals. Blubber is thinnest in summer and may reach a minimum thickness that does not reflect body condition (Ryg et al. 1990a). Seals begin to fatten in the fall and comparing blubber thickness over time at this time of year may provide the best index to body condition related to food availability.

Diet

Oceanographic changes are being observed in the Bering Sea (Niebauer 1980, 1983, 1988; Ebbesmeyer et al. 1991; Trenberth 1990; Grebmeier et al. 2006) that has likely affected prey assemblages. We are analyzing prey data to describe the present diet of seals; however, we will need to compare them to historical data to determine if changes in changes in diet have occurred over time (see **Future Work)**.

Contaminants

Metals and other elements occur naturally in the marine environment and levels can vary widely in Alaska depending upon regional geology. Little is known about what the normal ranges are for marine mammals. Cadmium and mercury are commonly present at high concentrations in liver and kidney tissue of marine mammals. The concentration of elements we observed are similar to the findings of other studies conducted in Alaska (Becker et al. 1995, Dehn et al. 2005) and lower than studies conducted in Canada (Smith and Armstrong 1975, Muir et al. 1999). Most studies indicate that element concentrations generally increase with age (see reviews in Northern Contaminants Program 2003), yet few studies have sufficient samples to analyze for the affects of age. The concentrations of some elements however may decline with age and some relationships may be non-linear (Dehn et al. 2005). We are selecting samples for analysis that will represent all age classes and our sample sizes are growing.

There are several forms of mercury with variable toxicities. Inorganic mercury has low bioavailability and is less toxic while methyl mercury is highly bioavailable and therefore more toxic. The percentage of methyl mercury was lowest in bearded seals. The individual with the highest level of total mercury of all of the seals tested was an adult male bearded seal; however it also had the lowest percentage of methyl mercury (0.2%). Marine mammals are known for their ability to use selenium to detoxify mercury and elevated mercury levels are usually accompanied by elevated selenium levels (Koeman et al. 1975).

Cadmium is another element that can be toxic at elevated levels, however in marine mammal kidney and liver it tends to be bound to metallothionein, which makes it less bioavailable and therefore less toxic (Goyer 1991, Groten et al. 1990). In addition to documenting trace element concentrations in seal tissues, more work needs to be done to determine what proportion of these elements are bioavailable and potentially toxic to the seals and what concentrations affect seal health. Such results are necessary prior to the development of meaningful food safety standards for humans.

Ribbon seals had the highest mean concentrations of all OC categories except HCH. Bearded and ringed seals had lower concentrations. Ribbon seals are uncommon in the Alaskan subsistence harvest because their distribution tends toward the central and western Bering Sea. Ribbon seal diet is not well known (Frost and Lowry 1980) but what is known appears to be similar to that of spotted seals (Lowry and Frost 1981), therefore diet alone does not explain their higher contaminant concentrations. It may be that their more western distribution puts them in contact with contaminants coming from Russia and the North Pacific.

In general, we observed lower OC concentrations than what other studies have observed in Canada (e.g., Muir et al. 1999). However, comparison of studies can be problematic. First,

studies often examine different OC congeners, so direct comparisons across studies can be difficult. Comparisons are further complicated, because concentration may depend both on sex and age, therefore a comparison of means between two studies may have more to do with the sex ratio of the seals sampled than the location or time period. OC levels generally increase with animal age for males, but not females (Addison and Smith 1974). Females may transfer OCs through the placenta or via lactation, thus decreasing their own levels once they become reproductive. Accounting for age effects are important if different age distributions are sampled. Future analyses of OC levels will account for sex and age once our sample is large enough to represent all sex and age classes. We will then work with the State of Alaska, Division of Public Health, to determine if any seal tissues that are regularly consumed by humans have concentrations detrimental to human health.

Genetics

In order for a species to develop separate stocks, breeding adults would need to return to the same area to breed each year and their offspring would need to return to breed there as well. If separate stocks exist within a harvested species it is important to know if the harvest focuses on any particular stock and whether that harvest is sustainable. Our skin samples come from harvested seals and most of the harvest occurs outside of the breeding season when seals may have traveled some distance from their breeding areas. Our analysis of mitrochondrial DNA from harvested ringed, bearded, and ribbon seals shows high diversity with each seal having its own haplotype. This appears to indicate that no particular stock dominates the harvest, however it does not confirm there is no stock structure within each species. The high levels of genetic diversity observed in the Bering Strait region suggest that all three species, ringed seals in particular, belonged to historically large populations. Examining variation in a different region of the current markers or investigating variation in other markers may also be worth pursuing.

Spotted seal genetics have been analyzed and reported previously (O'Corry-Crowe and Westlake 1997) and findings were similar to other species in that that spotted seals from the Chukchi and Bering seas did not indicate any stock structure. There may be some differentiation, however, among spotted seals from distant geographic regions in the Bering Sea, Sea of Okhotsk, and Sea of Japan (Chapskii 1967).

Traditional Ecological Knowledge

In order to best interpret results of our analyses we need to understand potential biases caused by the way people hunt (i.e., timing, preferences for sex, size, or species). The traditional knowledge questionnaire provided that information and information about hunting seasons, the importance of each species, condition of seals, hunters' concerns about the seals and their environment, and a way to communicate this information and concern.

Composition of the Sampled Harvest

The composition of our samples may reflect the composition of the harvest in some villages; however, we do not know what proportion of the total harvest we sampled and there are potential biases that require a concentrated harvest survey effort. For example, we expect that because our sampling at Point Hope has occurred mostly during the bearded seal harvest, the proportion of bearded seals in their annual harvest would be overestimated by our samples. The people collecting the samples in the villages tend to be the same from year to year and they may be

collecting from the same hunters. If those hunters have preferences for certain species, or can only hunt during certain months because of jobs or other activities, the samples may not represent the harvest village-wide. However, other harvest related data may still be unbiased. For example, the age and sex of the species sampled may still be representative of the harvest because hunters cannot discern age and sex as easily as species.

Conclusions

We established an ice seal bio-monitoring program and collected samples from more than 1,100 seals harvested for subsistence in eight villages. Small sample sizes currently restrict us from many analyses and limit inference strength. As such, these conclusions should be considered preliminary at best. To date, we have found that trace elements and OC levels are lower in the Bering and Chukchi seas than in Canada. Genetic analyses (mtDNA) have yet to identify stock structure in any species. Reproductive rates suggest that females of all species are becoming pregnant at rates that can produce stable or growing populations. The asymptotic length of ringed seals appears to be longer now than it was in the late 1970s, possibly indicating that current environmental conditions (e.g., food availability, ice conditions) are favorable and promote growth. Hunter questionnaires (TEK) indicate that populations of ringed, bearded, and spotted seals are not declining. There is currently little information to suggest that ice seals are declining; however, this assessment is based upon small sample sizes and incomplete analyses. We will update our assessment as our monitoring program continues and we collect more samples. When sample sizes allow, we will also compare our data (reproductive rate, age at first reproduction, blubber thickness, age at length) with historic data to determine trends in population indices (see **Future work**).

We were successful in working with subsistence hunters in selected communities and we have collected samples useful for determining the current status of ice seal populations in Alaska. We also shared our results with local communities and at regional and national meetings. The only objective we did not accomplish entirely was to determine the species, age, and sex composition of the annual harvest. We have, however, built the relationships that are necessary to develop a harvest-monitoring program. We believe that with the help of the Ice Seal Committee a harvest-monitoring program could be developed in the near future.

Future work

We are planning to compare our current sampling effort with past sampling efforts to document changes in population status over time. By comparing our current metrics of diet, body condition, and reproduction, with historic metrics, we can infer how ice seal populations have changed in the past and how they may change in the future. Sampling occurred at the same locations in the 1960s, 1970s, and 1980s (DeMaster et al. 1997, Sheffield et al. 1997) and we have access to these data at ADF&G.

Publications and Other Products

O' Corry-Crowe, G., A. Frey, and K. Coultrup. 2003. Molecular genetic study of population structure and dispersal patterns in four species of ice seals in the Bering, Chukchi, and Beaufort Seas – feasibility analysis. Final Report, NMFS Southwest Fisheries Science Center/Aquatic Farms Inc. Alaska Department of Fish and Game, Fairbanks, AK. 5 pp.

O' Corry-Crowe, G., and C. Bonin. 2004. The molecular ecology of marine mammals in the Bering Strait: A pilot investigation of ribbon seals, *Phoca fasciata*. Final Report, NMFS Southwest Fisheries Science Center/Aquatic Farms Inc. Alaska Department of Fish and Game, Fairbanks, AK. 5 pp.

Quakenbush, L. T. 2005. Polybrominated diphenyl ether (PBDE) compounds in blubber from the Bering Sea subsistence harvest of ice seals in Alaska. 16th Biennial Conference of the Biology of Marine Mammals, San Diego, CA, 12–16 December. (Abstract)

Quakenbush, L., and G. Sheffield. 2003. Ice seals as an indicator of change in the Arctic marine environment. Study of Environmental Arctic Change (SEARCH) Workshop, Seattle, WA. Arctic Research Consortium of the United States, 25-26 October 2003. (Abstract)

Quakenbush, L. T., L. Hughes, and G. Sheffield. 2005. Organochlorine contaminants in ice seal blubber from the Bering Sea subsistence harvest in Alaska. Joint meeting of the Alaska Chapter of the Wildlife Society and the Alaska Chapter of American Foresters, 21–23 April, Fairbanks, AK. (Abstract).

Sheffield, G. 2004. Traditional knowledge regarding seals and seal hunting. Performance Report to NSF Office of Polar Programs, OPP Grant 9910319, Washington, DC.

Quakenbush, L. T. 2007. Polybrominated diphenyl ether compounds in ringed, bearded, spotted, and ribbon seals from the Alaskan Bering Sea. Marine Pollution Bulletin 54:232–236.

Quakenbush, L., and J. Citta. 2006. Metals and organochlorine concentrations in bearded seals (*Erignathus barbatus*) harvested by subsistence hunters near Kivalina, Alaska in 2005. Final report to Teck Cominco Alaska Inc. 29 pp.

Outreach

Presentations:

Quakenbush, L. T. 2005. Alaska Department of Fish and Game Ice Seal Program. Presentation to the Marine Mammal Commission, Scientific Advisory Committee, 12–14 December, Anchorage, AK.

Quakenbush, L. T., and G. G. Sheffield. 2006. Ice seal bio-monitoring in the Bering and Chukchi Sea region. Presentation to the Marine Science in Alaska Symposium, 23–25 January, Anchorage, AK.

Community Meetings:

Pt. Hope, Diomede, Shishmaref, Gambell, and Savoonga.

Community Reports:

Pt. Hope, Diomede, Shishmaref, Gambell, Savoonga, and Hooper Bay.

Presentations at Schools:

Diomede, Shishmaref, Gambell, Savoonga

Other Reports:

Ice Seal Committee and Eskimo Walrus Commission

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Literature Cited

Reports:

Bukhtiyarov, Y. A., K. J. Frost, and L. F. Lowry. 1984. New information on foods of the spotted seal, *Phoca largha*, in the Bering Sea in spring. Pages 55–59 *in* F. H. Fay and G. A. Fedoseev, eds. Soviet-American cooperative research on marine mammals. Vol. 1. Pinnipeds. NOAA Technical Report. NMFS 12.

Burns, J. J., and T. J. Eley. 1978. The natural history and ecology of the bearded seal (*Erignathus barbatus*) and the ringed seal (*Phoca hispida*). U.S. Department of Commerce, NOAA, Outer Continental Shelf and Environmental Assessment Program, Alaskan Continental Shelf, Annual Report. 1:99–162.

DeMaster, D. P., D. J. Rugh, B. Jones, L. F. Lowry, K. J. Frost, and G. Sheffield. 1997. Summaries of data collected from ice-associated seals in the Bering, Chukchi, and Beaufort seas, 1975–1991. Report to NOAA, Office of Protected Resources, National Marine Fisheries Service, Silver Spring, MD.

Harwood, L. A. 2005. Reproduction and body condition of the ringed seal (*Phoca hispida*) in the eastern Beaufort Sea, NT, Canada, as assessed through a harvest-based sampling program at Sachs Harbour, NT in 2005. Progress report to Minerals Management Service, #1435-01050-CT-39145.

Johnson, M. L., C. H. Fiscus, B. T. Ostenson, and M. L. Barbour. 1966. Marine Mammals. Pages 877–924 *in*: N. J. Wilimovsky and J. N. Wolfe, eds. Environment of the Cape Thompson Region, Alaska. U.S. Atomic Energy Commission, Oak Ridge, TN.

Lowry, L. F., K. J. Frost, and J. J. Burns. 1978. Trophic relationships among ice-inhabiting phocid seals. U.S. Department of Commerce, NOAA, OCSEAP, Environmental Assessment of the Alaskan Continental Shelf, Annual Report 1:161–372.

Lowry, L. F., K. J. Frost, and J. J. Burns. 1981. Trophic relationships among ice-inhabiting phocid seals and functionally related marine mammals in the Bering Sea. U.S. Department of Commerce, NOAA, OCSEAP Environmental Assessment of the Alaskan Continental Shelf, Final Report, Biological Studies 11:97–173.

National Marine Fisheries Service (NMFS) 1995. Status review of the United States Steller sea lion (*Eumetopias jubatus*) population. Report prepared by National Marine Mammal Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, Seattle, WA. 45 pp. (Available from National Marine Mammal Laboratory Library, NMFS, 7600 Sand Point Way NE, Seattle, WA 98115).

Northern Contaminants Program. 2003. Canadian Arctic contaminants assessment report II: Contaminant levels, trends, and effects in the biological environment. Minister of Public Works and Government Service Canada, Ottawa, Canada.

O' Corry-Crowe, G., A. Frey, and K. Coultrup. 2003. Molecular genetic study of population structure and dispersal patterns in four species of ice seals in the Bering, Chukchi, and Beaufort Seas – feasibility analysis. Final Report, NMFS Southwest Fisheries Science Center/Aquatic Farms Inc. Alaska Department of Fish and Game, Fairbanks, AK. 5 pp.

O' Corry-Crowe, G., and C. Bonin. 2004. The molecular ecology of marine mammals in the Bering Strait: A pilot investigation of ribbon seals, *Phoca fasciata*. Final Report, NMFS Southwest Fisheries Science Center/Aquatic Farms Inc. Alaska Department of Fish and Game, Fairbanks, AK. 5 pp.

Quakenbush, L. T., B. D. Taras, and B. P. Kelly. 1999. Topographic variation in blubber thickness among Pacific walruses, *Odobenus rosmarus*. Report to U.S. Geological Survey, Biological Resources Division, Anchorage, AK. 25 pp.

Sheffield, G., L. Lowry, and K. J. Frost. 1997. Summaries of data collected from ice-associated seals in the Bering, Chukchi, and Beaufort seas, 1975–1991. Report to National Marine Fisheries Service, National Marine Mammal Laboratory, Seattle, WA. 50 pp.

Proceedings:

Ebbesmeyer, C. C., D. R. Cayan, D. R. McLain, F. H. Nichols, D.H. Peterson, and K. T. Redmond. 1991. 1976 step in the Pacific climate: Forty environmental changes between 1968–1975 and 1977–1984. Pages 129–141 *in* J. L. Bentancourt and A. V. Tyler, eds. Proceedings of the Seventh Annual Pacific Climate Workshop, April 1990, California Department of Water Resources Interagency Ecological Studies Program Technical Report No. 26.

Kocher, T. D., W. K. Thomas, and A. Meyer. 1989. Dynamics of mitochondrial DNA evolution in animals: Amplification and sequencing with conserved primers. Proceedings of the National Academy of Sciences 86(16): 6196-6200.

Lowry, L. F. 1984. A conceptual assessment of biological interactions among marine mammals and commercial fisheries in the Bering Sea. Pages 101–117 *in* Proceedings of the workshop on biological interactions among marine mammals and commercial fisheries in the southeastern Bering Sea, Anchorage, Alaska. University of Alaska, Fairbanks, Sea Grant Report 84-1.

Parsons, J. L. 1977. Metabolic studies on ringed seals (*Phoca hispida*) MS thesis, University of Guelph, Guelph, Canada.

Articles:

Addison, R. F., and T. G. Smith. 1974. Organochlorine residue levels in arctic ringed seals: variation with age and sex. Oikos 25:335–337.

American Society of Mammalogists. 1967. Standard measurements of seals. Journal of Mammalogy 48: 459–462.

Amstrup, S. C., and D. P. DeMaster. 1988. Polar bear, *Ursus maritimus*. Pages 39–56 *in*: J. W. Lentfer, ed. Selected marine mammals of Alaska: species accounts with research and management recommendations. Marine Mammal Commission, Washington, D.C.

Andersen, M., A. M. Hjelset, I. Gjertz, C. Lydersen, and B. Gulliksen. 1999. Growth, age at sexual maturity and condition in bearded seals (*Erignathus barbatus*) from Svalbard, Norway. Polar Biology 21:179–185.

Antonelis, G. A., S. R. Melin, and Y. A. Bukhtiyarov. 1994. Early spring feeding habits of bearded seals (*Erignathus barbatus*) in the central Bering Sea, 1981. Arctic 47(1):74–79.

Becker, P. R., S. A. Wise, B. J. Koster, and R. Zeisler. 1991. Alaska Marine Mammal Tissue Archival Project: revised collection protocol. U.S. Dept. Commerce, National Institute of Standards and Technology Laboratory, Galthersburg, MD. 33 pp.

Becker, P. R., E. A. Mackey, M. M. Schantz, R. R. Greenberg, B. J. Koster, S. A. Wise, and D. C. G. Muir. 1995. Concentrations of chlorinated hydrocarbons, heavy metals and other elements in tissues banked by the Alaska Marine Mammal Tissue Archival Project. U.S. DOC, National Institute of Standards and Technology NISTIR 5620.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and inference: A practical information-theoretic approach, 2nd ed. Springer-Verlag, New York, New York, USA.

Burns, J. J. 1967. The Pacific bearded seal. Alaska Department of Fish and Game. Juneau. 66 pp.

Burns, J. J. 1978. Ice seals. Pages 192–205 *in:* D. Haley, ed. Marine Mammals. Pacific Search Press, Wattle, WA.

Burns, J. J. 1981. Ribbon Seal — *Phoca fasciata*. Pages 89–109 *in* S. H. Ridgway and R. J. Harrison, eds. Handbook of marine mammals. Vol. 2. Seals. Academic Press, NY.

Burns, J. J., and K. J. Frost. 1983. The natural history and ecology of the bearded seal, *Erignathus barbatus*. U.S. Department of Commerce. NOAA, OCSEAP Final Report. 19: 311–392.

Chapskii, K. K. 1967. Morpho-taxonomic characteristics of the pagetoda form of the Bering Sea largha. Pages 147–176 *in* K. K. Chapskii and M. Ya. Yakovenko, eds. Investigations of marine mammals. Murmansk: Poiarnaia Pravda. (Translated from Russian by Fisheries Research Board of Canada, No. 1108, 1968).

Comiso, J. C. 2002. A rapidly declining perennial sea ice cover in the Arctic. Geophysical Research Letters 29(20) 1956 doi:10.1029/2002GL015650.

Comiso, J.C. 2006. Arctic warming signals from satellite observations. Weather 61(3): 70-76.

Congdon, P. 2003. Applied Bayesian Modeling. John Wiley and Sons, Ltd. West Sussex, UK.

Dehn, L-A., G. G. Sheffield, E. H. Follmann, L. K. Duffy, D. L. Thomas, G. R. Bratton, R. J. Taylor, and T. M. O'Hara. 2005. Trace elements in tissues of phocid seals harvested in the Alaskan and Canadian Arctic: influence of age and feeding ecology. Canadian Journal of Zoology 83: 726–746.

Dehn, L-A., Follmann, E.H., Rosa, C., Duffy, L.K., Thomas, D.L., Bratton, G.R., Taylor, R.J. and O'Hara, T.M. 2006. Stable isotope and trace element status of subsistence hunted bowhead (*Balaena mysticetus*) and beluga whales (*Delphinapterus leucas*) in Alaska and gray whales (*Eschrichtius robustus*) in Chukotka. Marine Pollution Bulletin 52: 301–319.

DeMaster, D. P. 1978. Calculation of the average age of sexual maturity in marine mammals. Journal of the Fisheries Research Board of Canada 35: 912–915.

Fedoseev, G. A. 2000. Population biology of ice-associated forms of seals and their role in the northern Pacific ecosystems. Center for Russian Environmental Policy. Translated from Russian by I. E. Sidorova. 271 pp.

Fowler, C. W. and D. B. Siniff. 1992. Determining population status and the use of biological indices in the management of marine mammals. Pages 1025-1037 *in:* D. R. McCullough and R. H. Barrett, eds. Wildlife 2001: Populations. Elsevier, New York, NY.

Frost, K. J., and L. F. Lowry. 1980. Feeding of ribbon seals (*Phoca fasciata)* in the Bering Sea in spring. Canadian Journal of Zoology 58: 1601–1607.

Frost, K. J., and L. F. Lowry. 1981. Ringed, Baikal and Caspian seals — *Phoca hispida*, *Phoca sibirica*, and *Phoca caspica*. Pages 29–53 *in* S. H. Ridgway and R. J. Harrison, eds. Handbook of marine mammals. Vol. 2. Seals. Academic Press, NY.

Gelman, A., and D. B. Rubin. 1992. Inference from iterative simulation using multiple sequences. Statistical Science 7: 457–511.

Gelman, A., J. B. Carlin, H. S. Stern, and D. B. Rubin. 2004. Bayesian Data Analysis, 2nd ed. Chapman and Hall/CRC, Boca Raton, FL.

Goyer, R. A. 1991. Toxic effects of metals. Pages 634–638 *in* M. O. Amdur, J. Doull, and C. D. Klassen, eds. The Basic Science of Poisons. Pergammon Press, NY.

Groten, J. P., E. J. Sinkeldam, J. B. Luten, and P.J. van Bladeren. 1990. Comparison of the toxicity of inorganic and liver-incorporated cadmium: A 4-wk feeding study in rats. Chemical Toxicology 28(6): 435–441.

Grebmeier, J. M., J. E. Overland, S. E. Moore, E. B. Farley, E. C. Carmack, L. W. Cooper, K. E. Frey, J. H. Helle, F. A. Mc Laughlin, and S. L. McNutt. 2006. A major ecosystem shift in the northern Bering Sea. Science 311: 1461–1463.

Kelly, B. P. 1988. Ringed seal. Pages 59–75 *in* J. W. Lentfer, *ed.* Selected marine mammals of Alaska: species accounts with research and management recommendations. Marine Mammal Commission, Washington, D. C.

Koeman, J. H., W. S. M. van de Ven, J. J. M. de Goeij, P.S. Tjioe, and J.L. van Haaften. 1975. Mercury and selenium in marine mammals and birds. Science of the Total Environment 3: 279–287.

Lowry, L. F., K. J. Frost, and J. J. Burns. 1980. Variability in the diet of ringed seals, Phoca hispida, in Alaska. Canadian Journal of Fisheries and Aquatic Sciences 37: 2254–2261.

Lydersen, C., and I. Gjertz. 1987. Population parameters of ringed seals (*Phoca hispida* Schreber, 1775) in the Svalbard area. Canadian Journal of Zoology 65: 1021–1027.

McLaren, I. A. 1958. The biology of the ringed seal (*Phoca hispida* Schreber) in the eastern Canadian Arctic. Fisheries Research Board of Canada Bulletin No. 118. 146 pp.

McLaren, I. A. 1993. Growth in pinnipeds. Biological Review 68: 1–79.

Method 1630. EPA-821-R-01-020. 2001. Methyl mercury in water by distillation, aqueous ethlyation, purge and trap, and CVAFS. U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, Washington, D.C.

Muir, D., B. Braune, B. DeMarch, R. Norstrom, R. Wagemann, L. Lockhart, B. Hargrave, R. Addison, J. Payne, and K. Reimer. 1999. Spatial and temporal trends and effects of contaminants in the Canadian Arctic marine ecosystem: a review. The Science of the Total Environment 230(1–3): 83–144.

Niebauer, H. J. 1980. Sea ice and temperature fluctuations in the eastern Bering Sea and the relationship to meteorological fluctuations. Journal of Geophysical Research 85: 7505–7515.

Niebauer, H. J. 1983. Multiyear sea ice variability in the eastern Bering Sea: An update. Journal of Geophysical Research 88: 2733–2742.

Niebauer, H. J. 1988. Effects of El Niño-Southern Oscillation and North Pacific weather patterns on interannual variability in the subarctic Bering Sea. Journal of Geophysical Research 93: 5051–5068.

O'Corry-Crowe, G. M., and R. L. Westlake. 1997. Molecular investigations of spotted seals (*Phoca largha*) and harbor seals (*P. vitulina*), and their relationship in areas of sympatry. Pages 291–304 *in:* A. E. Dizon, S. J. Chivers, and W. F. Perrin, eds. Molecular Genetics of Marine Mammals. Special Publication No. 3 of the Society for Marine Mammals.

Pitcher, K. W. 1986. Variation in blubber thickness of harbor seals in southern Alaska. Journal of Wildlife Management 50(3): 463–466.

Quakenbush, L. T. 1988. Spotted seal. Pages 107-124 *in* J. W. Lentfer, *ed.* Selected marine mammals of Alaska: species accounts with research and management recommendations. Marine Mammal Commission, Washington, D. C.

Rigor, I. G., and J. M. Wallace. 2004. Variations in the age of Arctic sea-ice and summer sea-ice extent. Geophysical Research Letters, Vol. 31, L09401, doi:10.1029/2004GL019492.

Ryg, M., T. G. Smith, and N. A. Ortisland. 1990. Seasonal changes in body mass and body composition of ringed seals (*Phoca hispida*) on Svalbard. Canadian Journal of Zoology 68: 470-475.

SAS Institute. 1999. The SAS system for Windows, version 8.0. SAS Institute Inc., Cary, North Carolina, USA.

Schnute, J. 1981. A versatile growth model with statistically stable parameters. Canadian Journal of Fisheries and Aquatic Sciences 38: 1128–1140.

Shustov, A. P. 1965. The food of the ribbon seal in the Bering Sea. TINRO 59: 178–183. (Translated from Russian by U.S. Department of the Interior, Bureau of Commercial Fisheries, Seattle, WA. 1968. 10 pp.)

Smith, T. G. 1973. Population dynamics of the ringed seal in the Canadian eastern Arctic. Fisheries Research Board of Canada Bulletin No. 181. Ottawa, Canada.

Smith, T. G., and F. A. J. Armstrong. 1975. Mercury in seals, terrestrial carnivores, and principal food items of the Inuit, from Holman, N.W.T. Journal of the Fisheries Research Board of Canada 32(6): 795–801.

Smith, T. G., F. A. J. Armstrong. 1978. Mercury and selenium in ringed and bearded seal tissues from Arctic Canada. Arctic 31: 75–84.

Stewart, R. E. A., B. E. Stewart, I. Stirling, E. Street. 1996. Counts of growth layer groups in cementum and dentine in ringed seals (*Phoca hispida*). Marine Mammal Science 12: 383–401.

Tikhomirov, E. A. 1966. Reproduction of seals of the family Phocidae in the North Pacific. Zoological Zhurnal 45: 275–281. (Translated from Russian by Fisheries Research Board of Canada, 1971, Translation series 1889. 19 pp.)

Trenberth, K. E. 1990. Recent observed interdecadal climate changes in the Northern Hemisphere. American Meteorological Society 71(1): 988–993.

Trites, A. W. 1992. Northern fur seals: why have they declined? Aquatic Mammals 18.1: 3–18.

Woshner, V. M., T. M. O'Hara, G. R. Bratton, R. S. Suydam, and V. R. Beasley. 2001a. Concentrations and interactions of selected essential and non-essential elements in bowhead and beluga whales of Arctic Alaska. Journal of Wildlife Diseases 37: 693–710.

Woshner, V. M., T. M. O'Hara, G. R. Bratton, and V. R. Beasley. 2001b. Concentrations and interactions of selected essential and non-essential elements in ringed seals and polar bears of Arctic Alaska. Journal of Wildlife Diseases 37: 711–721.

DATASHEET

Village: _____

Date the seal was killed: _____

Date the seal is sampled: _____

What kind of seal? *Ringed, Spotted, Bearded, Ribbon,* _____

Sex: *male/female/not known*

Pregnant with a fetus? *Yes/No/Didn't check*

MEASUREMENTS:

Straight (standard) length: _____ cm

Armpit (axillary) girth: _____ cm

Hip girth: _____ cm

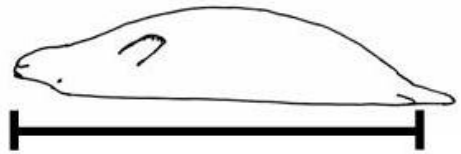
Blubber between flippers: _____ cm

Weight: _____lbs

SAMPLES: (circle the ones collected): Jaw, Ovaries, Stomach, Liver, Kidney, Blubber, Muscle

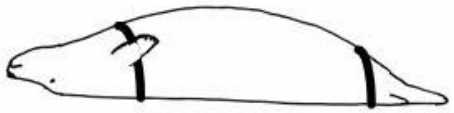
MEASUREMENTS

Straight (standard) **length**



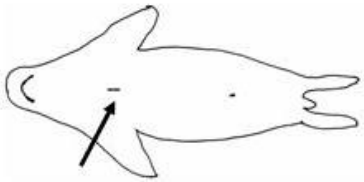
Tip of nose Tail

Armpit (axillary) and **Hip girth**



Armpit Hip

Blubber between flippers (thickness includes skin)



Slice through to meat. How thick is the blubber?

Questions? Call Gay Sheffield (ADF&G) 907-459-7248

Appendix B. Traditional Ecological Knowledge questionnaire.

Traditional Knowledge: Seals and Seal Hunting

Community: _____ Surveyor name: _____
Date: _____ Household name: _____

When (what year) did you first begin to hunt for seals? _____
year,

When was the last time you tried to catch (hunted) seals? _____
year, month

I want to ask you some questions about each of the different kinds of seals that you hunt.

Ringed Seals

Has the number of ringed seals (population) changed from when you first started hunting?
(Circle one) More now Less now Same Don't know

Are ringed seals found in the same areas or different areas now, compared to several years ago?

_____

Which months are the best for hunting ringed seals? (Circle all that apply)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Are there certain months when you avoid catching ringed seals? (Circle all that apply)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Why? _____
_____

Do you hunt ringed seals the same months now as you used to? Yes No
If no, why? _____
_____

Have you had to change anything about the way you hunt for ringed seals? Yes No
If yes, what? _____
_____

Do you try to catch certain types of ringed seals? Males Females Small Big Old Young
Why? _____
_____

Have you noticed anything different about the ringed seals from when you first started hunting (such as amount of fat, condition of skin, types or number of sores or growths)? _____

_____

Is there anything else you want to tell me about ringed seals? _____

Traditional Knowledge: Seals and Seal Hunting

Bearded Seals

Has the number of bearded seals (population) changed from when you first started hunting?
(Circle one) More now Less now Same Don't know

Are bearded seals found in the same areas or different areas now, compared to several years ago?

_____

_____

Which months are the best for hunting bearded seals? (Circle all that apply)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Are there certain months when you avoid catching bearded seals? (Circle all that apply)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Why? _____

_____

Do you hunt bearded seals the same months now as you used to? Yes No
If no, why not? _____

_____

Have you had to change anything about the way you hunt for bearded seals? Yes No
If yes, what? _____

_____

Do you try to catch certain types of bearded seals? Males Females Small Big Old Young

Why? _____

_____

Have you noticed anything different about bearded seals from when you first started hunting (such as amount of fat, condition of skin, types or number of sores or growths)?

_____

_____

Is there anything else you want to tell me about bearded seals?

_____

Traditional Knowledge: Seals and Seal Hunting

Spotted Seals

Has the number of spotted seals (population) changed from when you first started hunting?
(Circle one) More now Less now Same Don't know

Are spotted seals found in the same areas or different areas now, compared to several years ago?

_____

_____

Which months are the best for hunting spotted seals? (Circle all that apply)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Are there certain months when you avoid catching spotted seals? (Circle all that apply)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Why? _____

_____

Do you hunt spotted seals the same months now as you used to? Yes No
If no, why not? _____

_____

Have you had to change anything about the way you hunt for spotted seals? Yes No
If yes, what? _____

_____

Do you try to catch certain types of spotted seals? Males Females Small Big Old Young
Why? _____

_____

Have you noticed anything different about spotted seals from when you first started hunting (such as amount of fat, condition of skin, types or number of sores or growths)?

_____

_____

Is there anything else you want to tell me about spotted seals? _____

_____

Traditional Knowledge: Seals and Seal Hunting

Ribbon Seals

Has the number of ribbon seals (population) changed from when you first started hunting?
(Circle one) More now Less now Same Don't know

Are ribbon seals found in the same areas or different areas now, compared to several years ago?

_____

_____

Which months are the best for hunting ribbon seals? (Circle all that apply)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Are there certain months when you avoid catching ribbon seals? (Circle all that apply)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Why? _____

_____

Do you hunt ribbon seals the same months now as you used to? Yes No
If no, why not? _____

_____

Have you had to change anything about the way you hunt for ribbon seals? Yes No
If yes, what? _____

_____

Do you try to catch certain types of ribbon seals? Males Females Small Big Old Young
Why? _____

_____

Have you noticed anything different about ribbon seals from when you first started hunting (such as amount of fat, condition of skin, types or number of sores or growths)?

_____

_____

Is there anything else you want to tell me about ribbon seals? _____

_____

Traditional Knowledge: Seals and Seal Hunting

General Questions

What kind of seal is most important seal to you? Ringed Bearded Spotted Ribbon

Why? _____

_____

Have you noticed any changes in the ocean that you think are affecting the seals?

_____

_____

_____

Any Other Comments?

_____

_____

_____

_____

_____

_____

_____

Return to: Alaska Department of Fish & Game
Arctic Marine Mammal Program
1300 College Road
Fairbanks, Alaska 99701

Contacts: Lori Quakenbush 459-7214
Gay Sheffield 459-7248