Ice Seal Monitoring in the Bering-Chukchi Sea Region

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Progress Report

A. Project Identifiers

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B. Project Summary

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 of their association with sea ice and their dependence on it for feeding, resting, and pupping. Ice seals are important components of the Bering, Chukchi, and Beaufort sea ecosystems and they are important to the subsistence culture of Alaska Natives for food and skins. There are concerns regarding the status, health, and availability of ice seals due to changes occurring in thickness, persistence, and distribution of sea ice. 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. Little is known about the biology and ecology of ice seals and they have received little attention compared with other Bering Sea species known to be in decline. 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. Large decreases in abundance could be occurring and are likely to go undetected until low numbers affect subsistence harvests.

By consistently collecting and analyzing harvest information and biological samples from subsistence-harvested seals at selected locations, we can assess the health and status of each species. Information about the status and health of the population can be obtained from sex and age of seals harvested, age at first reproduction, pregnancy rate, growth rate, body condition, diet, and contaminant load. It is believed that the arctic marine ecosystem is changing and data collected from this monitoring program would provide a means to detect and monitor such changes. For example, changes in the prey available to ice seals today could be known by comparing diet data collected during this project with that collected in the 1960s, 1970s, and 1980s. These historic data are available at the Alaska Department of Fish and Game (ADF&G). Similarly, changes in species distribution and body condition would also be detectable by comparison. This project will provide essential information on the health and status of ice seals and will allow us to monitor, document, and evaluate changes in population status, species distribution, availability to subsistence hunters, and contaminant load.

C. Summary of Progress and Results

***Objective 1:* Conduct an ice seal monitoring program.** We are continuing to collect samples in the original seven selected villages: Point Hope, Shishmaref, Diomede, Savoonga, Gambell, Nome, and Hooper Bay. An eighth and ninth village, Barrow and Kaktovik, respectively have been added in cooperation with the Ice Seal Committee (ISC), the Alaska Nanuuq Commission (ANC), and the North Slope Borough (NSB). Substantial historic collections were made in Barrow that will allow for retrospective comparisons. The sampling will be done by ISC and ANC and we will process and analyze the samples. Samples were collected in Barrow from 19 seals and have been processed. Visits were made to Hooper Bay, Gambell, Savoonga, Diomede, Nome, Shishmaref, and Point Hope in 2007 to collect samples, work with current samplers, train new samplers, answer questions about the program, and report on sampling results to the communities.

***Objective 2:* Collect samples from ice seals harvested for subsistence.** Local residents were trained and hired to collect information and samples in Kaktovik, Barrow, Shishmaref, Diomede, Nome, Savoonga, Gambell, and Hooper Bay. We collected the samples at Point Hope. We have received samples from the spring 2007 harvest and have sampled a total of 1,469 seals since 2002 (Table 1). Samples have been collected under NMFS Permit Nos. 358-1585 and 358-1787.

Table 1. Number of seals sampled by village and species.

	Kaktovik	Barrow	Point Hope	Shishmaref	Diomede *	Nome	Gambell	Savoonga	Hooper Bay	Total
Ringed	0	13	34	210	154	3	23	14	61	**512**
Bearded	2	14	105	126	143	3	26	22	11	**452**
Spotted	1	2	0	344	45	9	27	16	13	**457**
Ribbon	0	0	2	0	40	0	1	2	3	**48**
Totals	**3**	**29**	**141**	**680**	**382**	**15**	**77**	**54**	**88**	**1,469**

* The National Science Foundation (NSF) (OPP Grant #9910319) provided funding for the collection of samples from Little Diomede (2000–2005). The North Pacific Research Board (NPRB) provided partial funding for the collection of samples for all villages in 2005–2006.

***Objective 3:* Sample Analysis.**
Diet – Stomachs from 735 seals have been processed (Table 2). Prey items are sorted into major groups, and identified to the lowest taxonomic level possible. William Walker at the National Marine Mammal Laboratory identifies otoliths to species. The University of Alaska Fairbanks, Institute of Marine Science identifies invertebrate prey items.

Table 2. Number of stomachs analyzed by village and by species, October 2002 – 2007.

	Kaktovik	Barrow	Point Hope	Shishmaref	Diomede *	Nome	Gambell	Savoonga	Hooper Bay	Total
Ringed	0	5	2	144	87	1	17	5	32	**293**
Bearded	2	2	21	48	86	0	14	1	12	**186**
Spotted	1	0	0	206	19	5	9	1	7	**248**
Ribbon	0	0	1	0	4	0	1	0	2	**8**
Totals	**3**	**7**	**24**	**398**	**196**	**6**	**41**	**7**	**53**	**735**

We calculated the percent frequency of occurrence of the major prey items for the 157 spotted, 118 ringed, and 41 bearded seals harvested near Shishmaref between 2000 and 2005 (Table 3). 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. We will do the same for the other villages as sample sizes allow.

Table 3. Percent frequency of 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 n=157	**Ringed** n=118	**Bearded** 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 3). 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%). Shrimp (20%) and amphipods (16%) were the most commonly observed invertebrates 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 shrimp (71%) and molluscs (61%; Table 3).

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.

<u>Genetics</u> – We are continuing to collect skin samples in order to expand upon our preliminary genetic analyses of ringed, bearded, and ribbon seal stock structure. 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 Chukchi seas.
All species were found to have a high diversity of nucleotides and haplotypes in the analyses done by Greg O'Corry-Crowe (SWFSC, NMFS). We are also working with collaborators to acquire skin samples from outside our sampling area to further investigate stock structure.

Most of the skin samples analyzed come from the spring and fall harvests that occur after the most recent breeding season or prior to the subsequent one. Therefore, we may not be sampling seals that are still in their breeding areas, which is where stock identification would best be determined. No stock structure was apparent in the seals we analyzed using mtDNA however; which may indicate that the harvests we are sampling do not appear to be focused on a particular stock of ringed, bearded, or ribbon seal.

During this reporting period the genetic analysis was expanded to include microsatellite DNA analysis and 30 polymorphic loci were tested for variation in bearded seals. A preliminary analysis was done on 38 bearded seals from the Bering Sea (St. Lawrence Island) and the Beaufort Sea (Barrow and Kaktovik) using 19 loci and significant genotypic (χ^2=59.9, p=0.0133) and allelic (χ^2=64.8, p=0.0043) differences were found between the two regions (O'Corry-Crowe and Bonin 2007). This is the first evidence of population genetic structure in Alaskan bearded seals and indicates that using polymorphic nuclear loci may be more informative than the hypervariable mtDNA genome in detecting population subdivision in bearded seals.

We have additional skin samples from more than 252 ringed, 308 bearded, 76 spotted, and two ribbon seals available for analysis. The immediate focus for the future will be to continue to explore and refine the use of microsatellites for stock identification of bearded seals.

Contaminants

Metals and Other Elements

We quantified concentrations of 19 elements (metals and other elements) in liver samples of 75 seals including, 23 ringed, 29 bearded, 15 spotted, and eight ribbon seals (Table 4). 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.

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 and summarized organochlorine (OC) concentrations in blubber (Table 5) and liver (Table 6) of ringed, bearded, spotted, and 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) in both tissues. In blubber, spotted seals had the highest geometric mean concentration of ΣHCH (103.0 ng/g lipid wt), which was similar to that of ribbon seals. Ribbon seals had the highest mean concentrations of ΣCHL (357.8 ng/g lipid wt), ΣDDT (446.6 ng/g lipid wt), and ΣPCB (547.8 ng/g lipid wt). Bearded seals had the lowest concentrations of all categories: ΣHCH (14.6 ng/g lipid wt), ΣCHL (107.0 ng/g lipid wt), ΣDDT (93.7 ng/g lipid wt), and ΣPCB (192.7 ng/g lipid wt). OC concentrations in liver tissue were an order of magnitude lower than blubber and the pattern relative to species was the same (Table 6).

Of the 82 congener and congener groups that we tested for PCBs, six made up the majority of the ΣPCBs in all species. They were, in decreasing dominance; 153/132, 101/90, 138/160, 99, 180, and 118. Of the six compounds composing ΣDDT, the most dominant compound detected was DDE, which is a compound degraded from the source compound DDT and indicates that seals in Alaska are not in the immediate vicinity of recent applications of DDT. This is an important finding due to Alaska's geographic proximity to Russia where DDT was thought to possibly still be in use.

Perfluorinated Contaminants

We analyzed liver tissue from eight ringed, eight bearded, seven spotted, and seven ribbon seals for perfluorinated contaminants (PFCs) and found detectable concentrations of perfluorooctane sulfonate (PFOS), perfluorononanoic acid (PFNA), perfluorodecanoic acid (PFDA), and perfluoroundecanoic acid (PFUnDA). We detected no significant differences in mean PFOS concentrations among species (Kruskal-Wallis $P = 0.43$). In all species combined, concentrations of PFOS ranged from 2.8–22.8 (median = 7.5) ng/g wet weight. Concentrations of PFNA ranged from 1.1–29.6 (median = 7.6) ng/g wet. These concentrations are lower than those found in ringed seals in Canada, Greenland, and the Baltic Sea. These are the first data on PFCs for ice seals in Alaska, although the contaminant has been found in polar bears from Alaskan stocks and therefore assumed to be present in seals, their primary prey. Concentrations of PFCs that may be toxic are unknown as are what affects such concentrations may have on animals. PFCs are not lipophilic like OCs and the way they are acquired and how they bioaccumulate are not known. Our preliminary results show that the species may be affected differently. Young bearded seals appear to have higher concentrations than older bearded seals; however young ringed seals appear to have lower concentrations than older ringed seals. Our initial sample sizes per species were small but we plan to continue to investigate PFCs with additional samples.

We have submitted additional blubber and liver samples for 21 seals (nine ringed, nine bearded, two spotted, and one ribbon) to laboratories for metals, OCs, and PFOS analyses. These samples will expand our sample sizes and allow us to conduct sex and age specific analyses.

Table 4. Geometric mean concentration and ranges (µg/g or ppm wet wt) for selected metals in liver from ice seals harvested in Alaska 2003–2006.

Metal		**Species**			
		Ringed	**Bearded**	**Spotted**	**Ribbon**
	n	23	29	15	8
Al	Mean	0.42	0.69	0.48	0.58
	SD	0.51	0.48	0.47	2.44
	Range	(0.30-2.69)	(0.29-1.91)	(0.28-1.67)	(0.29-7.22)
As	Mean	0.68	0.38	0.34	0.38
	SD	0.31	0.29	0.28	0.25
	Range	(0.13-1.29)	(0.04-1.15)	(0.19-1.05)	(0.16-0.96)
B	Mean	0.32	0.31	0.31	0.31
	SD	0.13	0.13	0.08	0.01
	Range	(0.27-0.91)	(0.27-0.89)	(0.28-0.59)	(0.29-0.33)
Ba	Mean	0.03	0.04	0.03	0.03
	SD	0.00	0.05	0.00	0.00
	Range	(0.03-0.03)	(0.03-0.29)	(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	0.01
	Range	(0.01-0.02)	(0.01-0.02)	(0.01-0.02)	(0.01-0.02)
Cd	Mean	1.44	2.00	0.34	3.04
	SD	4.13	8.15	0.90	5.08
	Range	(0.17-20.80)	(0.01-39.93)	(0.02-3.73)	(0.42-12.66)
Cr	Mean	0.06	0.07	0.08	0.11
	SD	0.02	0.14	0.03	0.24
	Range	(0.01-0.09)	(0.01-0.77)	(0.07-0.18)	(0.07-0.76)
Cu	Mean	9.41	25.57	8.11	7.70
	SD	11.47	14.46	5.32	3.2
	Range	(2.89-60.33)	(6.20-70.74)	(0.99-22.38)	(4.77-13.06)
Fe	Mean	384.88	580.60	617.08	1209.61
	SD	448.99	182.83	584.86	666.74
	Range	(100.8-1603.2)	(272.9-1078.7)	(223.8-2594.2)	(420.5-2198.5)
Hg	Mean	1.13	1.82	0.90	1.60
	SD	3.42	5.46	1.45	3.96
	Range	(0.14-12.88)	(0.13-28.31)	(0.03-4.85)	(0.41-10.27)

Table 4. Continued.

Metal		Species			
		Ringed	**Bearded**	**Spotted**	**Ribbon**
Mg	Mean	218.10	182.77	210.67	209.55
	SD	14.60	17.25	18.10	8.95
	Range	(185.65-255.34)	(127.88-218.73)	(186.32-242.20)	(199.04-222.13)
Mn	Mean	4.31	4.64	3.89	3.81
	SD	1.36	1.05	1.35	1.09
	Range	(2.20-8.24)	(2.67-6.78)	(0.68-6.17)	(2.92-6.23)
Mo	Mean	0.38	0.34	0.31	0.35
	SD	0.21	0.12	0.07	0.24
	Range	(0.27-1.00)	(0.27-0.61)	(0.28-0.58)	(0.29-0.98)
Ni	Mean	0.06	0.07	0.06	0.08
	SD	0.02	0.02	0.02	0.01
	Range	(0.03-0.09)	(0.03-0.14)	(0.03-0.08)	(0.07-0.08)
Pb	Mean	0.04	0.04	0.04	0.04
	SD	0.03	0.02	0.05	0.02
	Range	(0.03-0.12)	(0.03-0.011)	(0.03-0.22)	(0.03-0.07)
Se	Mean	2.82	3.80	2.04	2.92
	SD	2.87	3.49	1.08	2.01
	Range	(0.95-12.64)	(1.29-18.48)	(0.82-4.74)	(1.47-6.95)
Sr	Mean	0.08	0.19	0.08	0.07
	SD	0.14	0.26	0.19	0.05
	Range	(0.03-0.55)	(0.09-1.47)	(0.03-0.81)	(0.03-0.20)
V	Mean	0.16	0.29	0.11	0.21
	SD	0.23	0.58	0.08	0.19
	Range	(0.07-0.92)	(0.07-2.90)	(0.07-0.30)	(0.07-0.66)
Zn	Mean	35.85	59.62	46.50	49.52
	SD	11.96	17.02	11.10	5.75
	Range	(0.48-67.39)	(30.83-115.19)	(25.81-66.12)	(42.34-57.40

Table 5. Geometric mean concentration and ranges (ng/g or ppb wet wt) for total organochlorines in blubber from ice seals harvested in Alaska 2003–2006.

Compound		**Species**			
		Ringed	**Bearded**	**Spotted**	**Ribbon**
	n	23	25	15	8
∑ HCH	Mean	56.2	14.6	**103.0**	100.6
	SD	32.8	5.6	**61.7**	57.7
	Range	(17-150)	(3-28)	**(35-313)**	(53-228)
∑ CHL	Mean	108.3	107.0	198.4	**357.8**
	SD	87.9	82.5	160.4	**604.1**
	Range	(24-342)	(51-415)	(38-580)	**(199-1979)**
∑ DDT	Mean	131.9	93.7	197.5	**446.6**
	SD	131.4	126.6	195.8	**445.9**
	Range	(39-628)	(26-605)	(30-695)	**(168-1382)**
∑ PCB	Mean	281.3	192.4	409.9	**547.8**
	SD	200.7	190.7	357.1	**500.5**
	Range	(92-908)	(69-942)	(99-1256)	**(231-1467)**

Table 6. Geometric mean concentration and ranges (ng/g or ppb wet wt) for total organochlorines in liver from ice seals harvested in Alaska 2003–2006.

Compound		**Species**			
		Ringed	**Bearded**	**Spotted**	**Ribbon**
	n	23	20	15	8
∑ HCH	Mean	1.0	0.9	**1.8**	1.5
	SD	2.5	2.5	**2.3**	2.6
	Range	(0-12)	(0-10)	**(0-10)**	(0-7)
∑ CHL	Mean	4.3	5.0	5.7	**9.4**
	SD	3.8	5.0	16.2	**17.6**
	Range	(1-19)	(1-20)	(2-67)	**(3-57)**
∑ DDT	Mean	2.5	5.3	4.4	**15.7**
	SD	2.8	8.6	24.6	**14.5**
	Range	(1-13)	(1-39)	(1-99)	**(5-46)**
∑ PCB	Mean	10.4	18.9	16.0	**37.1**
	SD	36.6	25.2	42.1	**43.0**
	Range	(4-175)	(5-86)	(4-174)	**(15-144)**

Productivity – We analyzed the reproductive tracts from 228 females (Table 7). Pregnancy rates ranged from 77–92% for sexually mature females of all species. Ribbon seals had the highest pregnancy rate, followed by bearded, spotted, and ringed seals, in descending order (Table 7).

Table 7. Reproductive status by species of females sampled between 2000 and 2007.

	Nulliparous[1]	**Primiparous[2]**		**Multiparous[3]**		**Unknown**		**No.**	**Total**	**Total**
	No.	**No.**	**% preg.**	**No.**	**% preg.**	**No.**	**% preg.**	**mature**	**% preg.**	**repros.**
Ringed	47	10	70	6	83	6	83	22	77	**69**
Bearded	21	4	75	36	92	2	100	42	91	**63**
Spotted	57	6	50	11	100	2	100	19	84	**76**
Ribbon	8	5	80	7	100	-	0	12	92	**20**

[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 8).

Table 8. Average age of seals pregnant for the first time.

Species	**n**	**Average age**	**Range of ages**
Ringed	7	14.6	3–30
Bearded	3	11.7	8–19
Spotted	5	5.0	2–9
Ribbon	5	3.0	2–4

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 become 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 are not yet sufficient for morphometric analyses.

Asymptotic length

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

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.

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 9). The asymptotic length for ringed seals was 132.0 cm (95% CI = 119.2 to 157.0; Fig. 1). 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 9. 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

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.

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 10). 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 10. 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

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 relationship between month and blubber thickness, we then examined six models that included different additive and multiplicative effects of species and sex (Table 9). 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).

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 11). Two other models that included species alone 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. 2).

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 11. 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 1. Von Bertalanffy growth curves fit to ringed and spotted seal data.

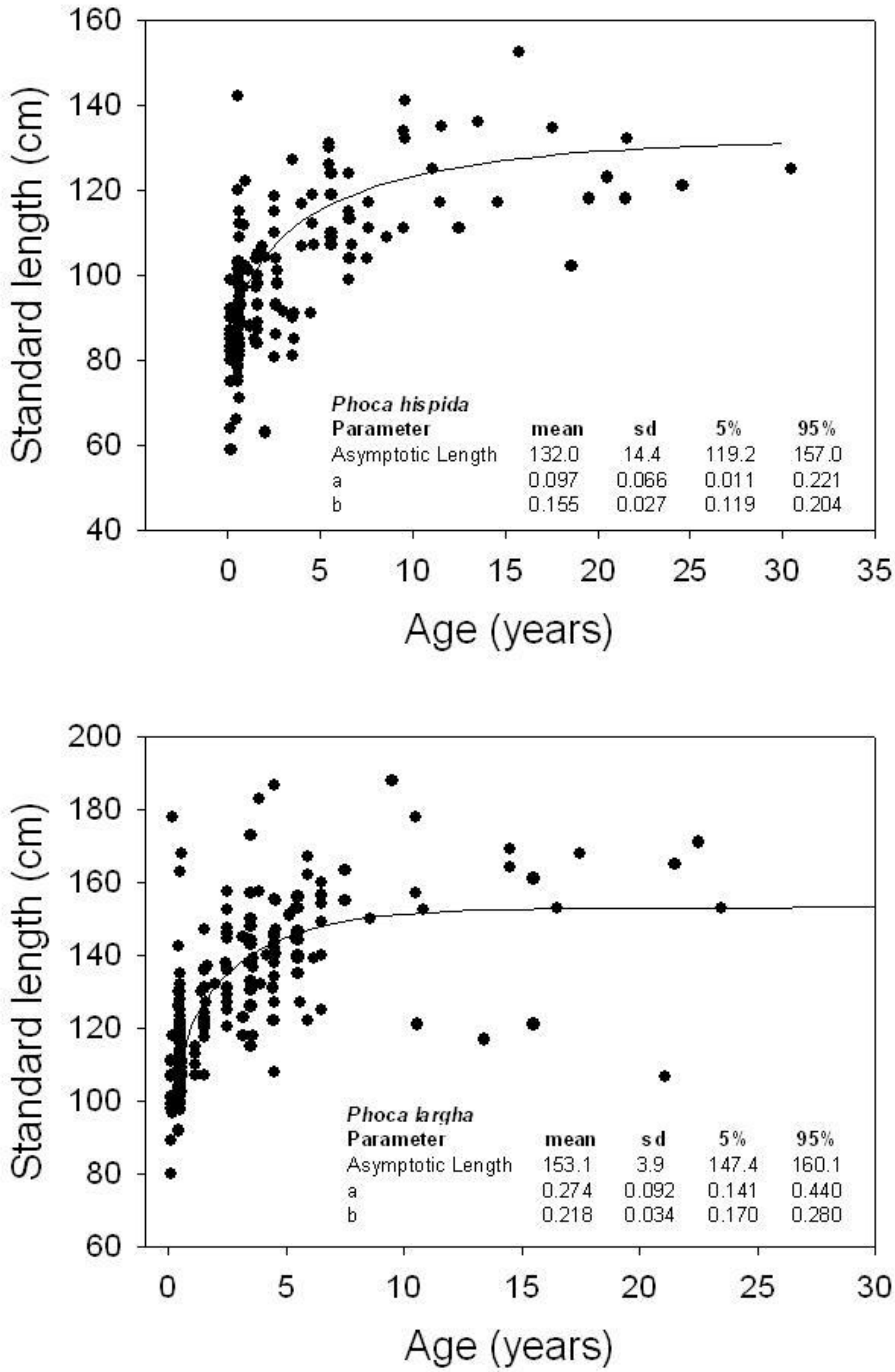
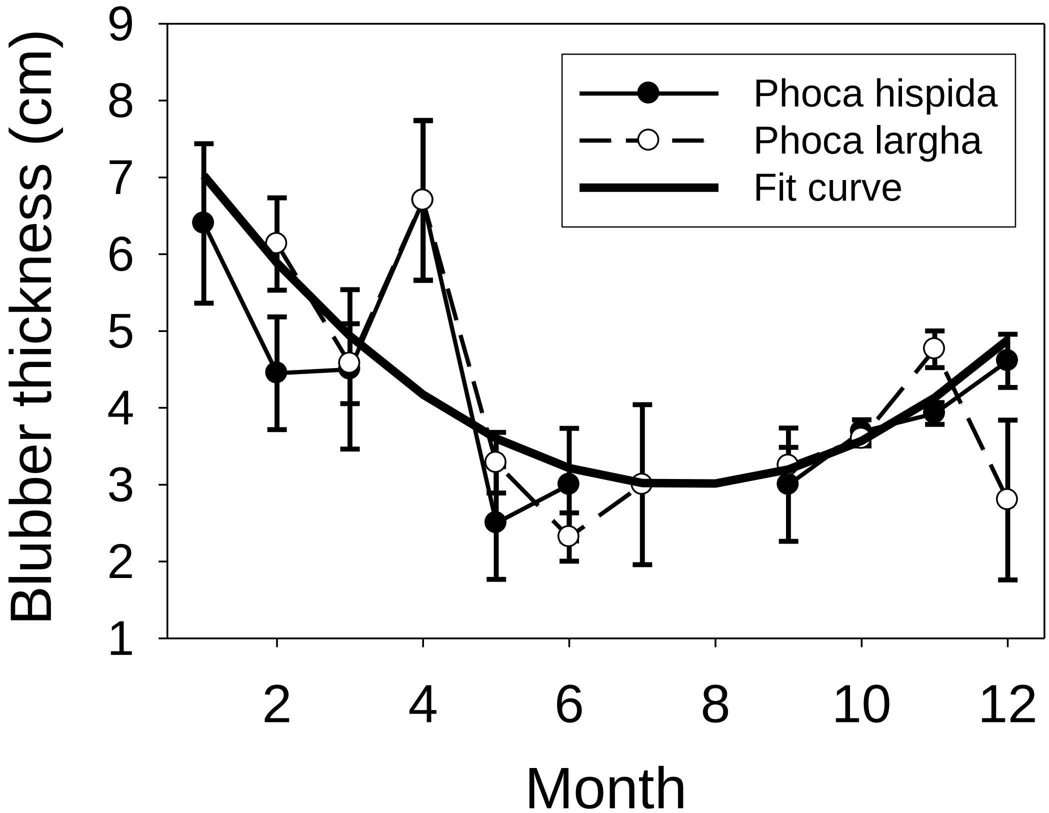


Figure 2. Empirical means and 95% confidence intervals for sternal blubber thickness of ringed and spotted seals. The curve is from the best approximating model for blubber thickness and does not include sex or species specific variation.



***Objective 4:* Traditional Knowledge.** A total of 90 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 we have summarized the responses of some of the questions by village (Table 12).

Responses regarding seal population status did not indicate decreases in any species at any location. The majority of respondents from all villages, except Hooper Bay, reported that seals are found in the same locations as in the past. Hooper Bay reported that some seals are found in different areas now. The timing of hunting has not changed for any species in any village. The villages differed most in the respondent's preference 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 respondents hunted 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 or bearded seals combined with other species were the most important seals for all respondents. 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).

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 residents with an avenue for communicating concerns about seals and the environment.

Objective 5: **Ice Seal Harvest Calendar.** With initial funding from NMFS, Alaska Region, we developed an Ice Seal Harvest Calendar for subsistence hunters to use to record their seal harvest, by species and sex, on a weekly basis. The calendar was tested in Point Hope and Hooper Bay and the responses were positive, including comments such as 1) we need calendars, 2) the pictures are nice and of our subsistence activities, 3) the calendar is easy to use, and 4) the idea of prizes is good. The calendar itself appears to be ready to use, there were no comments regarding corrections, confusion about its use, or mistakes in filling out the monthly pages. To be successful however, this project needed significant coordination and attention and has been incorporated into a larger project to design a statewide harvest monitoring program for ice seals. The project is being funded by ADF&G State Wildlife Grants.

Objective 6: **Ice Seal Committee Meetings.** No Ice Seal Committee meetings were held during this reporting period.

Table 12. Summary of selected Traditional Ecological Knowledge (TEK) questions regarding seal harvest. Numbers are the percentage of respondents answering in the affirmative to selected questions. Responses of "don't know" are not included in this table. See Appendix B for the complete TEK questionnaire.

		Location				
Species	**Question**	**Point Hope** n = 16	**Diomede** n =19	**Shishmaref** n = 14	**Gambell** n =13	**Hooper Bay** n = 28
Ringed	Have numbers remained the same?	31	33	43	54	15
	Have numbers decreased?	31	44	36	31	27
	Have numbers increased?	13	0	7	15	0
	Are seals found in the same areas?	73	88	85	83	37
	Does the hunt occur at the same time?	71	89	71	85	87
	Do you try for certain types of this seal?	86	44	36	85	57
	What is the hunting season?	Jan–Aug	Sept–Jun	Jun; Sept–Nov	Aug–Mar; Jun	Sept–May
Bearded	Have numbers remained the same?	56	47	64	62	19
	Have numbers decreased?	19	11	7	8	33
	Have numbers increased?	13	5	21	23	10
	Are seals found in the same areas?	100	78	92	83	47
	Does the hunt occur at the same time?	100	100	71	100	90
	Do you try for certain types of this seal?	56	29	50	23	57
	What is the hunting season?	May–Jun	Apr–Jun; Oct–Dec	May–Jun	Sept–Jun	Aug–Jun
Spotted	Have numbers remained the same?	56	53	36	38	26
	Have numbers decreased?	13	26	36	38	22
	Have numbers increased?	0	5	21	15	35
	Are seals found in the same areas?	100	94	85	83	53
	Does the hunt occur at the same time?	94	100	100	100	94
	Do you try for certain types of this seal?	44	29	31	46	68
	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	13
	Have numbers decreased?	23	17	0	15	28
	Have numbers increased?	0	17	0	15	6
	Are seals found in the same areas?	55	82	43	83	36
	Does the hunt occur at the same time?	89	92	80	60	77
	Do you try for certain types of this seal?	0	20	33	44	58
	What is the hunting season?	May–Jun	May–Jun	May–Jun; Oct–Nov	May–Jun	Year round

Objective 7: **Habitat Use and Movements of Bearded Seals.** We assisted Kathy Frost, the Kotzebue IRA, ISC representative John Goodwin and other local hunters in a project to capture and place satellite transmitters on nine bearded seals by providing permit support, and analyzing samples collected from the seals captured. We also provided transmitters and ARGOS time for satellite transmitters placed on three ringed seals captured during the bearded seal study in 2006. The ringed seals were the first captured during the fall and traveled approximately 300 miles between Kotzebue and Nome. We provided maps of the ringed seal movements for the Kotzebue IRA website and we will analyze the movements and dive data. The fall capture of ringed seals in 2006 prompted another telemetry study of ringed seals tagged near Kotzebue for October 2007. We will use transmitters purchased with funds from this grant to support that project.

Objective 8: **Co-Management Project Priorities.** We provided financial support for a project proposed and conducted by Kawerak, Inc. that was determined to be a priority project by ISC. The project titled, "*A proposal to test .17 and .22 caliber rimfire and centerfire terminal performance in the harvest of ice seals, and in situ ballistics examination*". The project was of interest to hunters to determine how to best use smaller caliber rifles to be effective in successful ice seal harvests. The final report detailed the findings of an examination of small caliber ballistics and performance. Young seal hunters will be able to review the report to help them become better hunters. The experienced hunter may also find this information useful, as there has been little published information available on small caliber use in hunting large animals.

This project also queried experienced hunters as to the proper methods of shot placement, caliber choice, and hunting technique to ensure that seals are successfully retrieved. No additional co-management projects were funded during this reporting period.

Future Objective: **Retrospective Analyses.** Historical data based on samples from 1960–1961, 1963–1971, 1975–1979, and 1983–1984 are available for comparisons of sex and age of harvest, growth, body condition, diet, reproductive rate, and age at first reproduction. By comparing data collected during this project with historical data from the same villages we can examine the status of the current populations relative to the historical ones. For example, a lower reproductive rate, older age at first reproduction, and older seals in the current harvest compared with data from the past would indicate a stable or declining population relative to the historic population. Without other methods to evaluate population status, these population indices are especially important. During this reporting period we began analyzing the historical data for sample sizes by species and location for the parameters of interest. We performed power analyses to determine samples sizes we need from our current sampling program to make meaningful comparisons. We have also determined effect sizes that are detectable given various sample sizes in order to guide us in our collection.

Recent Products and Publications

Bentzen, T. W., L. T. Quakenbush, and J. J. Citta. 2007. Perfluorinated contaminants in liver tissue of ringed, bearded, spotted, and ribbon seals from the Alaskan Bering Sea. 17th Biennial Conference on the Biology of Marine Mammals, 29 November – 4 December 2007, Cape Town, South Africa. (Abstract)

Dehn, L. A., G. G. Sheffield, E. H. Follmann, L. K. Duffy, D. L. Thomas, and T. M. O'Hara. 2007. Feeding ecology of phocid seals and some walruses in the Alaskan and Canadian

Arctic as determined by stomach contents and stable isotope analysis. Polar Biology 30(2):167-181.

Hughes, L., J. J. Citta, and L. T. Quakenbush. 2007. Patterns of stable isotope (C and N) variability in bearded, ringed, and spotted seals from the Bering and Chukchi seas. 17th Biennial Conference on the Biology of Marine Mammals, 29 November – 4 December 2007, Cape Town, South Africa. (Abstract)

O' Corry-Crowe, G., and C. Bonin. 2007. Molecular genetic study of population structure, dispersal and breeding patterns in four species of ice seal. Report from Harbor Branch Oceanographic Institution, Fort Pierce, Florida to Alaska Department of Fish and Game, Fairbanks, AK. 7 pp.

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.

Posters and flyers were prepared to update the villages with results of sample collections. Presentations were given at ISC meetings, Eskimo Walrus Commission meetings, and the Marine Mammal Commission Meetings.

D. Problems

None.

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Principal Investigator