NORTH PACIFIC RESEARCH BOARD FINAL PROJECT REPORT

Consequences of Fur Seal Foraging Strategies (COFFS)

NPRB Project 414 Final Report

Year 1

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Abstract

Northern fur seals (*Callorhinus ursinus*) have declined by two-thirds in the North Pacific (NP) since the 1950s. While abundance during the breeding season (Jul-Oct) at the Pribilof Is. on the continental shelf of the eastern Bering Sea continues to fall, it has increased exponentially at Bogoslof I. in the deep ocean basin of the eastern Aleutians. Fur seals are also highly migratory, spending 8 months/year far south in the NP. Is the overall population decline due to fisheries, climate change and bottom-up forcing, or is it predation? Does the problem lie in the Bering Sea, reflecting consequences of summer foraging strategies, or elsewhere in the NP, reflecting consequences of winter foraging strategies? To answer these questions, we are undertaking a multiyear study examining consequences of maternal winter-summer foraging strategies and diets on milk output, pup growth, and productivity at St. Paul I. (SP, Pribilofs) and Bogoslof. Results from the first year indicate that on SP, females at parturition (40.2 kg, n=20) were significantly heavier than those on Bogoslof (36.8 kg, n=20, P=0.005). Pup birth mass (6.0 vs 5.7 kg, respectively) and pup mass gain during the 6-9 d perinatal period (2.6 % per d vs 1.9 % per d, respectively) did not differ between locations. However, following the perinatal period, females on SP foraged within 300 km from the rookery and trips averaged 6.5 d, while at Bogoslof, females foraged within 130 km and trips lasted only 2.4 d. Consequently, pup mass gain from Jul-Oct at Bogoslof was significantly greater than that at SP ($P<0.001$), such that near-weaning pups were heavier (14.8 kg) and likely fatter than those at SP (11.9 kg), with possibly a higher probability for survival. The contrasting female foraging strategies and consequences may be related to the divergent population trajectories in the shelf and basin habitats. This study is continued as NPRB project 514.

Key Words

Northern fur seal, *Callorhinus ursinus*, Bering Sea, Bogoslof Island, St. Paul Island, Foraging, Diet, Body composition, Milk intake, Fatty acid techniques

Citation

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Study Chronology

This report summarizes the work that was conducted during the first year of this project between November 2004 and October 2005. The original title, "Seasonal Foraging Strategies and Consequences for Northern Fur Seals at Colonies with Opposite Population Trends," was shortened to "Consequences of fur seal foraging strategies (COFFS)." Field samples were collected in November 2004, July 2005, and October 2005. Winter foraging location data were recorded continuously from satellite transmitters in November 2004 to July 2005, or until the transmitters failed or were lost. Summer foraging location and dive depth data were recorded continuously from satellite transmitters and time-depth recorders (TDRs) that were deployed in July-October 2005. Sample and data analyses were conducted at the University of Alaska Fairbanks (UAF), Dalhousie University, and the National Marine Mammal Laboratory (NMML). A second year of research was funded by NPRB and began in November 2005. This report includes some of the results from the first year of this study; however, most of our results will not be available until the end of our second year. Three progress reports have been submitted and some of the information included in this report was presented in those reports.

Introduction

Fur seals on the Pribilof Islands have been declining for 40 years, and losses since the early 1970s remain unexplained. Leading hypotheses include effects of commercial fisheries and climate change on prey availability in the Bering Sea, and predation by killer whales. However, most fur seals are highly migratory and spend two thirds of the year in the North Pacific Ocean, far south of the Bering Sea. Thus, issues of concern in the Bering Sea may not be as important as factors elsewhere. In contrast to declines on the Pribilofs, fur seals have increased markedly at Bogoslof Island in the eastern Aleutian Is., where oceanographic conditions and food web structure differ substantially from the Pribilofs. Our study compares consequences to the health and fitness of fur seal mothers and their pups of foraging in different habitats of the Bering Sea (Pribilof Is. vs. Bogoslof I.) in summer versus that of winter foraging in the North Pacific. Our goal is to provide information on fundamental aspects of fur seal ecology in the Bering Sea and N. Pacific that will be of benefit to the conservation of fur seals, the rational management of commercial fisheries, and an understanding of effects of climate change on marine ecosystems

Objectives

Our goal is to provide information on fundamental aspects of fur seal ecology in the Bering Sea and N. Pacific that will be of benefit to the conservation of fur seals, the rational management of commercial fisheries, and an understanding of effects of climate change on marine ecosystems.

To accomplish this goal we have two specific objectives:

1. Compare fundamental elements of fur seal biology (e.g., diet, foraging range and region, and attendance patterns) during the summer lactation period at two contrasting locations and assess the consequences of different strategies on the fitness of individual mothers and their pups.

2. Conduct longitudinal studies of individual fitness through complete annual cycles to gain an understanding about the importance of conditions in the Bering Sea compared to conditions in the N. Pacific, where female and juvenile seals spend 8 months of the year.

Methods

Field locations

Data were collected from northern fur seal females and pups on St. Paul I. where the population is declining and from Bogoslof I. where the population is increasing. St. Paul I. is part of the Pribilof Islands and is located on the continental shelf at 57º09'N, 170º13'W and Bogoslof I. is located approximately 60 miles northwest of Unalaska Island in the deep ocean basin at 53º56'N, 168º02'W. We stayed at the NMFS Staff Quarters at St. Paul I. and collected samples from Vostochni and Reef rookeries. We constructed a cabin on Bogoslof I. to house our kitchen and field laboratory and we collected samples from the NE and the SW spit rookeries. Transportation to and from St. Paul I. was provided by Penair and transportation to and from Bogoslof I. was provided by the FV Miss Alyssa out of Dutch Harbor, AK.

Field sampling

Synopsis

We attached satellite transmitters to 20 females just prior to their departure from the rookeries in November 2004 and we took a series of samples to assess their physiological condition at that time. We selected females judged to be at least 8 years old based on vibrissae color and pelage characteristics. In July 2005, when females returned to St. Paul I. after their winter migrations, we recaptured as many of the females as possible that were sampled and instrumented the previous November. Additional females to constitute a sample size of 20 were captured as necessary. Captures were made in July within 1 to 2 days postpartum and samples were collected to assess physiological condition and determine diet composition over the previous several months; telemetry packages (PTT, VHF, TDR) were attached to females to determine summer foraging areas, foraging effort, and attendance patterns; pups were captured to assess birth condition and marked prior to release. At the end of the perinatal period, we recaptured the pups to reassess body condition and determine the rate at which milk was transferred to them by their mothers. Three-fourths of the way through lactation (early October, approximately 3 months postpartum), we again recaptured these mother-pup pairs to assess their body condition, determine maternal diet composition, measure pup growth rates (inferring overall milk delivery rates), and recover transmitters that were attached to the mothers.

We used data from the summer portion of the longitudinal study conducted on St. Paul, and the same suite of data collected from Bogoslof I. during the same time period, to make comparisons between two contrasting rookery sites. The first captures on Bogoslof I. were made in July 2005 when females returned to the island after their winter migrations. Twenty adult females and their pups were captured 1-2 days post partum and for the duration of the breeding season sampling and instrument deployments mirrored those that were being done on St. Paul I. as described above for the longitudinal studies.

Pre-winter tagging

At St. Paul I. in early November 2004, 20 recently molted females were captured and restrained following the techniques of Gentry and Holt (1982). A blood sample was collected from the flipper of each female as near as possible to the time of capture for measurement of background isotope levels. Females were then weighed to the nearest 0.1 kg and administered a precisely weighed dose of 99.8% deuterium oxide (D_2O; Sigma Aldrich) by gastric intubation to determine total body water (TBW) and hence body composition. Blood samples (5-10 cc) were collected from a rear flipper at 2:10 and 2:30 hours following isotope administration for measurement of isotope concentration and to confirm equilibration. During this time, the female was injected with oxytocin (IM) to facilitate milk let-down and a milk sample (≤ 15 mL) was collected for fatty acid analysis and proximate composition. A full-depth blubber biopsy was taken from the posterior neck region of the female using a 6 mm sterile biopsy punch according to Kirsch et al. (2000), to estimate diet and its contribution to onboard energy reserves using quantitative fatty acid signature analysis (QFASA; Iverson et al. 2004). Prior to release, satellite transmitters (Kiwisat 101 PTT, Sirtrack Ltd.) were attached to the pelage medial to the scapula with 5 Minute® Epoxy (Devcon). Females were given uniquely numbered tags (Allflex Global Medium, Allflex USA, Inc.) in the fore flippers for identification.

Perinatal sampling

Twenty females with newborn pups were captured 1-2 days postpartum at St. Paul I. and Bogoslof I. in July 2005. Newborn pups were identified by the presence of an umbilicus. Pairs were captured according to Goebel (2002), and restrained. On St. Paul, three of the females that were sampled and instrumented the previous November were included in the twenty. Upon capture, a blood sample was collected from the rear flipper of both female and pup for measurement of background isotope levels. Female and pup were then weighed to the nearest 0.1 kg and given isotopically labeled water to determine TBW and body composition, and perinatal milk intake of the pup. Females were injected (IM) with a precisely weighed quantity of tritiated water (^3H_2O). Pups were first intubated to remove any milk in their stomachs (which delays equilibration) and then given a precisely weighed dose (at 3 $g \cdot kg^{-1}$) of 99.8% deuterium oxide (D_2O; Sigma Aldrich) by gastric intubation (if the milk volume removed was >100 mL, it was saved and introduced back into the pup by gastric intubation just prior to release). Female and pup were kept together but not allowed to suckle during a 2:30 hour equilibration period. Two serial blood samples (5-10 cc) were collected from both as described above.

Prior to the final blood sampling, a milk sample was collected and a blubber biopsy taken from the adult female as described above. Females were instrumented with PTTs (as described above) to determine summer foraging areas, time-depth recorders (MK9 TDR, Wildlife Computers) to assess foraging effort, and VHF transmitters (MM420, Advanced Telemetry Systems, Inc) to monitor attendance patterns. Females were given a uniquely numbered tag in the fore-flipper and pups were given a unique mark with commercial hair-bleach and then both were released. Each female and pup pair was observed after release to make sure that the mother-pup bond was intact.

Daily observations using VHF receivers and visual identification were made of the rookeries to determine when the female ended her perinatal suckling period and departed to sea, generally 5-7 days. The pup was then briefly captured to obtain a body

mass measurement and blood sample for D_2O analysis to determine milk intake during the perinatal suckling period.

All samples (blood, milk, and blubber) were stored in a cooler on ice during collection periods in the field. Upon return to the field laboratory, blood samples were centrifuged and serum was collected into cryovials and frozen. A 0.25 g aliquot of milk and each blubber sample were stored in glass vials containing chloroform and 0.01% BHT for fatty acid analysis and the remaining milk was frozen for proximate analysis.

Late lactation sampling

At approximately 3 months postpartum (3/4 way through the lactation period), the same mother-pup pairs were captured as described above. Instruments (PTT, TDR, VHF) were removed from the females and a blood sample was taken to measure background isotope levels. All other procedures for weights, measurements, and isotope determination of body composition of both mothers and pups were repeated as described above, with the exception that pups were administered D_2O at 1 $g \cdot kg^{-1}$ to just measure equilibration levels. We used pup growth rate and body condition as a proxy for overall milk intake rate to avoid continual and long-term recaptures of mother-pup pairs throughout lactation.

Prey sampling

Large numbers of prey commonly eaten by northern fur seals were collected prior to the start of this project in the course of other projects (e.g., ReFER) funded by NPRB (project 320) and CIFAR. We have built on this collection during the past year to assemble a more inclusive fatty acid prey library. Collections were made by the Fisheries Resourse Division (FRD/SWFSC/NOAA) during their Oregon–Washington Sardine survey in March 2005 and during their pelagic biomass/CALCOFI survey in April 2005. The mid-water assessment and conservation engineering group (MACE/AFSC/NOAA) collected samples for use during their echo integration-trawl surveys of walleye pollock around Bogoslof Island March 5-11, 2005. The resource assessment and conservation engineering division (RACE/AFSC/NOAA) from their biennial Gulf of Alaska bottom trawl survey, which was conducted May 20 - August 1 2005, and from their annual eastern Bering Sea bottom trawl survey, which was conducted June 1 - August 1, 2005. Prey samples were frozen at sea and returned to the lab for processing.

Laboratory analyses and interpretation

Tagging data

Female foraging areas during the winter migration period and the summer lactation period were determined from satellite telemetry data. Locations were calculated by Service Argos Inc., and filtered iteratively based on Argos location quality rankings, time sampling/transmission intervals and maximum swim speed, similar to methods described by Robson et al. (2004) and Ream et al. (2005). Female dive effort during the summer was assessed with TDRs that measure depth (resolution of ± 1m) every 10s. Dives ≥ 3m and > 15s were used to calculate dive rate, mean and maximum dive depth, and to classify dive type (deep, shallow, mixed; Goebel 2002) for comparisons of females among rookeries. Female presence or absence data from VHF transmitters were used to

determine arrival and departure times at the rookeries during the summer. These attendance patterns were used to compare female visits and foraging trip duration.

Body composition and milk intake

Female serum samples were distilled using the method of Ortiz et al. (1978) and counted for ^{3}H activity using a Beckman LS 5000CE scintillation counter. Pup serum samples were distilled using the method of Oftedal and Iverson (1987) and analyzed for D_2O concentration on a single-beam, fourier transform, infrared spectrophotometer (Perkin-Elmer FT-IR Paragon 1000), using gravimetrically prepared standards and distilled water as reference. Isotope dilution space was converted to total body water (TBW) using the equation derived by Bowen and Iverson (1998). TBW was then used to calculate total body fat (TBF) and total body protein (TBP) content using the equations of Reilly and Fedak (1990). Milk intake of pups during the perinatal period was determined according to Oftedal and Iverson (1987) and Iverson et al. (1993).

Fatty acid analyses and QFASA

Lipids were quantitatively extracted from blubber, milk, and prey (after recording length and mass of each whole prey) according to Iverson et al. (2001). Fatty acid methyl esters were prepared, identified, and analyzed according to Iverson et al. (1997, 2001, 2002) using temperature-programmed gas liquid chromatography on a Perkin Elmer Autosystem II Capillary FID gas chromatograph fitted with a 30m x 0.25 mm id. column coated with 50% cyanopropyl polysiloxane (0.25µ film thickness; J&W DB-23; Folsom, CA) and linked to a computerized integration system (Turbochrom 4 software, PE Nelson). QFASA estimates of diet will be determined from female blubber and milk samples according to Iverson et al. (2004) using the prey database available from this and other studies and using calibration coefficients recently determined for otariids (Tollit et al. 2003).

Results

Instrument data

In November 2004, 20 females were captured and instrumented with satellite transmitters at two St Paul I. rookeries – 10 from Reef and10 from Vostochni. Tracking began immediately and continued through the winter migration period. By March females were spread out across the North Pacific from the coast of Washington (deep, off-shelf waters), westward to the transition region of the west-central North Pacific Ocean (37°N, 176 °W). (Fig. 1) During the winter migration period, none of the fur seals appeared to be using the continental shelf region of the North Pacific. Further analysis of the female winter movements during this time period are ongoing.

Satellite transmitters and TDRs were deployed on female fur seals 1-2 days postpartum in July and removed in October to determine foraging strategies during the summer breeding season in the Bering Sea. Twenty females from St. Paul I. (10 from Vostochni and 10 from Reef), and 20 females from Bogoslof I. were instrumented and tracking began immediately. There were three distinct foraging areas that were utilized by the female fur seals in our study (Fig. 2). Females from the Vostochni rookery traveled north and northeast over the shelf, females from the Reef rookery foraged to the south and southwest close to the shelf break, and females from Bogoslof foraged a

relatively short distance from Bogoslof in all directions. The mean maximum distance that females from the two rookeries on St. Paul I. traveled was not significantly different and averaged 350 km. Females from Bogoslof traveled significantly shorter distances which were less than 150 km (Fig. 3). Trip durations were also significantly different between islands. Females from St. Paul I. foraged an average of 7 days, whereas females from Bogoslof I. foraged an average of 2.5 days. The time that females spent on shore with their pups averaged 1.8 days on St. Paul I. and 1.2 days on Bogoslof I.

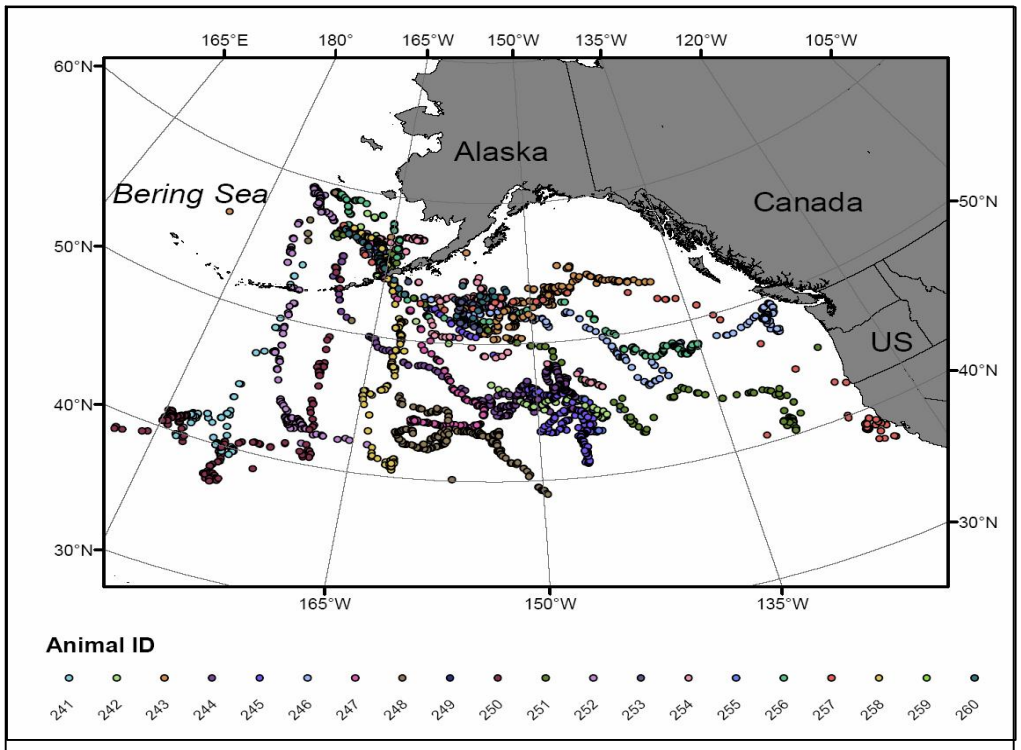

Figure 1. Winter migration movements of adult female fur seals from St. Paul I. between November 2004 and March 2005.

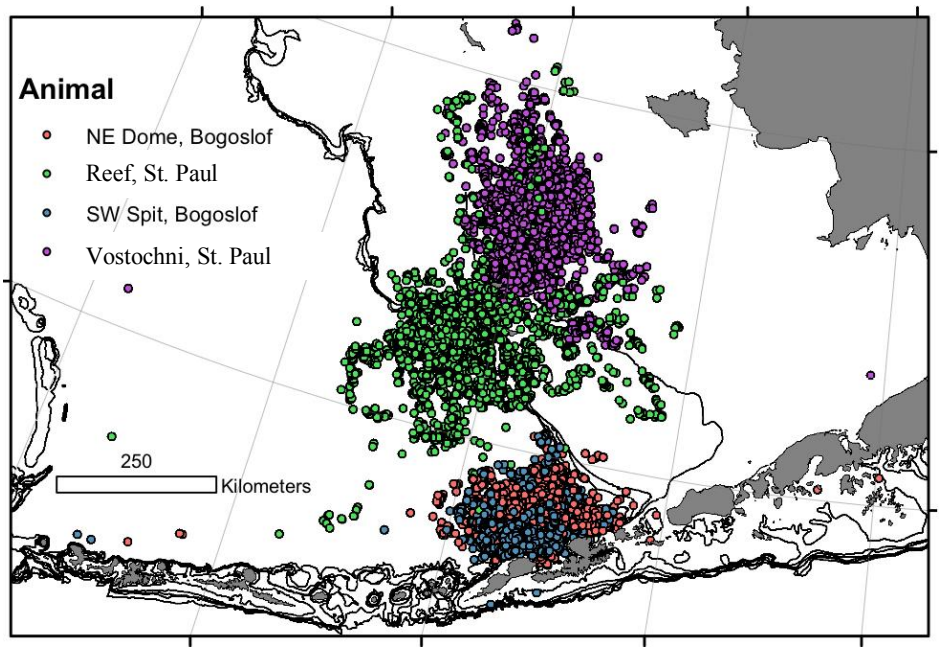

Figure 2. Summer foraging locations of adult female fur seals from St. Paul I. and Bogoslof I. in July-October 2005.

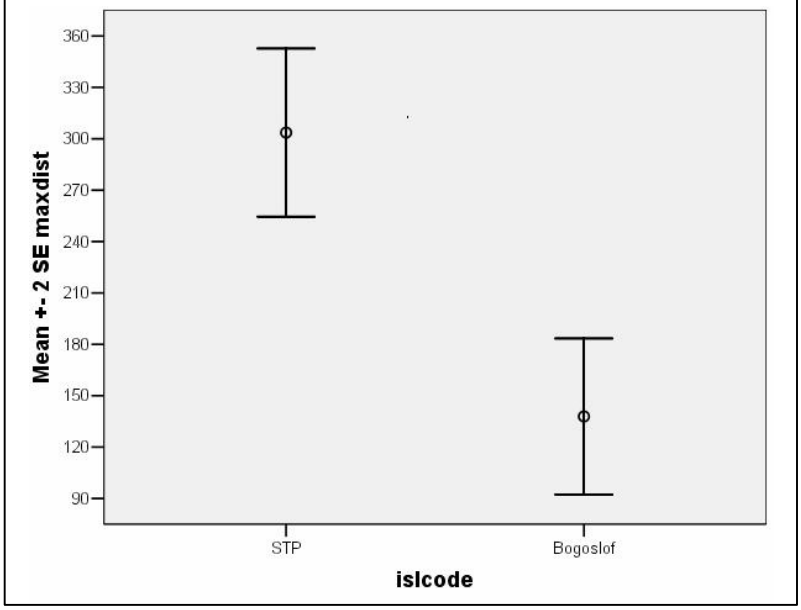

Figure 3. Female mean maximum trip duration.

Female mass change

Body mass data were collected from 20 females on St. Paul I. in November 2004 (ten from Vostochni and ten from Reef). There was no significant difference in the body mass data between rookery sites on the same island (P=0.31). Females averaged 39.8 kg (both rookeries combined, Table 1).

The following July, twenty females from St. Paul I. and twenty females from Bogoslof I. were weighed 1-2 days post-partum. Sampling was again equally split between Vostochni and Reef rookeries on St. Paul I. and between NE Dome and SW Spit rookeries on Bogoslof I. There was no significant difference in mass between females sampled at intra-island rookery sites (St. Paul P=0.78, Bogoslof P=0.44). Females were slightly but significantly (P=0.005) heavier on St. Paul I. than on Bogoslof I. (40.2 kg and 36.8 kg, respectively)

In October, at approximately three months postpartum, females were weighed again on St. Paul I. and Bogoslof I. Again, there was no significant difference between intra-island rookery sites (St. Paul P=0.95, Bogoslof P=0.50). Sixteen of the 20 females that were caught in July were recaptured and weighed on St. Paul I. and their average mass was 37.5 kg. All twenty females were recaptured on Bogoslof I. and their average mass was 35.6 kg. There was no significant difference in female mass between St. Paul and Bogoslof in October (P=0.23).

Location	Nov-04	Jul-05	Oct-05
St. Paul	39.8±1.6	40.2±1.3	37.5±1.7
Bogoslof	-	36.8±0.8	35.6±1.0

Table 1. Average female mass (kg) by month. The red weights in July were significantly different between islands (P=0.005).

Pup birth mass and mass gain

There were no significant differences in pup birth mass between intra-island rookery sites, so data were grouped by island. At 1-2 days post partum pup mass did not differ between islands (P=0.11) at an average of 6.0 kg on St. Paul I. and 5.7 kg on Bogoslof I. (Table 2). During the perinatal period, pup mass increased by approximately 2.6% per day on St. Paul I. and 1.9% per day on Bogoslof I. This rate of increase during the perinatal period was also not significantly different between the two locations (P=0.13). By the end of the perinatal period, pups from St. Paul I. weighed an average of 6.9 kg and pups from Bogoslof weighed an average of 6.3 kg.

Pups were caught again at both locations in October to assess body condition at the end of the breeding season close to the time of weaning. Pups from Bogoslof I. weighed an average of 14.8 kg, which was significantly greater (P<0.001) than the average of 11.9 kg on St. Paul I. Between the end of the perinatal period and October, pups from Bogoslof I. increased in mass at a rate of 1.6 % per day, which was not significantly different from the perinatal period (P=0.36); however, pups from St. Paul I. increased at a significantly slower rate of 0.9 % per day (P<0.001) (Table 3). Thus, pups from St. Paul I. were likely weaned at a lighter mass than those from Bogoslof I. (Fig. 4).

Location	Birth Jul-05	End perinatal Jul-05	Oct-05
St. Paul	6.0±0.2	6.9±0.2	11.9±0.4
Bogoslof	5.7±0.2	6.3±0.2	14.8±0.5

Table 2. Average pup mass (kg). The red weights in October were significantly different between islands.

Location	Perinatal	End of perinatal to Oct	Entire breeding season
St. Paul	2.6±0.5	0.9±0.1	1.2±0.1
Bogoslof	1.9±0.3	1.6±0.1	1.8±0.1

Table 3. Average pup mass % change per day over the period indicated. The percentages in red indicate a significant difference between islands.

Body composition and milk intake

Hydrogen isotope techniques were used to determine female body composition on St. Paul in November 2004 and female and pup body composition on St. Paul and Bogoslof at birth in July 2005 and again late in lactation (October) 2005. Additionally isotope dilution was used to measure pup milk intake over the perinatal period. In November 2004, female body composition averaged 64.8±0.3 % water, 22.5±0.1 % protein, and 10.1±0.5 % fat. Samples from July and October are in the process of being analyzed.

Diet data

Milk samples were taken from females to assess recent diet and blubber samples were collected to assess long-term diet. Milk and blubber fatty acids are being extracted in Fairbanks and analysis is ongoing. Diet estimation using QFASA (Iverson et al. 2004) will be performed once the prey library is completed.

Prey library

Fish samples from the North Pacific where females spend their winter migrations were collected by FRD (SWFSC, NMFS) off the coast of California, Oregon, and Washington in March and by RACE (AFSC, Seattle) in the Gulf of Alaska between May and July. Additional samples were collected from the Bering Sea where female fur seals forage during the breeding season by the BASIS program (Auke Bay Lab, NMFS), MACE (AFSC, Seattle) and RACE (AFSC, Seattle). Processing of these samples is ongoing at UAF and Dalhousie U. for use in diet estimates.

Milk composition data

Milk samples will also be used to assess female milk composition. Samples were collected in November, July and October from each female and analysis is ongoing.

Satellite tracking data

Additional information on foraging locations and movement patterns of females from St. Paul I. and Bogoslof I. will be forthcoming in the next several months.

TDR data

Dive depth and duration data are being analyzed at NMML. Results will be forthcoming in the next several months as well.

Discussion

Fur seals on the Pribilof Is. have been declining for 40 years, and losses since the early 1970s remain unexplained. The National Marine Mammal Laboratory (NMML) conducted their semi-annual northern fur seal population census on the Pribilof Is. in 2004 and determined that between 2002 and 2004 alone, pup production decreased by 15.7% on St. Paul I. and by 4.1% on St. George Island. The total number of pups born in the Pribilof Is. in 2004 was less than one third the number born during the 1950's. In contrast to declines on the Pribilof Is., fur seals have increased markedly at Bogoslof I. in the eastern Aleutian Is., where oceanographic conditions and food web structure differ substantially from the Pribilof Is. The first population census to be conducted on Bogoslof I. since 1997 was completed this past summer (2005) and found that pup production continues to increase exponentially. An estimated 12,631 pups were born on Bogoslof I. during 2005. These results indicate that pup production has increased at 12% per year since pups were last counted in 1997. These two contrasting rookery sites provide a natural system in which to compare fundamental aspects of fur seal ecology and investigate the consequences of different strategies on the health and fitness of fur seal mothers and their pups.

Preliminary results reveal differences in female energy expenditure and female and pup mass gain between St. Paul I. and Bogoslof I. The differences in mean maximum foraging distance (St. Paul, 350 km; Bogoslof, 150 km) and trip duration (7 d and 2.5 d, respectively) indicate that females from St. Paul I. expend more time and effort foraging. However, since on shore times remain similar (1.8 d and 1.2 d, respectively), pups experience a larger number of feeding events, as well as reduced fasting periods, on Bogoslof. These factors likely contributed to the differences in mass that we observed in females and pups between islands. Female fur seals on St Paul I. decreased in mass at a faster rate during the summer breeding season than females from Bogoslof and pups were significantly heavier on Bogoslof in October shortly before weaning. The fact that pups on Bogoslof appear to be weaned at a heavier mass, with a likely greater fat content, suggest they have a higher probability of survival. That is, in most mammals, including pinnipeds, juvenile survival is positively correlated with body size at weaning (reviewed in Meulbert et al. 2003).

Further analysis of the diet, body composition, foraging location and dive depth data will provide a greater understanding of how females acquire and expend energy, and how they allocate resources to their pups. The results included in this report are only preliminary from the first year of this study. Two years were funded by NPRB and our final results and conclusions will be made after the second year of research is completed. We will use female data on morphology, winter and summer and recent and long-term

diet, foraging location and dive depth, milk composition, and body composition plus pup data on morphology, milk intake rates and body composition to make our final conclusions.

Complimentary work is also being conducted by researchers at NMML. Mary-Anne Lea and others deployed 40 satellite transmitters on pups from the Pribilof Is. and 20 on pups from Bogoslof in October and November 2005 to determine pup movements after weaning, during the winter migration period. In addition, two of the 2004/05 winter migration females entered areas where Seagliders (autonomous underwater vehicles) were sampling temperature, conductivity, dissolved oxygen, chlorophyll fluorescence, and red and blue backscatter from the surface to 1000 m. The information from the Seagliders was combined with remotely sensed data (sea surface height and surface chlorophyll *a*) and fur seal movement data to characterize areas of foraging. This information was presented as a poster at the Society for Marine Mammalogy Conference held in San Diego, California in December of 2005. Information from these studies will be useful in interpretation of our data and collaborative work in both of these cases may be undertaken in the future to gain further insight into northern fur seal biology.

Conclusions

Our preliminary results from Year 1 indicate that there are differences in the fundamental elements of fur seal biology during the summer lactation period at two contrasting locations and there appear to be consequences to individual mothers and their pups. Further sample and data analyses will be used to investigate these relationships in more detail and to construct longitudinal studies to address our second objective. Ultimately, we will use the final results from this project to provide information on northern fur seals in the Bering Sea and N. Pacific that will be of benefit to the conservation of fur seals, the rational management of commercial fisheries, and an understanding of effects of climate change on marine ecosystems.

Publications

Publications will be prepared and submitted after our second year of data collection is completed.

Outreach

All members of research our team have participated in outreach activities for the purposes of informing the scientific and public communities of our project and providing updates of our results. The following summarize those done to date:

Exhibits/demonstrations of project development

- USFWS Alaska Maritime National Wildlife Refuge, September 2004 by S.Iverson and A. Springer
- Pribilof Island Collaborative fur seal meeting, January 2005 by R. Ream

Conference presentations

- Marine Mammal Society Biennial mMeeting (poster), Dec. 2005 by J. Sterling
- Marine Science in Alaska 2005 by S. Iverson

Community meetings

- St. Paul I., July 2005 by S. Iverson, A. Springer, J. Sterling, and B. Fadely

- Unalaska Island, July 2005 by Rolf Ream

Presentations at festivals and events

- Sitka Whalefest, November 2005 by B. Fadely

Presentations at schools

- Belmont Hill School, grades 7-12, in Boston Massachusetts by A. Banks
- University of Alaska Fairbanks, Rasmusson Fisheries Foundation by A. Banks.

Press articles

- Smithsonian Magazine
- New York Times
- Anchorage Daily News
- Fairbanks Daily News Miner
- Dutch harbor fisherman
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Literature Cited

Bowen, W. D. and S.J. Iverson. 1998. Estimation of total body water in pinnipeds using hydrogen-isotope dilution. Physiol. Zool. 71: 329-332.

Gentry, R.L. and J.R. Holt. 1982. Equipment and techniques for handling northern fur seals. NOAA Tech. Rep. NMFS SSRF-758. [Available from D822, User Services Branch, Environmental Sciences Information Center, NOAA, Rockville, MD.]

Goebel, M.E. 2002. Northern fur seal lactation, attendance and reproductive success in two years of contrasting oceanography. Ph.D. thesis, University of California, Santa Cruz.

Iverson S.J. 1993. Milk secretion in marine mammals in relation to foraging: can milk fatty acids predict diet? Symposium of the zoological Society of London. 66:263-291.

Iverson S.J., W.D. Bowen, D.J. Boness, and O.T. Oftedal. 1993. The effect of maternal size and milk energy output on pup growth in grey seals (*Halichoerus grypus*). Physiol. Zool. 66:61-88.

Iverson, S.J., C. Field, W.D. Bowen, and W. Blanchard. 2004. Quantitative fatty acid signature analysis: a new method of estimating predator diets. Ecol. Monogr. 74(2): 211-235.

Iverson, S. J., K.J. Frost, and S. Lang. 2002. Fat content and fatty acid composition of forage fish and invertebrates in Prince William Sound, Alaska: factors contributing to among and within species variability. Mar. Ecol. Prog. Ser. 241: 161-181.

Iverson, S. J., K.J. Frost, and L.L. Lowry. 1997. Fatty acid signatures reveal fine scale structure of foraging distribution of harbor seals and their prey in Prince William Sound, Alaska. Mar. Ecol. Prog. Ser. 151: 255-271.

Iverson, S.J., S. Lang, and M. Cooper. 2001. Comparison of the Bligh and Dyer and Folch methods for total lipid determination in a broad range of marine tissue. Lipids 36:1283-1287.

Iverson, S.J., J. MacDonald, and L.K. Smith. 2001. Changes in diet of free-ranging black bears in years of contrasting food availability revealed through milk fatty acids. Can. J. Zool. 79: 2268-2279.

Kirsch, P.E., S.J. Iverson, and W.D. Bowen. 2000. Effect of diet on body composition and blubber fatty acids in captive harp seals (*Phoca groenlandica*). Physiol. Biochem. Zool. 73: 45-59.

Muelbert, M. M. C., Bowen, W. D. and S.J. Iverson (2003) Weaning mass affects changes in body composition and food intake in harbour seal pups during the first month of independence. Physiological and Biochemical Zoology 76: 418-427.

Oftedal O.T. and S.J. Iverson. 1987. Hydrogen isotope methodology for measurement of milk intake and energetics of growth in suckling young. Pages 67-96 In A.C. Huntley, D.P. Costa, G.A.J. Worthy, and M.A. Castellini, (eds.), Approaches to marine mammal energetics. Allen Press, Lawrence, KS.

Ortiz C.L., D.P. Costa, and B.J. LeBoeuf. 1978. Water and energy flux in elephant seal pups fasting under natural conditions. Physiol. Zool. 51: 166-178.

Reilly J.J. and M.A. Fedak. 1990. Measurement of living grey seals (*Halichoerus grypus*) by hydrogen isotope dilution. J. Appl. Physiol. 69: 885-891.

Ream, R.R., J.T. Sterling and T.R. Loughlin. 2005. Oceanographic influences on northern fur seal migratory movements. Deep-Sea Res. II. 52(5-6): 823-843.

Robson, B.W., M.E. Goebel, J.D. Baker, R.R. Ream, T.R. Loughlin, R.C. Francis, G.A. Antonelis and D.P. Costa. 2004. Separation of foraging habitat among breeding sites of a colonial marine predator, the northern fur seal (*Callorhinus ursinus*). Can. J. Zool. 82(1): 20-29.

Tollit, D., S.J. Iverson, S. Heaslip, D. Rosen, and A.W. Trites. 2003. Validation studies of blubber quantitative fatty acid signature analysis (QFASA) with captive Steller sea lions (*Eumetopias jubatus*). 15th Biennial Conference on the Biology of Marine Mammals, Greensboro, NC (December).