

Alaska Ice Seal Research Plan: 2023



Alaska Ice Seal Research Plan

A coordinated plan for research on ice-associated seals in Alaska, including accomplishments and critical unfunded research

Prepared jointly by
The Ice Seal Committee
National Marine Fisheries Service
(Alaska Fisheries Science Center, Marine Mammal Laboratory)
Alaska Department of Fish and Game
(Division of Wildlife Conservation)

Table of Contents

Executive Summary	1
Introduction	3
Management Needs	5
Objectives of the Ice Seal Research Plan	7
A. Current and Proposed Projects	7
A.1 Population identity and status	7
A.1.1 Ice Seal Life History Studies	
A.1.2 Genetic population structure of ice-associated seals in Alaska	
A.1.3 Auditory biology of bearded, ringed, and spotted seals	
A.1.4 Captive studies of ice seal health and physiology	
A.1.5 A.1.5 (New Project) Bearded seal abundance and demographics using close-kin mark-recapture methods	
A.2 Mortality and harvest	13
A.2.1 Harvest monitoring	
A.3 Habitat and climate change	15
A.3.1 Movements, habitat use, and foraging behavior of adult bearded seals in the Chukchi and Bering Seas	
A.3.2 Movements, habitat use, and foraging behavior of ribbon and spotted seals in the Bering Sea	
A.3.3 Using aerial surveys, bio-logging, and satellite remote sensing to characterize Arctic ringed seal denning habitat	
A.3.4 Bering-Okhotsk Seal Surveys (BOSS)	
A.3.5 Chukchi and East Siberian Surveys (ChESS)	
A.3.6 Joint Beaufort Sea surveys (JobSS) for seals and polar bears	
A.3.7 Acoustic habitat of ice-living seals in Kotzebue Sound	
A.3.8 Ice seal health research	
A.3.9 Monitoring body condition of seals in Alaska using small UAS	
A.3.10 Integration of traditional knowledge and western science using a Bayesian approach for fully informed models	
A.3.11 Documenting movements, behavior, and distribution of Arctic ice seals	
A.3.12 Evaluating novel assessment approaches for coastal ice seal haul-out areas and behavior in the Alaskan Beaufort Sea	
A.3.13 (New Project) Ringed seal winter density	
A.3.14 (New project) Oceanographic influences on spotted seal foraging	
A.3.15 (New Project) The trophic roles of ice seals in the Bering and Arctic Marine Ecosystems of Alaska	
A.3.16 (New Project) Bering Sea Ice Seal Surveys	
A.3.17 (new Project) Monitoring bearded seals in the NPR-A through tagging and acoustics	
A.4 Education and outreach	31
B. Completed projects	32



- B.1 Population identity and status** 32
 - B.1.1 Traditional ecological knowledge of seals in Norton Bay, Alaska
 - B.1.2 Correction factor for ringed seal surveys
 - B.1.3 Timing and re-interpretation of ringed seal surveys
 - B.1.4 Densities of ringed and bearded seals in the eastern Chukchi Sea
 - B.1.5 Population structure and seasonal movements of ringed seals
 - B.1.6 Population structure of ringed seals (*Phoca hispida*) in the Chukchi and Beaufort seas
 - B.1.7 Densities and distribution of ribbon, spotted, and bearded seals in the eastern Bering Sea
 - B.1.8 Beaufort Sea ice seal sampling and archival project
- B.2 Mortality and harvest** 36
 - B.2.1 Bering Strait seal harvest survey 2002
 - B.2.2 Nutrients and contaminants in spotted seal based foods, and assessment of risks and benefits to human consumers
- B.3 Habitat and climate change** 36
 - B.3.1 Ice seal habitat use and selection near St. Lawrence Island
 - B.3.2 Ice seal contaminant level assessment in tissues consumed by humans
 - B.3.3 Movements, habitat use, and foraging behavior of ringed seals in the Chukchi and Bering Seas
 - B.3.5 Movements, habitat use, and foraging behavior of young-of-the-year bearded seals in the Chukchi and Bering Seas
 - B.3.6 Movements, habitat use, and foraging behavior of ringed, bearded, and spotted seals
 - B.3.7 First documentation of oil fouling in subsistence-harvested ringed (*Phoca hispida*) and spotted (*Phoca largha*) seals in Bering Strait
- B.4 Education and Outreach** 41
 - B.4.1 Kawerak Ice Seal and Walrus Project, 2010-2014
 - B.4.2 Traditional hunting workbook – ice seals
- Literature cited** 43

Executive Summary

Four species of ice-associated seals, bearded (*Erignathus barbatus*), ringed (*Pusa hispida*), spotted (*Phoca largha*) and ribbon seals (*Histiophoca fasciata*), inhabit the Bering, Chukchi, and Beaufort seas of the Alaskan Arctic. Collectively, they are often referred to as “ice seals” and despite the fact that these seals are vital resources for Alaska Native communities, as well as key ecological components of arctic marine ecosystems, relatively little is known of the seals’ population status, stock structure, trends in abundance, life history, seasonal movements, diving behavior, diet or harvest rates. Ice seals are highly dependent on suitable sea ice condition and distribution, and therefore may be particularly vulnerable to climatic change, offshore oil development, or other environmental impacts that could alter their habitat. Indeed, concern about loss of sea ice habitat in the current warming climate has been the basis for petitions to the National Marine Fisheries Service (NMFS) for listing all four species as threatened or endangered under the Endangered Species Act.

The Ice Seal Research Plan is a consolidated plan for Alaskan ice seal research and monitoring that is primarily funded in whole or in part through the NMFS budget, but it also includes research projects with Alaska ice seals that have other sources of funding. Research on Alaska’s ice seals is carried out principally by NMFS, Alaska Department of Fish and Game (ADF&G), and communities in the Alaska Native Regions represented by the Ice Seal Committee (North Slope Borough, Maniilaq, Kawerak, Bristol Bay Native Association, and the Association of Village Council Presidents). The combined research efforts by these groups focus on ice seal population abundance and trends, harvest, stock identification, general biology and life history, and human interactions. The principal objectives of the research plan are to:

1. Consolidate currently-funded projects into a single coordinated effort with maximum relevance to management objectives; and
2. Describe additional research projects that are currently unfunded, but for which funds are critically needed;
3. Increase the dialogue, coordination, and collaboration among interested parties through the process of annually reviewing, evaluating and updating the research plan.

The Research Plan describes 23 current and proposed projects that identify and address specific research needs, including the identity and status of ice seal populations, the comprehensive assessment of ice seal mortality including harvest, and the impact of industrial & climatological events on ice seal habitat.







Introduction

Four species of ice-associated seals — bearded seals (*Erignathus barbatus*), ringed seals (*Pusa hispida*), spotted seals (*Phoca largha*) and ribbon seals (*Histiophoca fasciata*) — inhabit the Bering, Chukchi, and Beaufort seas (Burns 1970). These species have been important in the subsistence economy of northern Indigenous Peoples for thousands of years (Hall 1866, Murdoch 1885, Boas 1888, Rozanov 1931, Cox and Spiess 1980, Freeman 1984, Wenzel 1984), and large numbers were commercially harvested by the former Soviet Union in the 1960's (Shustov 1965, Shustov 1972, Mineev 1975, Mineev 1984). Threats to the populations include offshore oil development (Kelly 1988c, Kelly 1988a, Kelly 1988b, Quakenbush 1988) and reductions in sea ice associated with climate change. Sea ice is a key element of the habitat for ice-associated seals (Fay 1974), and changes in snow and ice cover of polar waters may have severe impacts on those species (Tynan and DeMaster 1997, Kelly 2001, Smith and Harwood 2001, Stirling and Smith 2004, Ferguson et al. 2005).

Subsistence hunters have extensive knowledge of ice-associated seals (Nelson 1969, Krupnik 1978, Huntington 2000) and have contributed traditional knowledge to scientific research and management through interviews, contributions of biological samples, and participation in scientific field projects (Allen 1880, Nelson and True 1887, Johnson et al. 1966, Lowry et al. 1980b, Lowry et al. 1980a, Whiting and Frost 2007). Despite the interests of subsistence users, scientists, and managers, ice-associated seal populations are poorly understood and documented, relative to many other living resources, and many basic questions concerning their ecology and population status remain unanswered. This Research Plan describes a coordinated effort to answer these basic questions and enhance understanding of ice-associated seals inhabiting the waters surrounding the state of Alaska.



Table A.1 Importance of research tasks identified by a working group for ice-associated seals in 1984. Tasks were rated as “critically important,” “essential,” or “necessary” to known or possible conservation problems (Twiss et al. 1988)

Task	 Bearded seals	 Ringed seals	 Spotted seals	 Ribbon seals
Monitor Harvest	<i>Essential</i>	<i>Essential</i>	<i>Essential/Critical</i>	<i>Essential/Critical</i>
Determine population discrepancies	<i>Essential</i>	<i>Essential</i>	<i>Necessary</i>	<i>Necessary</i>
Estimate population size	<i>Essential</i>	<i>Essential</i>	<i>Critical</i>	
Determine habitat requirements		<i>Essential</i>	<i>Necessary</i>	<i>Necessary</i>
Monitor population size	<i>Essential</i>	<i>Essential</i>	<i>Necessary</i>	<i>Necessary</i>

Management Needs

The Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA) provide the statutory context for critical objectives of monitoring and managing these special resources. The ESA took on new relevance to ice seal management in December, 2007, when the National Marine Fisheries Service (NMFS) received a petition to list ribbon seals as threatened or endangered under the ESA, primarily based upon concern about potential loss of suitable sea ice habitat due to the warming climate. A similar petition for listing bearded, ringed, and spotted seals followed in May of 2008. The MMPA requires that marine mammals be managed to ensure that they retain their function in the ecosystem, and furthermore that species harvested for subsistence by Alaska Natives be managed to ensure a sustainable harvest. The goals espoused by these statutes were established in recognition of the importance of ice seals to the integrity of a vast ecosystem and to the sustainability of human cultures that evolved as part of that ecosystem. These goals transcend the relatively simple economic values that are the basis for management of many other natural resources.

The fundamental information for reliable assessment and management of ice seal populations is largely unavailable, despite recognition of the data gaps for several decades. In 1984, the Marine Mammal Commission established working groups for marine mammals in Alaska (Twiss et al. 1988). For ice-associated seals, the working groups rated the importance of key conservation tasks as “critically important,” “essential,” or “necessary,” (Table A.1), and they estimated annual costs for the necessary, essential, and critical tasks for the ice-associated seals at \$200,000 - \$537,000 (1984 dollars) for each species. Nonetheless, appropriations for research have been totally lacking in most years and have only recently begun to approach these levels, even though it is now widely recognized that the need for information has become broader and more urgent because of the rapidly changing arctic climate.

In 1994, the National Science Foundation, the National Oceanographic and Atmospheric Administration, the Office of Naval Research, Texas A & M University, the University of Alaska, the U. S. Marine Mammal Commission, the Minerals Management Service, the North Slope Borough, and the Alaska Sea Grant Program sponsored a workshop entitled “Use of Ice-associated Seals in the Bering and Chukchi Seas as Indicators of Environmental Change” (DeMaster and Davis 1996). That workshop produced five “near-term action items”:

1. Update the research and management recommendations of the Marine Mammal Commission (Kelly 1988c, Kelly 1988a, Kelly 1988b, Quakenbush 1988, Twiss et al. 1988).
2. Create an ice seal database.
3. Reinitiate data collection from subsistence harvests.
4. Identify syntheses necessary to refine future research hypotheses.
5. Contrast importance of environmental factors influencing distribution and life history parameters of ringed and spotted seals.



In 2004, the Ice Seal Committee was formed to represent subsistence hunters of ice seals from five Alaska Native Regions: North Slope Borough, Maniilaq, Kawerak, Bristol Bay Native Association, and the Association of Village Council Presidents. A working group composed of representatives from the Ice Seal Committee, the National Marine Fisheries Service, and the Alaska Department of Fish and Game identified the following research needs:

- Population status and trends
- Contaminants and their source
- Health of seal populations
- Harvest data
- Hunter education
- Climate change
- Individual animal health anomalies
- Community feedback of results

In response to those needs, the working group drafted the initial version of this Ice Seal Research Plan and recommended an overall approach that emphasizes 1) defining the identity and status of ice seal populations, 2) the comprehensive assessment of ice seal mortality including harvest, and 3) the impact of industrial & climatological events on ice seal habitat and ecology.

The following sections provide a description of ongoing projects that are currently funded, partially funded, and proposed but unfunded (Section A), and a summary of completed projects as a context for ongoing and proposed research (Section B).

Objectives of the Ice Seal Research Plan

The Research Plan plays a key role in the co-management process put in place by the Ice Seal Committee and NMFS. The Plan enhances communication between the research agencies and the Ice Seal Committee by establishing a framework that will assist in setting priorities and tracking performance of research projects. The plan is also expected to provide helpful information to the Alaska Scientific Review Group about ice seal population status and research.

A. Current and Proposed Projects

A.1 Population identity and status

A.1.1 ICE SEAL LIFE HISTORY STUDIES

Objective: Collect samples from the subsistence harvest to assess life history parameters, population status and health of bearded, ringed, spotted, and ribbon seals. Determine reproductive rate, age at maturity, growth rate, and body condition. Identify prey remains from stomachs to determine diet. Determine concentrations of persistent organic compounds (OCs) such as PCB, DDT, HCLs, PBDEs, PFCs, and determine concentrations of trace elements of concern (e.g., Hg, Cd, Pb) in seal tissues by species and harvest location. Determine the prevalence of parasites, diseases, harmful algal bloom toxins, and investigate physical anomalies of seals harvested in villages participating in the ADF&G biomonitoring program. Provide data and tissues to other researchers and graduate students for studies important to ice

seals, their habitat, and their predators. Collect hunter knowledge and current information on seal availability, distribution, harvest patterns, and hunter preference through hunter questionnaires.

Justification: There is little information available about abundance and population status for any species of ice seal. Reproductive rate, age at maturity, growth rate, and body condition can be used to assess population status. Diet, parasites, disease, and contaminant loads are important in determining health. Contaminant levels can be high in the Arctic due to atmospheric transport even though the compounds have not been manufactured or used there. On the other hand, the banning of pesticides and other manmade chemicals should reduce those chemicals in the environment in the future. Many of the compounds are lipophilic and concentrate in marine mammal blubber. Genetics are important in determining the structure, history, and vulnerability of the populations. Investigating physical abnormalities can help to detect health issues within the population.

Methods: Morphometric measurements (e.g., standard length and sternal blubber depth) and tissues (e.g., teeth, stomach, liver, kidney, blubber, muscle, female reproductive tracts, skin, blood) are collected from the subsistence harvest. Tissues are analyzed for age, diet, contaminants, productivity, and genetics. Hunter knowledge and preference information is collected through a questionnaire filled out by hunters.

Product:

Bracht, A.J., Brudek, R.L., R.Y. Ewing, C.A. Manire, K.A. Burek, C. Rosa, K.B. Beckmen, J.E. Maruniak, and C.H. Romero. 2005. Genetic identification of novel poxviruses of cetaceans and pinnipeds. *Archives of Virology*, DOI 10.1007/s00705-005-0679-6

Carroll, S.S., Horstmann-Dehn, L., Norcross, B.L. 2013. Diet history of ice seals using stable isotope ratios in claw growth bands. *Canadian Journal of Zoology* 91:191-202

- Crain, D.D., S.A. Karpovich, L. Quakenbush, and L. Polasek. 2021. Using claws to compare reproduction, stress and diet of female bearded and ringed seals in the Bering and Chukchi seas, Alaska, between 1953–1968 and 1998–2014. *Conservation Physiology* doi:10.1093conphys/coaa115
- Crawford, J.A., Quakenbush, L.T., Citta, J.J. 2015. A comparison of ringed and bearded seal diet, condition and productivity between historical (1975-1984) and recent (2003-2012) periods in the Alaskan Bering and Chukchi seas. *Progress In Oceanography*. 18pp.
- Correa, L., Castellini, J.M., Quakenbush, L., O’Hara, T. 2015. Mercury and selenium concentrations in skeletal muscle, liver, and regions of the heart and kidney in bearded seals from Alaska, USA. *Environmental Toxicology and Chemistry* 34:2403-2408
- Foster, G., Ingebjørg, J.N., Kovacs, K.M., Beckmen, K.B., Brownlow, A.C., Baily, J.L., Dagleish, M.P., Muchowski, J., Perrett, L.L., Tryland, M., Lydersen, C., Godfroid, J., McGovern, B., Whatmore, A.M. 2018. First isolation of *Brucella pinnipedialis* and detection of *Brucella* antibodies from bearded seals *Erignathus barbatus*. *Diseases of Aquatic Organisms* 128:13-20
- Hendrix, A.M., K.A. Lefebvre, L. Quakenbush, A. Bryan, R. Stimmelmayer, G. Sheffield, G. Wisswaesser, M.L. Willis, E.K. Bowers, P. Kendrick, E. Frame, T. Burbacher, and D.J. Marcinek. 2021. Ice seals as sentinels for algal toxin presence in the Pacific Arctic and sub-arctic marine ecosystems. *Marine Mammal Science* DOI: 10.1111/mms.12822
- Kovacs, K. M., Citta, J., Brown, T., Dietz, R., Ferguson, S., Harwood, L., Houde, M., Lea, E., Quakenbush, L., Riget, F., Rosing-Asvid, A., Smith, T. G., Svetochhev, B., Svetocheva, O., and Lydersen, C. 2021. Variation in body size of ringed seals (*Pusa hispida hispida*) across the circumpolar Arctic: evidence of morphs, ecotypes, or simply extreme plasticity? *Polar Research*. 40:5753. <http://dx.doi.org/10.33265/polar.v40.5753>.
- Lang, A.R., Boveng, P., Quakenbush, L., Robertson, K., Lauf, M., Rode, K.D., Ziel, H., Taylor, B.L. 2021. Re-examination of population structure in Arctic ringed seals using DArTseq genotyping. *Endangered species research*. 44:11–31. <https://doi.org/10.3354/esr01087>
- Lefebvre, K.A., Quakenbush, L., Frame, E.R., Burek-Huntington, K., Sheffield, G., Stimmelmayer, R., Bryan, A., Kendrick, P., Ziel, H., Goldstein, T., Snyder, J.A., Gelatt, T., Gulland, F., Dickerson, B., Gill, V.A. 2016. Prevalence of algal toxins in Alaskan marine mammals foraging in a changing arctic and subarctic environment. *Harmful Algae* 55:13-24
- Norcross, B.L., Horstmann-Dehn, L., Holladay, B.A., Edenfield, L.E., Carroll, S.S. 2015. Trophic links: forage fish, their prey, and ice seals in the Northeast Chukchi Sea. In. *Coastal Marine Institute*, Fairbanks, Alaska
- Nymo, I.H., Rødven, R., Beckmen, K., Larsen, A.K., Tryland, M., Quakenbush, L., and Godfroid, J. 2018. *Brucella* antibodies in Alaskan true seals and eared seals – two different stories. *Frontiers in Veterinary Science*. 5:8. doi:10.3389/fvets.2018.00008
- Oxtoby, L.E., Horstmann, L., Budge, S.M., O’Brein, D.M., Wang, S.W., Schollmeier, T., and Wooller, M.J. 2017. Resource partitioning between Pacific walruses and bearded seals in the Alaska Arctic and sub-Arctic. *Physiological Ecology*. 184: 385–398. DOI 10.1007/s00442-017-3883-7
- Quakenbush, L. T. 2007. Polybrominated diphenyl ether compounds in ringed, bearded, spotted, and ribbon seals from the Alaska Bering Sea. *Marine Pollution Bulletin* 54:226–246.
- Quakenbush, L.T., and J.J. Citta. 2008. Perfluorinated contaminants in ringed, bearded, spotted, and ribbon seals from the Alaskan Bering and Chukchi seas. *Baseline/Marine Pollution Bulletin* 56:1802–1814.
- Quakenbush, L., and J. Citta. 2008. Biology of the ribbon seal in Alaska. Final Report to National Marine Fisheries Service from the Alaska Department of Fish and Game. 46 pp.
- Quakenbush, L.T., K. Beckmen, and C.D.N. Brower. 2009. Rehabilitation and release of marine mammals in the United States: concerns from Alaska. *Marine Mammal Science* 25(4):994–999. DOI:10.1111/j1748-7692.2009.00283.x
- Quakenbush, L., and J.J. Citta. 2009. Trace element concentrations in bearded seals (*Erignathus barbatus*) near Red Dog Mine compared to other locations in Alaska. *Journal of Marine Biology* DOI:10.1155/2009/275040.
- Quakenbush, L., J. Citta, and J. Crawford. 2009. Biology of the spotted seal (*Phoca largha*) in Alaska, 1962–2008. Final Report to National Marine Fisheries Service from the Alaska Department of Fish and Game. 66 pp.
- Quakenbush, L., J. Citta, and J. Crawford. 2011a. Biology of the bearded seal (*Erignathus barbatus*) in Alaska, 1961–2009. Final Report to National Marine Fisheries Service from the Alaska Department of Fish and Game. 71 pp.

- Quakenbush, L., J. Citta, and J. Crawford. 2011b. Biology of the ringed seal (*Phoca hispida*) in Alaska, 1960–2010. Final Report to National Marine Fisheries Service from the Alaska Department of Fish and Game. 72 pp.
- Rode, K.D., E.V. Regehr, J.F. Bromaghin, R.R. Wilson, M. St. Martin, J.A. Crawford, and L.T. Quakenbush. 2021. Seal body condition and atmospheric circulation patterns influence polar bear body condition, recruitment, and feeding ecology in the Chukchi Sea. *Global Change Biology* DOI:10.1111/gcb.15572
- Seymour, J., Horstmann-Dehn, L., Rosa, C., Lopez, J.A. 2014. Occurrence and genotypic analysis of *Trichinella* species in Alaska marine-associated mammals of the Bering and Chukchi seas. *Veterinary Parasitology* 200:153-164
- Stricker, C.A., K.D. Rode, B.D. Taras, J.F. Bromaghin, L. Horstmann, and L. Quakenbush. 2022. Summer/fall diet and macronutrient assimilation in an Arctic predator. *Oecologia* DOI:10.1007/s00442-022-05155-2
- Tengler, M.L., Dearolf, J., Bryan, A.L., Reichmuth, C., Thometz, N.M. In Review. Comparative muscle physiology of ringed (*Pusa hispida*), bearded (*Erignathus barbatus*), and spotted (*Phoca largha*) seals from the Bering and Chukchi Seas. *Journal Comparative Physiology B*.
- VanWormer, E., Mazet, J.A.K., Hall, A., Gill, V.A., Boveng, P.L., London, J.M., Gelatt, T., Fadely, B.S., Lander, M.E., Sterling, J., Burkanov, V.N., Ream, R.R., Brock, P.M., Rea, L.D., Smith, B.R., Jeffers, A., Henstock, M., Rehberg, M.J., Burek-Huntington, K.A., Cosby, S.L., Hammond, J.A., and Goldstein, T. 2019. Viral emergence in marine mammals in the North Pacific may be linked to Arctic sea ice reduction. *Scientific Reports*. 9:15569. <https://doi.org/10.1038/s41598-019-51699-4>
- Walden, H.S., A.L. Bryan, A. McIntosh, P. Tuomi, A. Hoover-Miller, R. Stimmelmayer, and L. Quakenbush. 2020. Helminth fauna of ice seals in the Alaskan Bering and Chukchi seas, 2006–15. *Journal of Wildlife Diseases* 56(4):863–872.
- Wang, S.M., Springer, A.M., Budge, S.M., Horstmann-Dehn, L., Quakenbush, L., Wooller, M.J. 2016. Carbon sources and trophic relationships of ice seals during recent environmental shifts in the Bering Sea. *Ecological applications: a publication of the Ecological Society of America* 26:830-845
- Wang, S.W., Frost, K., Whiting, A. 2015. Foraging ecology of ice seals in Kotzebue Sound, Alaska: Insights from fatty acid markers. *Marine Mammal Science* 32:765-776

Funding status: Funded by NOAA in 2003-2025, NOAA Section 6 in 2016-2019; partial funding by NSF 2000-2006 and NPRB in 2005-2006.

Project lead: ADF&G, Lori Quakenbush, lori.quakenbush@alaska.gov

Project partners: Ice Seal Committee, North Slope Borough, and hunters from Utqiagvik, Wainwright, Pt. Hope, Shishmaref, Diomedea, Gambell, Savoonga, and Hooper Bay.

A.1.2 GENETIC POPULATION STRUCTURE OF ICE-ASSOCIATED SEALS IN ALASKA

Objective: To assess population structure in bearded and ringed seals using genetic analysis of previously archived samples from breeding sites in the North Pacific.

Justification: The status reviews for both the ringed seal and the bearded seal noted that further investigation of population structure is needed to assess the potential for depletion due to localized threats. Both seal species travel widely during the foraging season, but some evidence indicates that seals may show inter- and intra-annual fidelity to breeding sites. However, it is not known for either species whether such fidelity is based on return to natal areas. To provide insight into this question, we sequenced mitochondrial DNA (mtDNA) control region of samples collected from both species (n=188, bearded seals; n=159, ringed seals) at breeding sites in the North Pacific between March and May. In addition, we used high throughput sequencing approaches to genotype a subset of these samples (n=190 bearded seals, n=79 ringed seals). These approaches, which can provide data for hundreds to thousands of nuclear loci, provide increased power to detect subtle, but potentially biologically significant, levels of genetic differentiation between breeding sites. They also provide data that can be used to design assays for genotyping additional samples, including museum quality specimens, in the future.

Methods: MtDNA control region sequences were generated from the ringed and bearded seal samples using traditional methods (i.e., Sanger sequencing). In order to genotype nuclear loci in both species, high throughput sequencing approaches were used to generate reduced representation ‘libraries’ for each sample. These approaches reduce the proportion of the genome that is sequenced so that the retained fragments have high sequencing coverage and can be genotyped with high confidence. After sequencing, the resulting data was filtered to remove erroneous genotypes and retain only high quality SNPs.

Product:

Lang, A.R., Boveng, P., Quakenbush, L., Robertson, K., Lauf, M., Rode, K.D., Ziel, H. and Taylor, B.L., 2021. Re-examination of population structure in Arctic ringed seals using DArTseq genotyping. *Endangered Species Research*, 44, pp.11-31.

High levels of mtDNA haplotype diversity were found in both species, but little to no genetic differentiation between sites was detected. High throughput sequencing allowed ~5700 SNP loci to be genotyped in ringed seals from four different regions of the Pacific Arctic. Comparison of the two most geographically separated strata (the eastern Bering vs. the Beaufort Sea) revealed statistically significant differences that, while small, were one to two orders of magnitude greater than expected based on divergence estimated for similarly sized populations connected by low dispersal. These results indicated that demographically important structure may be present among Arctic ringed seals breeding in different areas, although analysis of additional samples collected throughout the range of the subspecies is needed to more fully assess demographic structure and better understand the impacts of future environmental changes. The results of this work have now been published (Lang et al. 2021, <https://doi.org/10.3354/esr01087>).

Preliminary results of the analyses to assess population structure among bearded seals sampled at breeding sites in the North Pacific were presented at the Alaska Marine Science Symposium in 2017. Further analysis of the bearded seal genotyping-by-sequencing data is underway.

Funding status: The funding to complete the mtDNA control region analysis of population structure in ringed and bearded seals sampled at breeding sites in the North Pacific was provided by the National Fish and Wildlife Foundation. Funding for the project to conduct genotyping-by-sequencing on bearded seals was provided by the North Pacific Research Board; funding to complete the same work on ringed seals was received from the Marine Mammal Commission. In the future, we plan to search for funding to use the genotype data produced in the latter two projects to develop genetic markers that can be used with historic samples.

Project lead: NOAA/NMFS/SWFSC, Aimee Lang, aimee.lang@noaa.gov

Project partners: Samples contributed by NMFS/NMML, ADF&G, the U.S. Geological Survey's Alaska Science Center, and the University of Alaska Fairbanks Museum of the North; additional partners may be identified in the future.

A.1.3 AUDITORY BIOLOGY OF BEARDED, RINGED, AND SPOTTED SEALS

Objective: Our objective is to directly measure the amphibious hearing abilities of bearded, ringed, and spotted seals. Specifically, our aim is to train ice-associated seals living in captive care to participate in auditory research so that species-typical hearing profiles (audiograms) can be determined, the simultaneous effects of noise on hearing (masking) can be measured, and the residual effect of seismic air gun exposures on hearing (temporary threshold shift) can be estimated. This auditory research has now been completed with two spotted seals, two ringed seals, and two bearded seals at the University of California Santa Cruz. Another phase of studies focusing on very low-frequency hearing abilities and masking by low-frequency noise. This research is ongoing with two bearded seals in Santa Cruz and should extend through 2024. The project should improve understanding of sound reception abilities below 100 Hz and provide insight into how different human-generated noise sources (e.g., ice-breakers, seismic surveys using air guns, marine vibroseis technology) may affect hearing in ice-associated seals.

Justification: Traditional knowledge indicates that Arctic seals are highly sensitive to sound. However, prior to our research, few measurements were available concerning the hearing abilities of bearded, ringed, and spotted seals and their susceptibility to human-generated noise. Historically, these seals have inhabited polar seas with minimal exposure to sounds related to human presence, including those generated from shipping, tourism, recreation, military operations, and industry activities. Extreme global climate change is altering Arctic habitats in many ways—including habitat degradation through increasing levels of human activity and human-generated noise that are associated with sea ice loss. Increasing human accessibility to Arctic environments requires the assessment of risks posed to marine wildlife by noise pollution. Quantitative information on the hearing abilities of seals is needed so that zones of potential auditory effects can be estimated around specific sound sources. Noise may alter the normal hearing of animals through temporary or permanent changes in their ability to hear or identify biologically important signals. Such effects may be different for different species. The lack of relevant audiometric data for representative Arctic seal species is problematic for those charged with protecting these marine mammals from harmful human impacts. Reliable information is needed to establish appropriate risk assessments. The findings of these studies address data gaps for three biologically and culturally important Alaskan species and enable decision-making based on best available science.

Methods: Auditory research takes place at Long Marine Laboratory in Santa Cruz, California in specialized salt-water facilities that are designed for acoustics research with marine mammals. Participating seals are long-term captive individuals that cooperate in various tasks. The seals are trained for cooperative research using operant conditioning methods based on positive (fish) reinforcement. They participate voluntarily in acoustic signal detection trials while resting out of the water on mats in a quiet acoustic chamber or while diving in an acoustically calibrated pool. The seals are tested with brief tones spanning their frequency range of hearing in both air and water. Hearing thresholds are determined over many trials under different conditions to assess auditory performance (1) in the absence of noise, (2) in the presence of simultaneous noise, or (3) before and after exposure to impulsive sounds representative of received seismic (air gun) signals. Different testing conditions allow relevant parameters of acoustic signal detection, masking, and temporary threshold shift to be determined. Thus far, similar assessments have been completed with spotted, ringed, and bearded seals. The results of these studies have been shared with the Ice Seal Committee and published in the *Journal of Experimental Biology*, the *Journal of the Acoustical Society of America*, and *Polar Biology* (see below). Two bearded seals are now participating in a new phase of research that aims to characterize hearing at very low frequencies (< 100 Hz) in both quiet and noisy conditions. While this research focuses on hearing in a lower frequency range than we have tested previously, it relies on the same behavioral methods.

Hearing studies allow us to learn about the adaptations that seals use in Arctic and sub-Arctic habitats. In addition to hearing studies, we are also working to better understand how Alaskan seals produce and use sound by describing their vocal behavior throughout development. We recently completed a long-term effort to document the underwater calls of spotted seals. Male spotted seals produce at least eight different vocalizations in the winter and spring months prior to molt. Calling behavior is associated with reproductive status. This research may support future passive acoustic monitoring efforts to identify habitats important to breeding seals.

In our long-term research program, individual seals are studied in human care over many years. At the end of these studies the seals will not be reintroduced to wild populations. Rather, the seals may participate in other relevant research programs or be transferred to permanent captive display facilities through coordination with the National Marine Fisheries Service and the Ice Seal Committee. Thus far, two spotted seals have been transferred from Long Marine Laboratory to the Alaska SeaLife Center for participation in related studies of health and physiology.

Publications:

- Sills, J. M., and Reichmuth, C. (2022). Vocal behavior in spotted seals (*Phoca largha*) and implications for passive acoustic monitoring. *Frontiers in Remote Sensing* 3: 862435.
- Sills, J. M., Southall, B. L., and Reichmuth, C. 2020. Auditory biology of bearded seals (*Erignathus barbatus*). *Polar Biology* 43(11): 1681-1691.
- Sills, J. M., Ruscher, B., Nichols, R., Southall, B. L., and Reichmuth, C. 2020. Evaluating temporary threshold shift onset levels for impulsive noise in seals. *Journal of the Acoustical Society of America* 148(5): 2973-2986.
- Sills, J. M., Southall, B. L., and Reichmuth, C. 2017. The influence of temporally varying noise from seismic air guns on the detection of underwater sounds by seals. *Journal of the Acoustical Society of America* 141: 996-1008.
- Reichmuth, C., Ghouli, A., Sills, J. M., Rouse, A., and Southall, B. L. 2016. Low-frequency temporary threshold shift not observed in spotted or ringed seals exposed to single air gun impulses. *Journal of the Acoustical Society of America* 140: 2646-2658.
- Sills, J. M., Southall, B. L., and Reichmuth, C. 2015. Amphibious hearing in ringed seals (*Pusa hispida*): underwater audiograms, aerial audiograms, and critical ratio measurements. *The Journal of Experimental Biology*, 218: 2250-2258.
- Sills, J. M., Southall, B. L., and Reichmuth, C. 2014. Amphibious hearing in spotted seals (*Phoca largha*): underwater audiograms, aerial audiograms, and critical ratio measurements. *The Journal of Experimental Biology*, 217: 726-734

Funding status: Research is supported by the OGP Joint Industry Programme (JIP) on Sound and Marine Life and the Environmental Studies Program of the Bureau of Ocean Energy Management (BOEM). Supplemental support has been provided by the Northwest Arctic Borough Science Program, Shell Exploration and Production Company, the Alaska SeaLife Center, and small grants/gifts.

Project leads: Colleen Reichmuth and Jillian Sills (University of California Santa Cruz, coll@ucsc.edu, jmsills@ucsc.edu)

Project partners: Brandon Southall (SEA, Inc.), Alex Whiting, John Goodwin, Pearl Goodwin (Native Village of Kotzebue), and the Alaska SeaLife Center.

A.1.4 CAPTIVE STUDIES OF ICE SEAL HEALTH AND PHYSIOLOGY

Objective: Our objective is to provide currently unknown health and physiological parameters for bearded, ringed, and spotted seals through long-term studies of captive individuals. Supportive samples are obtained from collaborators during biosampling of harvested seals and/or seals handled during short-term catch and release efforts.

Justification: Seals are particularly vulnerable to the loss of seasonal sea ice and rapidly changing environmental conditions in the Arctic. They are high-level consumers that serve as sentinels of ecosystem health. Quantitative information about the biology and physiology of bearded, ringed, and spotted seals is needed to fill data gaps that cannot be addressed with free-ranging or harvested animals.

Recent unusual mortality events involving northern seals and walrus highlights the limited amount of information presently available to describe the health and physiology of ice-associated seals in good condition. By studying living animals trained to cooperate in research over multiple years, this project is contributing useful new information about ice-associated seals, including description of baseline health parameters and seasonal measures of body condition, metabolism, molt, thermoregulatory costs, and diving capacity. Obtaining longitudinal and comparative data with several spotted, ringed, and bearded seals living in human care enables physiological comparisons to be made both within and across species. The seals involved in this research live in permanent captivity, either at Long Marine Laboratory at the University of California in Santa Cruz, CA or at the Alaska SeaLife Center in Seward, AK. Most of the participating seals were acquired following stranding and subsequent rehabilitation in Alaska. Therefore, this research maximizes what can be learned from currently captive ice-associated seals trained to voluntarily participate in different research procedures.

Methods: This is a multi-year project that is ongoing. The project relies on husbandry and veterinary data collected as part of routine animal care practices, as well as data collected from ice seals trained to cooperate in research procedures. The methods and goals of this program include (1) using standard veterinary sampling to report baseline hematology parameters and other species-typical indicators of health; (2) evaluating individual animals to report patterns of food consumption, growth, tissue deposition rates, and body condition as a function of physiological, developmental, and environmental conditions; (3) using infrared thermography and direct heat flux measures to establish thermal profiles and patterns of heat flow for healthy individuals during

the year and annual molt; (4) using open-flow respirometry to determine the metabolic rates of seals in order to evaluate how age, season, physiological status, and environmental parameters influence the energetic needs of each species; (5) evaluating the coat condition of individual seals to document the timing, duration, and progression of molt in healthy individuals; (6) measuring the haul-out behavior of individual seals using temperature-sensing tags or video monitoring to aid in the development of correction factors for wild ice seal population surveys; (7) determining the energetic costs of routine swimming and diving activities from seals trained to cooperate in open-flow respirometry measurements; (8) evaluating heart rate and breathing rate patterns for seals at rest and while active using non-invasive methods; and (9) determining species-specific blood and muscle oxygen storage capacities through the analysis of blood and muscle samples from archival collections and subsistence-harvested ice seals. Other types of data are gathered opportunistically. Information from different project modules can be combined to address specific research questions and to estimate physiological constraints on diving and foraging in each species.

Products:

Tengler, ML, Dearolf, J, Bryan, A, Reichmuth, C, and Thometz, NM (submitted). Comparative muscle physiology of ringed (*Pusa hispida*), bearded (*Erignathus barbatus*), and spotted (*Phoca largha*) seals from the Bering and Chukchi seas. *Journal of Comparative Physiology B*.

Thometz, N. M., Rosen, D. A. S., Hermann-Sorensen, H., Meranda, M., Pardini, M., and Reichmuth, C. (2023). Maintaining control: metabolism of molting Arctic seals in water and when hauled out. *Journal of Experimental Biology* 226: jeb244862.

Sills, J. M., and Reichmuth, C. (2022). Vocal behavior in spotted seals (*Phoca largha*) and implications for passive acoustic monitoring. *Frontiers in Remote Sensing* 3: 862435.

Rosen, D.A.S., Thometz, N. M., and Reichmuth, C. (2021). Seasonal and developmental patterns of energy intake and growth in Alaskan ice seals. *Aquatic Mammals* 47(6): 559-573.

Thometz, N. M., Hermann-Sorensen, H., Russell, B., Rosen, D. A. S., and Reichmuth, C. (2021). Molting strategies of Arctic seals drive annual patterns in metabolism. *Conservation Physiology* 9: 10.1093/conphys/coaa112

Hermann-Sorensen, H., Thometz, N. M., Woodie, K., Dennison-Gibby, S., and Reichmuth, C. (2021) *In vivo* measurement of lung volume in ringed seals: insights from biomedical imaging. *Journal of Experimental Biology* 224: jeb235507

McHuron, E. A., Williams, T., Costa, D. P., Reichmuth, C. (2020) Contrasting whisker growth dynamics within the phocid lineage. *Marine Ecology Progress Series*, 634:231-236.

Goertz, C.E.C., Reichmuth, C., Thometz, N.M., Ziel, H., Boveng, P.L. (2019) Comparative Health Assessments of Alaskan Ice Seals. *Frontiers in Veterinary Science: Wildlife Medicine*, 6(4). Open access article: <https://doi.org/10.3389/fvets.2019.00004>

Kienle, S.S., Hermann-Sorensen, H., Costa, D.P., Reichmuth, C., and Mehta, R.S. (2018) Comparative feeding strategies and kinematics in phocid seals: suction without specialized skull morphology. *Journal of Experimental Biology*, 221: jeb179424.

Beltran, R., Peterson, S. McHuron, E., Reichmuth, C. Huckstadt, L., Costa, D. (2016) Seals and sea lions are what they eat, plus what? Determination of trophic discrimination factors for seven pinniped species. *Rapid Communications in Mass Spectrometry*, 30, 1115–1122.

McHuron, E.A., Walcott, S.M., Zelig, J., Skrovan, S., Costa, D.P., Reichmuth, C. (2016). Whisker growth dynamics in two North Pacific pinnipeds: implications for determining foraging ecology from stable isotope analysis. *Marine Ecological Progress Series* 554:213-224.

Funding status: Research was supported by NOAA through the Alaska Pinnipeds Program from 2015-2022. Additional funding is needed for continuation of this research program.

Project lead: Colleen Reichmuth (University of California Santa Cruz and Alaska SeaLife Center, coll@ucsc.edu), Nicole Thometz (University of San Francisco, nthometz@usfca.edu), and David Rosen (University of British Columbia, rosen@zoology.ubc.edu).

Project partners: The Alaska SeaLife Center and Long Marine Laboratory (captive animal research), Alaska Department of Fish and Game and cooperating subsistence hunters (biosampling), Marine Mammal Laboratory Polar Ecosystems Program (archival samples), National Marine Mammal Health and Stranding Program (archival data and samples).

A.1.5 A.1.5 (NEW PROJECT) BEARDED SEAL ABUNDANCE AND DEMOGRAPHICS USING CLOSE-KIN MARK-RECAPTURE METHODS

Objective: Use DNA from subsistence harvested bearded seals and close-kin mark-recapture methods to estimate the abundance and demographics of bearded seals.

Justification: Bearded seals are an important subsistence resource and are listed as threatened under the ESA, therefore a reliable population estimate is needed. This method combines genetics for kinship determinations with a population dynamics model to provide a population estimate independent of aerial surveys and provides previously unknown information about bearded seal life history.

Methods: A tooth and tissue sample are collected from subsistence harvested bearded seals. The tooth provides age for population dynamics modeling and the DNA, determined from the tissue sample, provides genetics for kinship determination.

Product:

Taras, B.D., L.T. Quakenbush, P.B. Conn, J.M. Ver Hoef. 2019. Exploring close-kin mark-recapture as a method for assessing bearded seal population abundance and status. The Wildlife Society Conference, September 29–October 3, Reno, Nevada (abstract).

Taras, B.D., P.B. Conn, M.V. Bravington, L. Quakenbush, A. Kilian, A.R. Lang, and A. Bryan. 2023. Close-kin mark-recapture used to estimate bearded seal population abundance and demographics. Alaska Marine Science Symposium, January 23–27, Anchorage, Alaska (abstract and poster).

Conn, P.B., B.D. Taras, M.V. Bravington, L. Quakenbush, A. Kilian, A. Lang, and A. Bryan. 2023. Using close-kin mark-recapture to estimate abundance and demography of bearded seals in Alaska. Euring Analytical Conference April 17–21, Montpellier, France. (abstract).

Funding status: Funded by NOAA.

Project lead: ADF&G, Lori Quakenbush, lori.quakenbush@alaska.gov

Project partners: NOAA, CSIRO, Diversity Arrays Technology

A.2 Mortality and harvest

A.2.1 HARVEST MONITORING

Objective: Document the Alaska Native subsistence harvest (and number struck and lost) of ice seals by species and time of year in as many communities as possible.

Justification: Collecting harvest information is a priority of the Ice Seal Committee (ISC) and a federal mandate for NOAA Fisheries. Prior to the start of this project in

2008, ice seal harvest data had rarely and inconsistently been collected following the end of the state bounty program in 1972. Some regions conduct household subsistence surveys that include ice seals along with fish, birds, and land mammals, but many do not collect detailed information about seal species or season of harvest. Ideally, communities should be surveyed repeatedly to better understand interannual variability in the harvest. A better understanding of struck and loss rates is also critically needed to improve harvest estimates. Describing factors that influence struck and loss rates may also help hunters minimize loss in the future. The documents produced by this project will be used by the ISC in their co-management activities and by NOAA Fisheries in their Stock Assessment Reports.

Methods: Prior to conducting harvest surveys in a community the project is discussed with the IRA council. Upon approval, local survey technicians are hired to conduct the surveys. The surveys are conducted confidentially and only harvest by community is presented (i.e., information by household or hunter is not available).

Results from individual communities are summarized and returned to the community as a report for approval. After community results are approved by the IRA council, they are added to an annual ice seal harvest report presented to the Ice Seal Committee at their annual meeting. The final report is then approved by the Ice Seal Committee before being made publicly available.

Use of harvest data: During the ten-year span of 2012-2022, only 2 of the 60 (3%) coastal communities that harvest ice seals have been surveyed in two consecutive years or more. Due to limited available data as well as high variability in seal harvest numbers (among years, within communities, among communities, and within regions), harvest data should not be extrapolated to other communities or regions. In addition, there is concern among hunters regarding the misuse of harvest data. Please contact the Ice Seal Committee for guidance prior to using these harvest data.

Product:

Ice Seal Committee. 2019. The subsistence harvest of ice seals in Alaska – a compilation of existing information, 1960-2017. Pages 1-86. Available at <http://www.north-slope.org/departments/wildlife-management/co-management-organizations/ice-seal-committee>

Nelson, M. A. 2012a. Togiak and Twin Hills Ice Seal Harvest Report: 2007 to 2011 Summary. Report to Togiak, Twin Hills, and the Ice Seal Committee. 17 pp.

Nelson, M. A. 2012b. Yukon Kuskokwim Delta Ice Seal Harvest Project: Emmonak 2011. Report to Emmonak and the Ice Seal Committee. 5 pp.

Nelson, M. A. 2013. Scammon Bay Ice Seal Harvest Report: 2011 and 2012 Summary. Report to Scammon Bay and the Ice Seal Committee. 11 pp.

Nelson, M., and L. Church. 2015. Quinhagak ice seal harvest report 2008, 2010-2014 Summary. Report to Quinhagak and the Ice Seal Committee. 15 pp.

Reports for individual years (2008, 2010-2014) are also available.

Nelson, M. A., R. J. Adam, J. Olnes, and A. Simon. 2018. Hooper Bay Ice Seal Harvest Report 2008 to 2017 Summary. Report to Hooper Bay and the Ice Seal Committee. 16 pp.

Reports for individual years (2008-2017) are also available.

Nelson, M., R. J. Adam, J. Olnes, and C. Inakuk. 2018. Tununak ice seal harvest report 2008-2012 and 2016 Summary. Report to Tununak and the Ice Seal Committee. 14 pp.

Reports for individual years (2008-2012, 2016) are also available.

Nelson, M.A., L.T. Quakenbush, B.D. Taras, and the Ice Seal Committee. 2019. Subsistence harvest of ringed, bearded, spotted, and ribbon seals in Alaska is sustainable. *Endangered Species Research* 40: 1–16. Doi:10.3354/esr00973

Olnes, J., M. Nelson, R. J. Adam, and A. Simon. 2020. Hooper Bay ice seal harvest report 2008 to 2018 Summary. Report to Hooper Bay and the Ice Seal Committee. 17 pp.

Reports for individual years (2008-2017) are also available.

Olnes, J., L. Quakenbush, M. Nelson, A. Simon, J. Burns, and the Ice Seal Committee. 2022. Trends in subsistence harvests of ice seals in the Yukon-Kuskokwim Delta region, Alaska, 1962–2018. *Arctic* 75(4):449–461. DOI:10.14430/arctic76302

All reports are available at <http://www.north-slope.org/departments/wildlife-management/co-management-organizations/ice-seal-committee>

Funding status: Funded by a State Wildlife Grant, NMFS through the Ice Seal Committee, and NMFS Species Recovery Grants to States (Section 6 Program)

Project lead: ADF&G, Justin Olnes, justin.olnes@alaska.gov

Project partners: Ice Seal Committee



A.3 Habitat and climate change

A.3.1 MOVEMENTS, HABITAT USE, AND FORAGING BEHAVIOR OF ADULT BEARDED SEALS IN THE CHUKCHI AND BERING SEAS

Objective: To document the seasonal movements, foraging behavior, and important habitats of adult and sub-adult bearded seals in Kotzebue Sound, the Chukchi Sea, and Bering Sea.

Justification: Bearded seals are an important subsistence resource, a key ecological component of the arctic marine ecosystem, and vulnerable to climate change because of their strong association with sea ice. Their seasonal movements, habitat use, and diving behavior have never been documented in Alaskan waters.

Methods: In 2009-2012, seven (4 male and 3 female) adult and sub-adult bearded seals were captured in Kotzebue Sound using large-mesh tangle nets. The seals were instrumented with Satellite-linked Data Recorders (SDRs) and then released. Information on the seals' movements and diving behavior were transmitted back to researchers via the ARGOS satellite system and analyzed to: 1) provide haul-out correction factors for past and future abundance and distribution sightings surveys, 2) assess the seasonal movements and patterns of distribution and diving/foraging behavior, 3) identify and determine the priority of importance for specific marine habitats associated with key ice seal life history events such breeding, pup rearing, and foraging and molting, and 4) describe seal dive depths and durations. This project involved direct collaboration between subsistence hunters and scientists, especially in capturing and tagging seals. The initial program grew out of a 2006-2006 collaboration with the Kotzebue IRA capturing

young-of-year bearded seals. The 2009 field season in Kotzebue Sound was expanded in 2010, 2011 and 2012 to include communities in the North Slope Borough; however seals were not captured in those locations. With the field work, data collection and analyses complete, research manuscripts are being prepared and finalized for publication in peer-reviewed journals.

Product:

Cameron, M., McClintock, B., Blanchard, A., Boveng, P., Crawford, J., Goodwin, J., Grebmeier, J., Jewett, S., Lauth, B., London, J., Lovvorn, J., Norcross, B., Quakenbush, L., Whiting, A. *In Revision*. Foraging habitat selection by bearded seals, related to benthic community composition, bathymetry and sediment in the Chukchi Sea. *Ecosphere*.

London, J.M., et al. *In Prep*. Haul-out behavior and detectability of bearded, ribbon, and spotted seals in the Bering and Chukchi Seas

Boveng, P.L., Cameron, M.F. Goodman, J., Johnson, S., and Whiting, A. *In Prep*. Winter site fidelity of bearded seals in the Bering Sea.

Hamilton, C. D., C. Lydersen, J. Aars, M. Acquarone, T. Atwood, A. Baylis, M. Biuw, A. N. Boltunov, E. W. Born, P. Boveng, T. M. Brown, M. Cameron, J. Citta, J. Crawford, R. Dietz, J. Elias, S. H. Ferguson, A. Fisk, L. P. Folkow, K. J. Frost, D. M. Glazov, S. M. Granquist, R. Gryba, L. Harwood, T. Haug, M. P. Heide-Jørgensen, N. E. Hussey, J. Kalinek, K. L. Laidre, D. I. Litovka, J. M. London, L. L. Loseto, S. MacPhee, M. Marcoux, C. J. D. Matthews, K. Nilssen, E. S. Nordøy, G. O’Corry-Crowe, N. Øien, M. T. Olsen, L. Quakenbush, A. Rosing-Asvid, V. Semenova, K. E. W. Shelden, O. V. Shpak, G. Stenson, L. Storrie, S. Sveegaard, J. Teilmann, F. Ugarte, A. L. Von Duyke, C. Watt, Ø. Wiig, R. R. Wilson, D. J. Yurkowski and K. M. Kovacs. 2022. Marine mammal hotspots across the circumpolar Arctic. Diversity and Distributions.

Boveng, P., J. London, M. Cameron, J. Jansen, and A. Whiting. 2019. A dataset from bio-loggers deployed on adult bearded seals (*Erignathus barbatus*) in Kotzebue Sound, Alaska, USA (2009–2012). Research Workspace. 10.24431/rw1k31x, version: 10.24431_rw1k31x_2019517231935.

Citta, J., Lowry, L., Quakenbush, L., Kelly, B., Fischbach, A., London, J., Jay, C., Frost, K., O’Corry Crowe, G., Crawford, J., Boveng, P., Cameron, M., Von Duyke, A., Nelson, M., Harwood, L., Richard, P., Suydam, R., Heide-Jørgensen, M., Hobbs, R., Litovka, D., Whiting, A., Marcoux, M., Kennedy, A., George, J., Orr, J., Gray, T. -2018. A multi-species synthesis of satellite telemetry data in the Pacific Arctic (1987–2015): Overlap of marine mammal distributions and core use areas (SOAR II). Deep Sea Research II

McClintock, B.T., et al. 2017. Bridging the gaps in animal movement: hidden behaviors and relationships revealed by integrating multiple data streams. Ecosphere.

McClintock, B.T., London, J.M., Cameron, M.F., Boveng, P.L. 2014. Modeling animal movement using the Argos satellite telemetry location error ellipse. *Methods in Ecology and Evolution*. DOI: 10.1111/2041-210X.12311

Boveng, P.L. and Cameron, M.F. 2013. Pinniped movements and foraging: seasonal movements, habitat selection, foraging and haul-out behavior of adult bearded seals in the Chukchi Sea. Final Report, BOEM Report 2013-01150. Bureau of Ocean Energy Management, Alaska Outer Continental Shelf Region, Anchorage, Alaska, USA. 96 Pp.

Cameron, M.F. and Boveng, P. 2011. Habitat use and seasonal movements of an adult and sub-adult bearded seals. AFSC Quarterly Report (Oct.-Dec. 2011)

Cameron, M.F. and Boveng, P.L. 2009. Habitat use and seasonal movements of adult and sub-adult bearded seals in Kotzebue Sound, Alaska. AFSC Quarterly Report (Aug-Oct 2009).

Funding status: Funded by NMFS/MML and the Bureau of Ocean Energy Management (BOEM)

Project lead: NMFS/MML, Michael Cameron, michael.cameron@noaa.gov

Project partners: UAF, ADFG, Native Village of Kotzebue, University of Maryland, Southern Illinois University

A.3.2 MOVEMENTS, HABITAT USE, AND FORAGING BEHAVIOR OF RIBBON AND SPOTTED SEALS IN THE BERING SEA

Objective: To document the seasonal movements, foraging behavior and important habitats of ribbon and spotted seals in the Bering Sea.

Justification: Relatively little is known of the abundances and distributions, seasonal migrations and habitat requirements, diving and foraging behaviors, population health, genetic discreteness and stock structures of ribbon and spotted seals, which breed at the southern margins of seasonal sea ice in the Bering Sea. Many of these attributes are likely highly sensitive to suitable habitats and sea ice conditions and may be particularly vulnerable to climatic change. Our ability to predict and manage for such impacts, however, is limited by our inadequate knowledge of ice seal ecology.

Methods: Ribbon and spotted seals are captured on the ice floes where they are hauled out, instrumented, and then released with Satellite-linked Data Recorders (SDRs). Data from instrumented animals are transmitted back to researchers via the ARGOS satellite system and analyzed to: 1) provide haul-out correction factors for past and future abundance and distribution sightings surveys, 2) assess the seasonal movements and patterns of distribution and diving/foraging behavior, 3) identify and determine the priority of importance for specific marine habitats associated with key ice seal life history events such as breeding, pup rearing, and foraging and molting, and 4) describe seal dive depths and durations.

In summer of 2005, 10 ribbon seals were tagged in near Kamchatka in the western Bering Sea. In the eastern and central Bering Sea (i.e., U.S. waters): 10 ribbon and 8 spotted seals were tagged in 2006, 28 ribbon and 12 spotted seals were tagged in 2007, 1 ribbon seal was tagged in 2008, 30 ribbon and 23 spotted seals were tagged in 2009, 17 ribbon and 8 spotted seals were tagged in 2010, 9 ribbon, 8 spotted and 2 bearded seals were tagged in 2014, 10 ribbon and 13 spotted seals were tagged in

2016, 2 bearded and 27 spotted seals were tagged in 2018 (mostly pups). The expedition in 2020 was cancelled due to COVID and in 2022, 1 ribbon and 4 spotted seals were tagged. Beginning in 2014, we switched our focus to capturing in the early spring. This change allows us to capture mother-up pairs of ribbon and spotted seals and to also collect samples that will provide baseline data about morphometrics, genetics, health, condition, and several life history parameters. We will continue to use sampling methods to collect data that can be replicated in the future to evaluate whether these metrics of general population health changed over time.

Product:

London, J.M., et al. *In Prep.* Haul-out behavior and detectability of bearded, ribbon, and spotted seals in the Bering and Chukchi Seas

London, J.M., Cameron, M.F., and Boveng, P.L. *In Prep.* Spatial use patterns of ribbon and spotted seals in the Bering and Chukchi Seas.

Cameron, M.F., Bengtson, J.L., Burkanov, V.N., Boveng, P.L., Stewart, B.S. *In Prep.* Movements, dive behavior and habitats of ribbon seals (*Histiophoca fasciata*) from the western Bering Sea.

Ziel, H. L., Goldstein, T., Conn, P.B., and Boveng, P.L. *In revision.* Serologic survey for exposure to potential pathogens in ribbon seals (*Histiophoca fasciata*), spotted seals (*Phoca largha*), and bearded seals (*Erignathus barbatus*) in the Bering Sea. *Marine Mammal Science*.

Hamilton, C. D., C. Lydersen, J. Aars, M. Acquarone, T. Atwood, A. Baylis, M. Biuw, A. N. Boltunov, E. W. Born, P. Boveng, T. M. Brown, M. Cameron, J. Citta, J. Crawford, R. Dietz, J. Elias, S. H. Ferguson, A. Fisk, L. P. Folkow, K. J. Frost, D. M. Glazov, S. M. Granquist, R. Gryba, L. Harwood, T. Haug, M. P. Heide-Jørgensen, N. E. Hussey, J. Kalinek, K. L. Laidre, D. I. Litovka, J. M. London, L. L. Loseto, S. MacPhee, M. Marcoux, C. J. D. Matthews, K. Nilssen, E. S. Nordøy, G. O’Corry-Crowe, N. Øien, M. T. Olsen, L. Quakenbush, A. Rosing-Asvid, V. Semenova, K. E. W. Sheldon, O. V. Shpak, G. Stenson, L. Storrie, S. Sveegaard, J. Teilmann, F. Ugarte, A. L. Von Duyke, C. Watt, Ø. Wiig, R. R. Wilson, D. J. Yurkowski and K. M. Kovacs. 2022. Marine mammal hotspots across the circumpolar Arctic. *Diversity and Distributions*.

Boveng, P. L., H. L. Ziel, B. T. McClintock and M. F. Cameron. 2020. Body condition of phocid seals during a period of rapid environmental change in the Bering Sea and Aleutian Islands, Alaska. *Deep Sea Research Part II: Topical Studies in Oceanography* 181-182: 104904.

VanWormer, E., J. A. K. Mazet, A. Hall, V. A. Gill, P. L. Boveng, J. M. London, T. Gelatt, B. S. Fadely, M. E. Lander, J. Sterling, V. N. Burkanov, R. R. Ream, P. M. Brock, L. D. Rea, B. R. Smith, A. Jeffers, M. Henstock, M. J. Rehberg, K. A. Burek-Huntington, S. L. Cosby, J. A. Hammond and T. Goldstein. 2019. Viral emergence in marine mammals in the North Pacific may be linked to Arctic sea ice reduction.” *Scientific Reports* 9(1): 15569.

Goertz, C. E. C., C. Reichmuth, N. M. Thometz, H. Ziel and P. Boveng. 2019. Comparative health assessments of Alaskan ice seals.” *Frontiers in Veterinary Science* 6: 4.

Citta, J., Lowry, L., Quakenbush, L., Kelly, B., Fischbach, A., London, J., Jay, C., Frost, K., O’Corry Crowe, G., Crawford, J., Boveng, P., Cameron, M., Von Duyke, A., Nelson, M., Harwood, L., Richard, P., Suydam, R., Heide-Jorgensen, M., Hobbs, R., Litovka, D., Whiting, A., Marcoux, M., Kennedy, A., George, J., Orr, J., Gray, T. -2018. A multi-species synthesis of satellite telemetry data in the Pacific Arctic (1987–2015): Overlap of marine mammal distributions and core use areas (SOAR II). *Deep Sea Research II*

Cameron, M., Boveng, P. and London, J. 2014 A research cruise to study the ecology of ice-associated seals in the central Bering Sea aboard the NOAA ship Oscar Dyson in April, 2014. *AFSC Quarterly Report* (April-June, 2014)

Ziel, H., Cameron, M., Goldstein, T., Johnson, S., and Boveng, P. 2010. Blood oxygen capacity of ribbon, spotted, and bearded seals. *AFSC Quarterly Report* (Jan-Mar, 2010).

Cameron, M.F., London, J.M. Boveng, P.L. 2009. Telemetry of ice seals captured during research cruise aboard the *McArthur II* in the eastern Bering Sea. *AFSC Quarterly Report* (May-July 2009)

Boveng, P., London, J., and Cameron, M. 2007. Telemetry of ice seals captured during the *Oscar Dyson* and USCGC *Healy* research cruises in the eastern Bering Sea. *AFSC Quarterly Research Reports* (Apr.-Jun. 2007).

Cameron, M.F. 2006. Ice seal operations aboard the Thomas G. Thompson. *AFSC Quarterly Research Reports* (Apr.-Jun. 2006).

Cameron, M.F. 2005. Habitat use and seasonal movements of ribbon seals in the Bering Sea and North Pacific. *AFSC Quarterly Research Reports* (Apr.-Jun. 2005).

Funding status: Funded by NMFS/MML

Project lead: NMFS/MML, Michael Cameron, michael.cameron@noaa.gov

Project partners: Ice Seal Committee

A.3.3 USING AERIAL SURVEYS, BIO-LOGGING, AND SATELLITE REMOTE SENSING TO CHARACTERIZE ARCTIC RINGED SEAL DENNING HABITAT

Objective: Combine data from aerial survey counts, satellite-tag bio-logging records of haul-out time, and remotely-sensed data on snow depth and melting to (1) understand and quantify ringed seals' habitat use, and (2) enhance capabilities to estimate abundance and trends of ringed seals.

Justification: A better understanding of ringed seals' dependence on snow cover is critical for assessing their vulnerability to future Arctic warming and for estimation of population abundance and trends. The relationships between snow depth, melt onset date, and date of ringed seal emergence from snow lairs are key to more informed projections of reproductive habitat suitability using climate model outputs. The same relationships are also fundamental for more reliable abundance estimation, due to the sensitivity of abundance estimates to the timing of emergence from lairs.

Methods:

REMOTE SENSING OF RINGED SEAL HABITAT FEATURES

We will continue ongoing evaluation of satellite-remote-sensed measures of snow depth, melt onset timing, and possibly indices of ice thickness or roughness. The primary focus will be on quantities that relate to common outputs of global climate models (for refining conservation risk assessments) and/or quantities that are available at suitable scales and resolutions for relating to aerial survey data (for abundance estimation).

The timing of snow melt onset has been derived from passive microwave data using the MDSA algorithm (Belchansky et al. 2004), and the Markus et al. (2009) algorithm. Remotely-sensed snow depths are available from the NASA Cryosphere database of 25-km gridded snow depths on sea ice. We will evaluate these indices for their ability to explain variability in ringed seal counts.

Our ability to relate seal distributions to snow variables may improve in the future as technology and/or climatological modeling continue to advance. The recently launched ICESat-2 satellite shows promise for remotely sensed surface roughness, and can be used in combination with the CryoSat2 satellite to produce snow depth

estimates with high vertical precision (Kacimi and Kwok 2020, Kwok et al. 2020). Gridded products are so far only available at the 25-km resolution. Non-gridded ICESat-2 sea ice data have a high along-track resolution of ~27-200 m (Kwok et al. 2019) but are only available >25 km from land, limiting their utility over landfast ringed seal habitats. Despite these continued challenges, future ringed seal aerial surveys can maximize the value of this satellite to ringed seal ecological research by aligning survey tracks with ICESat-2 ground tracks.

To determine the value of existing and future snow depth and melt products for habitat monitoring, continued intercomparison and ground-truthing via on-ice or air-borne measurements will be important, including along coastlines to assess the severity of land contamination. Research is also needed to assess how broad-scale snow depth patterns (e.g. at the 25-km scale) correspond to fine-scale habitat features such as snow drifts where lairs are constructed.

RINGED SEAL HAUL-OUT AND EMERGENCE TIMING

Availability, or the proportion of seals visible to aircraft when flying overhead, is ultimately a function of both emergence from lairs and behavioral changes in haul-out probability related to basking. One possible strategy is to account for changes in haul-out behavior using data from tagged seals, and then model overall changes in availability using temporal trends in aerial survey counts. In this manner, we may be able to isolate the magnitude of contributions from haul-out and emergence to increases in spring seal counts, improving the accuracy of ringed seal abundance estimates. Another strategy we will evaluate is to make use of changes in haul-out diel behavior from tagged seals to help model emergence using, for example, hidden Markov models.

The remote-sensing products described above are also relevant to analyses of haul-out and emergence timing, as are fine-scale weather products such as the North American Regional Reanalysis (Mesinger et al. 2006) database. These covariates will be incorporated into the haul-out and emergence timing to improve performance, as feasible.

Products:

Lindsay, J. M., K. L. Laidre, P. B. Conn, E. E. Moreland, and P. L. Boveng. 2021. Modeling ringed seal *Pusa hispida* habitat and lair emergence timing in the eastern Bering and Chukchi Seas. *Endangered Species Research* 46:1-17.

Lindsay, J. M., D. D. W. Hauser, A. R. Mahoney, K. L. Laidre, J. Goodwin, C. Harris, R. J. Schaeffer, R. Schaeffer Sr., A.V. Whiting, P. L. Boveng, N. J. M. Laxague, S. Betcher, A. Subramaniam, C. R. Witte, and C. J. Zappa. 2023. Characteristics of ringed seal *Pusa hispida* ('natchiq') denning habitat in Kotzebue Sound, Alaska, during a year of limited sea ice and snow. *Mar Ecol Prog Ser* 705:1-20. <https://doi.org/10.3354/meps14252>

Results from this project contribute to the products of projects A.3.4 – A.3.6.

Literature cited:

Belchansky, G. I., D. C. Douglas, I. N. Mordvintsev, and N. G. Platonov. 2004. Estimating the time of melt onset and freeze onset over Arctic sea-ice area using active and passive microwave data. *Remote Sensing of Environment* 92:21-39.

Kacimi, S., and R. Kwok. 2020. The Antarctic sea ice cover from ICESat-2 and CryoSat-2: freeboard, snow depth and ice thickness. *The Cryosphere Discuss.* 2020:1-33.

Kwok, R., S. Kacimi, M. A. Webster, N. T. Kurtz, and A. A. Petty. 2020. Arctic snow depth and sea ice thickness from ICESat-2 and CryoSat-2 freeboards: a first examination. *Journal of Geophysical Research: Oceans* 125:e2019JC016008.

Kwok, R., T. Markus, N. T. Kurtz, A. A. Petty, T. A. Neumann, S. L. Farrell, G. F. Cunningham, D. W. Hancock, A. Ivanoff, and J. T. Wimert. 2019. Surface height and sea ice freeboard of the Arctic Ocean from ICESat-2: characteristics and early results. *Journal of Geophysical Research: Oceans* 0

Markus, T., J. C. Stroeve, and J. Miller. 2009. Recent changes in Arctic sea ice melt onset, freezeup, and melt season length. *Journal of Geophysical Research: Oceans* 114:doi: 10.1029/2009JC005436.

Funding status: Funded 2022-2023

Project lead: NMFS/MML, Paul Conn, paul.conn@noaa.gov and UW SAFS, Jessie Lindsay, jmlinds@uw.edu

Project partners: ADF&G Arctic Marine Mammals, NSB Dept. of Wildlife Management, Department of Fisheries & Oceans Canada, University of Washington Applied Physics Laboratory and School of Aquatic and Fisheries Sciences.

A.3.4 BERING-OKHOTSK SEAL SURVEYS (BOSS)

Objective: To estimate abundances of ribbon, spotted, bearded, and ringed seals in the Bering and Okhotsk Seas.

Justification: Bearded, spotted, ribbon, and ringed seals are key components of Arctic marine ecosystems and

they are important subsistence resources for northern coastal Alaska Native communities. Although these seals are protected under the Marine Mammal Protection Act and bearded and ringed seals are listed as threatened under the Endangered Species Act, no reliable, comprehensive abundance estimates are available for any of the species. Obtaining reliable abundance estimates for ice-associated seals is therefore, vital for developing sound plans for management, conservation, and responses to potential environmental impacts of oil and gas activities and climate change.

Methods:

SURVEY EFFORT

Aerial surveys for bearded, spotted, ribbon, and ringed seals were conducted in the Bering and Okhotsk Seas in the spring of 2012 and 2013. Surveys were conducted using thermal imagers (to detect seals on the ice) paired with digital cameras (to help identify the seal to species) mounted in the belly ports of two US and one Russian fixed-wing aircraft in the spring of 2012 and 2013. Combined, the teams flew over 47,000 nautical miles (90,000 km) of survey track. The completion of this project marks the largest survey of ice-associated seals ever conducted and will provide the first comprehensive estimates of abundance for bearded, spotted, ribbon and ringed seals in the Bering Sea and Sea of Okhotsk.

ABUNDANCE ESTIMATION

Analyzing abundances from thermal video and digital photography presents several statistical challenges due to incomplete detection, false positives, and species misidentification. Novel statistical approaches were developed to deal with these challenges as part of a hierarchical modeling framework that also includes a temporal dimension to account for changing sea ice conditions during the our surveys. The coordinated US Russian analyses provide the most comprehensive estimates of abundance for bearded, spotted, ribbon and ringed seals in the Bering Sea and the Sea of Okhotsk.

Product:

Conn, P.B., Trukhanova, I.S., Boveng, P.L., and Chernook, V.I. *In Prep.* Abundance and distribution of ice-associated seals in the western Bering Sea and Sea of Okhotsk, 2012-2013. *Polar Biology*.

Conn, P.B., Moreland, E.M., VerHoef, J.V., McClintock, B.T., London, J.M., Cameron, M.F., and Boveng, P.L. *In review.* Abundance of ice-associated seals in the eastern Bering Sea in spring of 2012 and 2013: a cause for concern? *Scientific Reports*

Conn, P. B., & Trukhanova, I. S. (2022). Modeling vital rates and age-sex structure of Pacific Arctic phocids: influence on aerial survey correction factors. *Marine Mammal Science*, 1–14.

Lindsay, J.M., Lairdre, K.L., Conn, P.B., Moreland, E.E., and Boveng, P.L. 2021. Modeling ringed seal *Pusa hispida* habitat and lair emergence timing in the eastern Bering and Chukchi Seas. *Endangered Species Research* 46:1–17.

Boveng, P.L., Cameron, M.F., Conn P.B. and Moreland, E.E. 2017. Abundance Estimates of Ice-Associated Seals: Bering Sea Populations that Inhabit the Chukchi Sea during the Open-Water Period. Final Report, BOEM Report 2016-077. Bureau of Ocean Energy Management, Alaska Outer Continental Shelf Region, Anchorage, Alaska, USA.

Conn, P.B., Johnson, D.S., Thorson, J.T. 2017. Confronting preferential sampling when analyzing population distributions: diagnosis and model-based triage. *Methods in Ecology and Evolution* 8: 1535-1546

Conn, P.B., Johnson, D.S., and Boveng, P.L. 2015. On extrapolating past the range of observed data when making statistical predictions in ecology. *PLoS One* 10(10).

Conn, P.B., Johnson, D.S., Ver Hoef, J.M., Hooten, M. B., London, J.M. and Boveng, P.L. 2015. Using spatiotemporal statistical models to estimate animal abundance and infer ecological dynamics from survey counts. *Ecological Monographs* 85(2):235-252.

McClintock, B. T., Moreland, E.E., London, J.M., Dahle, S.P., Brady, G.M., Richmond, E.L., Yano, K.M. and Boveng, P.L. 2015. Quantitative assessment of species identification in aerial transect surveys for ice-associated seals. *Marine Mammal Science* 31(3):1057-1076.

Chernook V.I., Grachev A.I., Vasiliev A.N., Trukhanova I.S. Burkanov V.N., Solovyev B.A. Results of instrumental aerial survey of ice-associated seals on the ice in the Okhotsk Sea in May 2013 // *Izv. TINRO*. 2014. Vol. 179. Pg. 158–176.

Conn, P.B., VerHoef, J.V., McClintock, B.T., Moreland, E.M., London, J.M., Cameron, M.F., and Boveng, P.L. 2014. Estimating multi-species abundance using thermal video and digital photography: Ice-associated seals in the eastern Bering Sea. *Methods in Ecology and Evolution*, DOI 10.1111/2041-210X.12127

Conn, P.B., McClintock, B.T., Cameron, M.F., Laake, J.L., Johnson, D.S., Moreland, E.E., and Boveng, P.L. 2013. Accommodating species identification errors in transect surveys. *Ecology*. 94: 2607-2618.

Moreland, E., Cameron, M., and Boveng, P. 2013. Bering Okhotsk Seal Surveys (BOSS): Joint US-Russian aerial surveys for ice associated seals, 2012-2013. AFSC Quarterly Report (July-Sept, 2013)

Moreland, E., Cameron, M., and Boveng, P. 2012. Bering Okhotsk Seal Surveys (BOSS): Joint US-Russian aerial surveys for ice associated seals. AFSC Quarterly Report (April-June, 2012).

Funding status: Funded by NMFS/MML and the Bureau of Ocean Energy Management (BOEM)

Project lead: NMFS/MML, Erin Moreland, erin.moreland@noaa.gov

Project partners: BOEM, State Research and Design Institute for Fishing Fleet (“Giprorybflot”), RUSSIA

A.3.5 CHUKCHI AND EAST SIBERIAN SURVEYS (CHES)

Objective: To estimate abundances of bearded and ringed seals in the Chukchi and eastern East Siberian Seas.

Justification: Bearded and ringed seals are key components of Arctic marine ecosystems and they are important subsistence resources for northern coastal Alaska Native communities. Although these seals are protected under the Marine Mammal Protection Act and are listed as threatened under the Endangered Species Act, no reliable, comprehensive abundance estimates are available for either species in the Chukchi Sea. Obtaining reliable abundance estimates for ice-associated seals is therefore, vital for developing sound plans for management, conservation, and responses to potential environmental impacts of oil and gas activities and climate change.

Methods: Aerial surveys for bearded and ringed seals were conducted in the Chukchi and East Siberian Seas in the spring of 2016. Similar to the 2012-2013 Bering-Okhotsk Seal Surveys (BOSS), US and Russian researchers used thermal imagers (to detect seals on the ice) paired with digital cameras (to help identify the seal to species) mounted in the belly ports of US and Russian fixed-wing aircraft. In addition to seals, these surveys were also designed to provide information on the distribution of polar bears in the Chukchi Sea; data that are critical to the U.S. Fish and Wildlife Service. Combined, the US and Russian teams flew over 16,000 nautical miles (30,000 km) of survey track.

The seal abundance estimates were calculated using a novel hierarchical modeling framework developed for the BOSS project that includes the effects of incomplete detection, false positives, species misidentification and the temporal dimension to account for changing sea ice

conditions during the surveys. The data collected by our Russian collaborators has been published and integrated into a final analysis to provide the first comprehensive estimates of abundance for bearded and ringed seals in the Chukchi and eastern East Siberian Seas.

Product:

Boveng, P.L., Chernook, V.I., Moreland, E.E., Conn, P.B., Trukhanova, I.S., Cameron, M.F., Christman, C.L., Hardy, S., Richmond, E. *In Prep.* Abundance and distribution of bearded and ringed seals in the Chukchi Sea.

Conn, P.B., Chernook, V.I., Moreland, E.E., Trukhanova, I.S., Regehr, E.V., Vasiliev, A.N., Wilson, R.R., Belikov, S.E., and Boveng, P.L. 2021. Aerial survey estimates of polar bears and their tracks in the eastern Chukchi Sea.

Lindsay, J.M., Lairdre, K.L., Conn, P.B., Moreland, E.E., and Boveng, P.L. 2021. Modeling ringed seal *Pusa hispida* habitat and lair emergence timing in the eastern Bering and Chukchi Seas. *Endangered Species Research* 46:1–17.

Chernook V.I., Trukhanova I.S., Vasiliev A.N., Litovka D.I., Glazov D.M., Burkanov V.N. 2019. First experience of instrumental aerial survey of ringed seal (*Pusa hispida*) and bearded seal (*Erignathus barbatus*) in the Russian zone of the Chukchi and East-Siberian Seas in spring 2016 // *Izv. TINRO*. — Vol. 199. — P. 152–162

Conn, P.B., Moreland, E., Regehr, E.V., Richmond, E.L., Cameron, M.F. and Boveng, P. 2016. Using simulation to evaluate wildlife survey designs: polar bear and seals in the Chukchi Sea. *Royal Society Open Science*. <http://dx.doi.org/10.1098/rsos.150561>

Funding status: Funded by NMFS/MML, the Bureau of Ocean Energy Management (BOEM), and the U.S. Fish and Wildlife Service.

Project lead: NMFS/MML, Erin Moreland, erin.moreland@noaa.gov

Project partners: BOEM, State Research and Design Institute for Fishing Fleet (“Giprorybflot”), RUSSIA and the U.S. Fish and Wildlife Service.

A.3.6 JOINT BEAUFORT SEA SURVEYS (JOBSS) FOR SEALS AND POLAR BEARS

Objective: To estimate abundances of bearded and ringed seals in the Beaufort Sea.

Justification: Bearded and ringed seals are key components of Arctic marine ecosystems and they are important subsistence resources for northern coastal Alaska

Native communities. Although these seals are protected under the Marine Mammal Protection Act and are listed as threatened under the Endangered Species Act, no reliable, comprehensive abundance estimates are available for either species in the Beaufort Sea. Obtaining reliable abundance estimates for ice-associated seals is therefore, vital for developing sound plans for management, conservation, and responses to potential environmental impacts of oil and gas activities and climate change.

Methods: Similar to the 2012-2013 Bering and Okhotsk Sea Seal Surveys (BOSS) and the 2016 Chukchi and East Siberian Surveys (ChESS), we used thermal imagers (to detect seals on the ice) paired with machine vision color cameras (to help identify the seal to species) and machine vision ultraviolet cameras (to help with white coat pup and polar bear detection development) mounted in the belly ports of fixed-wing aircraft. Instrument-based aerial surveys were conducted in the U.S. Beaufort Sea, extending into Canadian waters to survey the Southern Beaufort Sea polar bear sub-population boundary between April 17 – June 11 when bearded seals were hauled out on the ice to molt and the snow lairs of ringed seals were melting. In addition to seals, these surveys also provided information on the distribution of the Southern Beaufort Sea polar bear stock, which are data critical to the U.S. Fish and Wildlife Service and the Department of Fisheries and Oceans (DFO) of Canada. The survey team flew over 9,000 nautical miles (18,000 km) of survey track. A machine learning detection model was used to detect thermal signatures in the infrared imagery and identify the location of animals in the color imagery. Final animal detection and species determination was made by a biologist. A hierarchical modeling framework accounting for incomplete detection, false positives, species misidentification, and temporal aspects such as changing sea ice conditions will be used to produce abundance estimates in spring 2023.

Product: Comprehensive estimates of the distributions and abundances of bearded and ringed seals in the Beaufort Sea.

Funding status: Funded by NMFS/MML; U.S. Fish and Wildlife Service

Project lead: NMFS/MML, Erin Moreland, erin.moreland@noaa.gov

Project partners: U.S. Fish and Wildlife Service, U.S. Geological Survey, Department of Fisheries and Oceans (DFO) CANADA, Government of Northwest Territories, CANADA

A.3.7 ACOUSTIC HABITAT OF ICE-LIVING SEALS IN KOTZEBUE SOUND

Objective: Measure and describe the year-round acoustic habitat of Kotzebue Sound, an area intermittently used by bearded, ringed, and spotted seals. Combine these ambient noise data with hearing data collected for these species in the laboratory to better understand hearing and auditory masking in typical environments.

Justification: This study seeks to improve understanding of the acoustic ecology of ice-living seals and typical acoustic conditions in near-shore Arctic habitats. Bearded, ringed, and spotted seals are important to trophic webs and subsistence communities in Alaska, and acoustic habitat is a fundamental but poorly understood resource for these seals. To support management decisions about anthropogenic noise in areas used by ice-living seals, more must be known about what sounds they hear, how they use sound, what types of acoustic habitat they rely on, and how human-induced changes in that habitat may affect their survival or reproductive success. To address these questions, it is necessary to measure and understand natural variability in representative underwater noise conditions. Combined with laboratory studies on hearing in ice seals, these measurements provide valuable perspective on the significance of acoustic information—including biological, environmental, and human generated sounds—for seals and other marine mammals living in Arctic waters.

Methods: Two DSG-Ocean Acoustic Dataloggers (Loggerhead Instruments, Sarasota, FL, USA) were deployed in Kotzebue Sound, Alaska, in September 2014, and successfully retrieved one year later. The DSG units comprise low-power acoustic recorders designed to sample continuously or on a duty cycle. The two deployed units were programmed to record two out of every 45 minutes at a 96 kHz sampling rate, enabling the description of variations in noise up to 48 kHz within and across hours, days, months, and seasons. These instruments were deployed near Cape Blossom in Kotzebue Sound, approximately 1.5 miles offshore. The locations were selected based on a combination of local and traditional knowledge and previously published data for this region. Specifically, the sites were chosen based on the following characteristics: at least 10 m depth, known ice seal habitat, minimal ice gouging during winter, and minimal sedimentation (far enough from river mouths and past any major sandbars).

Calibrated acoustic recordings were analyzed in terms of 1/3-octave band levels – a common way to describe ambient noise conditions. We characterized average noise levels and variability in noise based on frequency, time of day and year, and prevailing weather conditions

(when known). This type of 1/3-octave band analysis is also used to characterize typical ambient noise conditions in the laboratory during hearing studies, and therefore enables us to compare directly between laboratory and field measurements. Further, this method is relevant to ongoing studies of hearing because the frequency bandwidth over which noise interferes with the detection of a target sound is often well approximated by a 1/3-octave band.

Data were collected under an existing data-sharing agreement with the Kotzebue Sound Beluga Acoustics Team—with members from the Alaska Department of Fish and Game, the National Marine Mammal Laboratory, the North Slope Borough, the University of Washington, the Alaska Beluga Whale Committee, and the Native Village of Kotzebue. Raw data have been provided to the Kotzebue Sound Beluga Acoustics Team. Processed data will be shared when analysis activities are finished.

Product:

Sills, J.M., Reichmuth, C. and Whiting, A. (2018) Acoustic habitat utilized by ice-living seals: hearing and masking in natural noise environments. *Journal of the Acoustical Society of America*. 141(5):4002-4002.

Funding status: This project is currently unsupported. Data collection was funded by the Northwest Arctic Borough Science Program and the University of California Santa Cruz. Data analyses and writing are being completed opportunistically.

Project lead: Jillian Sills and Colleen Reichmuth (University of California Santa Cruz, jmsills@ucsc.edu and coll@ucsc.edu)

Project partners: Native Village of Kotzebue, Alex Whiting

A.3.8 ICE SEAL HEALTH RESEARCH

Objective: Conduct retrospective and prospective veterinary medicine based health assessment of subsistence harvested (healthy and hunter concern) and found dead ice seals.

Justification: There is little information available about natural causes of morbidity and mortality of ice seals. Hunter observations and satellite studies indicate that the Arctic is undergoing major changes in duration of seasonal sea ice extent and thickness, extreme weather patterns, more maritime traffic etc. Coupled to these environmental changes are noted changes in animal distribution, in migration routes and timing, in breeding season start, and arrival of new species to name just a few. The continuation of all these changes could negatively impact the rich marine mammal resources that are essential to Yupik and Inupiat subsistence communities. The North

Slope (NSB DWM) Marine mammal health program works with hunters and communities to support the families and communities, as they, as in the past, continue to adapt to changing environmental conditions, changes in wildlife abundance and accessibility. By continually monitoring the health of animals we can detect known and emerging diseases and contaminants early on that are of concern to people, provide veterinary medicine - science based information to hunters regarding “healthy” and “hunter concern” catches, and address individual and “big picture” concerns about native food health, food safety, and food security.

Methods: Post mortem examination of ice seals by veterinarian and tissue collection for life history parameters assessment and veterinary diagnostics (e.g. histopathology; marine biotoxins; contaminants; parasitology; infectious diseases; microplastics).

Product:

Stimmelmayer, R. Rotstein, D., Sheffield, G. et al. Bearded seal (*Erignathus barbatus*) Health and Disease: Review and Future Directions. in preparation

Lefebvre KA, Fachon E, Bowers EK, Kimmel DG, Snyder JA, Stimmelmayer R, Grebmeier JM, Kibler S, Ransom Hardison D, Anderson DM, Kulis D, Murphy J, Gann JC, Cooper D, Eisner LB, Duffy-Anderson JT, Sheffield G, Pickart RS, Mounsey A, Willis ML, Stabeno P, Siddon E. Paralytic shellfish toxins in Alaskan Arctic food webs during the anomalously warm ocean conditions of 2019 and estimated toxin doses to Pacific walrus and bowhead whales. *Harmful Algae*. 2022 May;114:102205.

Stimmelmayer, R., Boyer, GL., Rotstein, D., Sheffield, G. Surveillance for cyanobacteria algal toxins in liver tissue of ice seals, Alaska 2022 AMSS

Hendrix AM, Lefebvre KA, Quakenbush L, Bryan A, Stimmelmayer R, Sheffield G, Wisswaesser G, Willis ML, Bowers EK, Kendrick P, Frame E, Burbacher T, Marcinek DJ. Ice seals as sentinels for algal toxin presence in the Pacific Arctic and subarctic marine ecosystems. *Mar Mamm Sci*. 2021 Oct;37(4):1292-1308.

Keatts LO, Robards M, Olson SH, Hueffer K, Insley SJ, Joly DO, Kutz S, Lee DS, Chetkiewicz CB, Lair S, Preston ND, Pruvot M, Ray JC, Reid D, Sleeman JM, Stimmelmayer R, Stephen C, Walzer C. Implications of Zoonoses From Hunting and Use of Wildlife in North American Arctic and Boreal Biomes: Pandemic Potential, Monitoring, and Mitigation. *Front Public Health*. 2021 May 5;9:627654.

Stimmelmayer R, Rotstein D, Sheffield G. Prevalence of *Sarcocystis* in ringed and bearded seals, Alaska 2021 AMSS

Stimmelmayer R, Rotstein D, Bodefish K. Urinary stone formation caused by *Staphylococcus pseudintermedius* in a free-ranging ringed seal (*Phoca hispida*), Alaska 2021 AMSS

Walden S, Bryan AL, McIntosh A, Tuomi P, Hoover-Miller A, Stimmelmayer R, Quakenbush LT 2020 Helminth fauna of ice seals in the Alaskan Bering and Chukchi Seas, 2006–2015 *Journal of Wildlife Diseases* <https://doi.org/10.7589/2019-09-228>

Stimmelmayer et al 2019 Urine characteristics of ringed (*Phoca hispida*) and bearded seals (*Erignathus barbatus*) Utqiagvik, Alaska AMSS 2019

Rotstein DS, Stimmelmayer R, Adams B, Pederson M. 2019. Metastatic testicular Sertoli cell tumor in a free-ranging cryptorchid adult spotted seal *Phoca largha*. North Slope, Alaska, USA. *Dis Aquat Org* 133:1-5.

Stimmelmayer R., Rotstein, D. G. Sheffield. Liver Fluke Disease: Prevalence and distribution of associated pancreatic and hepatobiliary pathological findings in subsistence harvested bearded seals (*Erignathus barbatus*) and ringed seals (*Phoca hispida*) from the North Slope and Bering Strait, AK AMSS 2018

Stimmelmayer R, Borchard D. 2018. Lens Lipidomes among Phocids and Odobenidae Aquatic Mammals, 43(5), 506-518, 2018.

Stimmelmayer, R., M.G. Ylitalo, G. Sheffield, K. Beckmen, K. Burek, V. Metcalf, T. Rowles. 2018 Oil fouling in three subsistence-harvested ringed (*Phoca hispida*) and spotted seals (*Phoca largha*) from the Bering Strait region, Alaska: Polycyclic aromatic hydrocarbon bile and tissue levels and pathological findings. *Marine Pollution Bulletin*. 130:311-323

Funding status: NSB DWM, USFWS Prescott grant (F20AP10932-00); Alaska Ocean Observing System Subaward agreement H0025-01, ECOHAB subaward agreement.

Project lead: Raphaela Stimmelmayer (NSB DWM)

Project partners: Gay Sheffield (Alaska Sea Grant), Kathi Lefebvre (NWFSC), Lori Quakenbush (ADF&G)

A.3.9 MONITORING BODY CONDITION OF SEALS IN ALASKA USING SMALL UAS

Objective: To develop and deploy non-invasive, low-disturbance methods for monitoring the body condition of Arctic seals as an indicator of population health and productivity.

Justification: All five phocid (or ‘true’) seals in Alaska, are key components of their marine ecosystems and are important subsistence resources for coastal Alaska Native communities. All are NMFS Protected Resources under the Marine Mammal Protection Act, and two are listed as Threatened under the Endangered Species Act. Body condition (e.g., the ratio of mass over length) is a key indicator of population health and productivity, but it is challenging and expensive to assess by the traditional means of catching and measuring a large sample of individuals in the populations. Still, researchers have detected apparent changes in the body condition of young spotted and ribbon seals, from direct measurements, that may reflect impacts from recent warming and loss of sea ice in the Bering Sea, but the sample sizes are small and precision is poor for robust inference. Alaska Natives hunt seals for subsistence purposes and community efforts to biosample harvested animals have resulted in large and rich datasets that include information on body condition. (see project A.1.1). That study produces larger sample sizes than the live-seal measurements, but may be subject to unknown biases inherent in the harvest. In addition, the timing of most seal hunting is after mothers have weaned their young, and pups were the most sensitive to changes in body condition in our data. This project seeks to complement current information about seal body condition by developing a remote-sensing method that can be applied to a broad sector of the breeding population in conjunction with large, regional aerial surveys.

Methods: Photogrammetry, using unoccupied aircraft systems (UAS) with suitable imaging and positioning capabilities has the potential for vastly increasing the numbers of seals that can be measured, compared with direct measurement of live seals. Development of UAS photogrammetry methods for ice seals may also provide a step toward a method for monitoring body condition in conjunction with image-based surveys for population abundance, thereby greatly strengthening our capability for timely, accurate, and long-term detection of changes, particularly seal-prey-related ecosystem shifts and population threats. We extended existing photogrammetry methods for marine mammals based on battery-operated multi-rotor UAS, with particular focus on conditions relevant to Alaska, such as cold operating temperatures, remoteness of operating areas, needs for operating from a variety of vessels, and conducting photogrammetry of seals on floating ice that may be in motion during overflights. Initial testing and selection of sensors and various models of UAS were conducted in 2020 and 2021. Validation studies (confirming the system’s ability to accurately estimate the body condition of ice seals) were conducted in 2021 and 2022 at captive-care facilities with seals already trained for cooperation in physiological research. In April 2022, field

tests of the system were conducted during an expedition aboard the NOAA Ship Oscar Dyson, where researchers collected images of ice-associated seals hauled out at the southern edge of the Bering Sea marginal ice zone.

Once the images and data collected during the lab and field efforts have been validated, these new UAS-based methods will be deployed alongside the current direct measurement approach, to take advantage of larger numbers of seals that are seen during satellite-tagging operations but are inaccessible for capture. This will enhance researchers’ abilities to assess the status of Arctic seals with greater precision and efficiency. Ultimately, as a next step beyond this project, even greater gains in monitoring capability will stem from incorporation of the new methods into ongoing large-area, photo-based aerial surveys for abundance and distribution, in which thousands of seals are typically encountered.

Product:

Boveng, P. L., H. L. Ziel, B. T. McClintock, and M. F. Cameron. 2020. Body condition of phocid seals during a period of rapid environmental change in the Bering Sea and Aleutian Islands, Alaska. *Deep Sea Research Part II: Topical Studies in Oceanography* 181-182:104904.

Funding status: Funded by NOAA’s UxS Research Transition Office

Project lead: NMFS/MML, Michael Cameron, michael.cameron@noaa.gov

Project partners: Institute of Marine Sciences, University of California Santa Cruz, Long Marine Laboratory, and Alaska SeaLife Center.

A.3.10 INTEGRATION OF TRADITIONAL KNOWLEDGE AND WESTERN SCIENCE USING A BAYESIAN APPROACH FOR FULLY INFORMED MODELS

Objective: Our overall goal is to combine Traditional Knowledge (TK) with satellite telemetry data of seal movements in Alaskan waters to get a better understanding of seal habitat use and behavior. To do this we are using three species as a case study: ringed, bearded, and spotted seals. Our specific objectives are to:

1. Document TK on the habitat use and behavior of ringed, bearded, and spotted seals.
2. Convert the TK into a form that can be use in Bayesian species habitat and movement models.

Integrate both TK and satellite telemetry data on ringed, bearded, and spotted seals in models using a Bayesian framework.

Justification: To date, inferences about animal behavior and habitat-use have been largely based on western science, with TK seen largely as a separate, albeit valuable, body of information that can help inform capture and tagging efforts (e.g., Kelly et al. 2009) or serve as corroborative/ancillary information. However, TK can provide data that extends well beyond the timeframes of western science and does not suffer from limited sample size, which can be an issue in western science, particularly in satellite telemetry studies of marine mammals. Alternatively, western science can often provide data that extends into regions (e.g., offshore waters) where TK holders may have limited knowledge. Uniting these two fields within a single analytical framework enables synergies that increase the understanding of wildlife ecology beyond what is possible using each knowledge system in isolation.

Methods: TK interviews were conducted with local hunters in Utqiagvik, Kotzebue, and Point Hope, AK using a semi-directed format in a conversational style following Huntington (1998). The interviews focused on seal behavior (e.g., differences in diving patterns between traveling and foraging) and habitat use (e.g., are the seals predominantly associated with the ice edge or with pack ice?). Initial interviews were conducted in 2018 and 2019.

The TK collected will dictate the method of its inclusion within the Bayesian habitat models. For example, if there is TK available on the associations between species and ice-concentrations, the TK will be transformed to reflect the probability of an animal being associated with those concentrations. Once the TK has been modified, follow-up discussions with TK holders will be held to confirm that the transformation of the TK has been done in a manner that is consistent with the information provided. The TK will then be combined with satellite telemetry data for ringed, bearded, and spotted seals in Bayesian habitat and behavior models to produce more fully informed models that improve the understanding of habitat use for these species.

References:

Kelly BP. 2009. Studying Seals in Their Sea Ice Habitat. In *Field Techniques for Sea-Ice Research*, pp. 301-344. Ed. by H. Eicken and R. Gradinger. University of Alaska Press.

Huntington HP. 1998 Observations on the utility of the semi-directive interview for documenting traditional ecological knowledge. *Arctic* 51: 237–242.

Product:

Gryba R, HP Huntington, AL Von Duyke, B Adams, B Frantz, J Gatten, Q Harcharek, H Olemaun, R Sarren, J Skin, G Henry, M Auger-Méthé. 2021. Indigenous Knowledge of bearded seal (*Erignathus barbatus*), ringed seal (*Pusa hispida*), and spotted seal (*Phoca largha*) behaviour and habitat use near Utqiagvik, Alaska, USA. *Arctic Science* 7: 832–858 [dx.doi.org/10.1139/as-2020-0052](https://doi.org/10.1139/as-2020-0052)

Funding status: Primary funding from North Pacific Research Board from 2018-2022, with additional funds from North Slope Borough, Marine Mammal Commission, Polar Knowledge Canada - North Scientific Training Program, Stantec Research & Development, Canadian Research Chair program, and National Sciences and Engineering Research Council of Canada

Project Lead: University of British Columbia, Rowenna Gryba, r.gryba@stat.ubc.ca

Project partners: North Slope Borough – Department of Wildlife Management, Huntington Consulting, Kotzebue IRA, local hunters in Utqiagvik, Kotzebue, and Point Hope, AK

A.3.11 DOCUMENTING MOVEMENTS, BEHAVIOR, AND DISTRIBUTION OF ARCTIC ICE SEALS

Objective: Capture and instrument ice seals in the NPR-A with satellite tags to monitor their movements and behavior.

Justification: Information on ice seal spatial ecology is limited and questions remain concerning which factors are important to their behavior, movements, and habitat selection. This project will build upon current understanding of ice seal ecology, supplement existing data sets, help to predict impacts from climate change, and mitigate the impacts of proposed development and increased shipping.

Given the incredible distances that ice seals can travel, this research has statewide implications, particularly for the 55+ Alaskan coastal communities that range from Kaktovik to Bristol Bay that rely upon ice seals for subsistence.

The likely increase of industrial development and shipping in response to sea-ice decline has the potential to exacerbate the influence of changes that are already occurring with the fragile and shifting Arctic ecosystem. This information will inform science based wildlife management, critical habitat designations for ringed and bearded seals (both listed under the Endangered Species



Act - ESA), and is important to developing mitigation plans to minimize negative impacts to Alaska's four ice seal species, as well as the communities that rely upon them for their nutritional and cultural wellbeing.

Methods: Seals will be captured in floating nets, and will be instrumented with satellite transmitting tags (hereafter 'tags'). These tags will collect data on each seal's movements, haul-out behavior, and individual dive behavior. Though ringed seals will be targeted opportunistically, emphasis will be placed on spotted and bearded seals. All seals will be instrumented with two different tags, specifically a back mounted tag that is shed when the seal molts in the spring after it has been captured, and a flipper mounted tag that is permanently attached.

Basic morphological measurements will be taken, including: weight, length, and girth. Several biological samples will be collected for genetics and health assessment. Blood, which is collected from the holes punched in the webbing of the rear flipper, will be soaked up using blotter strips and archived. Skin samples (the hole punches) will be collected and archived for genetic, micro-histological, and disease profiling analyses. A small sample of fur and a single whisker will also be collected for use in stable isotope analysis that informs diet and chronic stress.

Location, haul-out, and dive-behavior data will be obtained as a time series using the Argos System. Data will be filtered to eliminate implausible locations and to ensure data quality. Daily locations for each seal will be estimated using a continuous-time correlated random walk model. A number of spatial, habitat, and environmental covariates will be annotated to each location estimate.

To inform our interpretation of variations in seal movements, habitat use, and haul-out behavior, we will construct a series of mixed models that to predict a variety of ecologically relevant response variables. Explanatory

variables will include a variety of demographic, seasonal, spatial, and environmental factors.

Product: The data collection phase has been completed, and analyses have begun. It is anticipated that a time series of spatial and behavioral data will be produced for each seal tagged in the vicinity of Utqiagvik, AK. Factors associated with seal movements, habitat use, and haul-out and dive behavior will be analyzed within a model selection framework. A manuscript is in prep and is anticipated to be submitted for publication in the fall of 2023.

Funding status: This work has been funded through a NPR-A grant (Grant # 20-NPRA-06).

Project lead: North Slope Borough Department of Wildlife Management, Andrew Von Duyke, andrew.von-duyke@north-slope.org

Project partners: North Slope Borough, Ice Seal Committee, ADF&G. All seal research will be conducted under NMFS permit #20466 and ADF&G Animal Care and Use Committee Protocol #0027-2017-27.

A.3.12 EVALUATING NOVEL ASSESSMENT APPROACHES FOR COASTAL ICE SEAL HAUL-OUT AREAS AND BEHAVIOR IN THE ALASKAN BEAUFORT SEA

Objectives: The goal of this pilot study is to evaluate the potential research value for new and emerging technologies, specifically time-lapse cameras (e.g. commonly known as 'game cameras') and small quad-copter style Uncrewed Aircraft Systems (sUAS, or commonly known as 'drones'), to monitor numbers and behavior of ice seals at coastal haul out sites. Specifically, we will (1) test and refine remote camera and sUAS survey methods to assess relative numbers, presence/absence, and behavior of spotted seals at known haul-out sites; (2) quantify the effects of environmental conditions on spotted seal summer-fall haul-out behavior; (3) assess the combined effects of environmental conditions and human activity on numbers and behavioral responses of hauled out spotted seals; (4) quantify disturbance effects of sUAS on hauled out spotted seals; and (5) assess feasibility of using sUAS to survey spotted seal abundance at coastal haul-outs.

Justification: Spotted seals (*Phoca largha*) are seasonally abundant throughout coastal regions of the Beaufort Sea during the summer and fall, frequently hauling out on coastal sandbars, spits, and islands. Yet, the influence of environmental factors and potentially increasing human disturbance on distribution, numbers, and behavior is unclear. The frequency, duration, and timing of haul-out

use can vary with local conditions (e.g., wind, water level, fish movements, seasonality, and human presence).

Methods: Remote cameras and sUAS will be used to evaluate coastal haul-out behavior, presence, and counts of spotted seals at study sites along the Chukchi and Beaufort Sea coasts, including Dease Inlet, Smith Bay, and Peard Bay. These haul-out sites represent a range of anthropogenic activities (low, intermediate, and high) during late summer to fall, and occur across representative substrates used for hauling out by ice seals across the region, thereby contributing to the broad applicability of these study sites. We will deploy an array of remote camera systems at each site to sample seal presence and behavior. An acoustic audio recorder will also continuously record the nearby passage of aircraft and boats. Additional environmental and weather variables will be sampled with local weather stations to complement concurrent weather and environmental observations collected by Iñupiat observers who are part of the Alaska Arctic Observatory & Knowledge Hub (AAOKH). Images will be reviewed manually or using machine learning techniques for presence, counts, and behavior of seals. Sound data will be processed to quantify ambient sound levels. Sound and environmental data will be summarized and synced to camera seal count and presence/absence data for analysis.

During July-October, we will routinely survey transects of the haul-out sites monitored with remote cameras using small quadcopter sUAS deployed from land, in close proximity to the haul-out site whenever possible. However, some sites may require deployment from a research vessel. Flight paths will be designed to provide full coverage of each haul-out. Sound levels produced by sUAS overflights will be measured and quantified by the simultaneous sound recordings at each haul-out, which will be helpful to understanding the acoustic signal produced by the sUAS instrument. To quantify the effect of sUAS surveys, we will post-hoc examine still and video imagery using a ranked categorical scale of increasing severity for potential behavioral responses. Seals will be categorized by species and age class, if possible, and we will count the number of seals at each haul-out site for an estimate of relative abundance. We will also use sUAS imagery to assess body size and condition.

Generalized additive models or linear mixed effects models will be used to produce explanatory models to assess the environmental and anthropogenic factors that determine counts, presence/absence, disturbance response, when, and where ice seals haul-out. Response variables will include hauled out seal counts and presence/absence relative to predictor variables such as human disturbance (categorical: low, intermediate, high, based on haul-out site; or continuous: frequency and/or intensity of vessel or aircraft disturbance, based on acoustic data), water

level, wind speed and direction, air temperature, precipitation, and cloud cover. Use of haul-outs may vary by month or haul-out site, so we will also include spatial and temporal explanatory variables. Generalized additive models or linear mixed effects models will also be used as explanatory models to assess disturbance response to sUAS. Assuming minimal behavioral response of the sUAS (i.e. no seals flush from the haul-out), counts of total number of seals hauled out will be compared to simultaneous counts of seals from the remote cameras to assess differences in survey techniques.

Products:

Expected project deliverables include:

1. Quarterly, annual, draft, and final reports, and draft and final technical summaries to CMI/BOEM.
2. Electronic data files and imagery.
3. At least one peer-reviewed scientific publication (e.g., Hauser, D.D.W., A.L. Von Duyke, et al. XXXX. Behavioral responses by ice seals to small unmanned aircraft surveys of summer-fall coastal haul-outs. Plos One).
4. Electronic files of presentations at the Alaska Marine Science Symposium (AMSS) and CMI Annual Meetings.
5. We propose to present final project results at AMSS, and will present interim reports at CMI research review meetings.
6. Outreach will include feature stories about project updates and results in the biannual *AAOKH News*, which is a newsletter featuring current news and activities by AAOKH and is sent to all mailbox holders in AAOKH communities. This work will also be highlighted in the NSB-DWM newsletter in both years and sent to all mailbox holders in North Slope communities. Websites for both the NSB-DWM and the Ice Seal Committee will also serve as venues to communicate the progress of this work.

Funding status: Camera monitoring components of this project have been funded by a grant from the Coastal Marine Institute and the Bureau of Ocean Energy Management (#AK-19-02-5), ending 31 March 2023. The project also relies on substantial funding from existing projects: the Alaska Arctic Observatory and Knowledge Hub (AAOKH) at the University of Alaska Fairbanks and the Ice Seal Research Program at the North Slope Borough Department of Wildlife Management (NSB-DWM). Additional funding requests are pending to continue this research into the future.

Project leads: UAF, Donna Hauser, dhauser2@alaska.edu; NSB, Andrew Von Duyke, andrew.vonduyke@north-slope.org

Project partners: University of Alaska Fairbanks, North Slope Borough, Ice Seal Committee, Coastal Marine Institute, Bureau of Ocean Energy Management, and Alaska Arctic Observatory and Knowledge Hub. We will operate under NMFS Letter of Confirmation No. 23546, UAF IACUC #1610672-2, and BLM Land Use Permit FF097621.

A.3.13 (NEW PROJECT) RINGED SEAL WINTER DENSITY

Objective: Determine the density of ringed seals within areas of oil and gas interest near Prudhoe Bay using dogs trained to find seal breathing holes and lairs. The density of seal structures and their snow depths determined during this study will be compared to a previous study conducted in 1982–1983.

Justification: Ringed seal winter density has not been investigated in the Beaufort Sea nearshore fast ice zone for 40 years. This area is used by the oil and gas industry for ice roads, drilling islands, and other infrastructure. In doing so, mitigation measures to minimize disturbance to ringed seals are required. Less sea ice and less snow on ice has been predicted to negatively affect ringed seals, therefore, a comparative study is necessary to determine whether the number of ringed seals using the area has changed.

Methods: Seal structures are not visible from the surface; therefore, trained dogs are used to find seal structures by scent. Structures are then instrumented (thermistors and cameras) and measured (e.g., snow and water depth, and lair dimensions when applicable).

Product:

Quakenbush, L., A. Bryan, and J. Crawford. 2022. Winter ringed seal density within Beaufort Sea oil and gas project areas. Annual Report to BOEM (AK021-01, Award No. M21AC00024). 36 pp with appendices.

Quakenbush, L., A. Bryan, and J. Crawford. 2023. Ringed seal behavior and winter density in Prudhoe Bay, Alaska, determined by wildlife detection dogs and instrumentation of subnivean lairs. Alaska Marine Science Symposium, January 23–27, Anchorage, Alaska (abstract for oral presentation).

Funding status: BOEM, BLM

Project lead: ADF&G, Lori Quakenbush, lori.quakenbush@alaska.gov

Project partners: North Slope Borough

A.3.14 (NEW PROJECT) OCEANOGRAPHIC INFLUENCES ON SPOTTED SEAL FORAGING

Objective: To use satellite telemetry oceanographic modeling and biological sampling to examine spotted seal foraging behavior.

Justification: Although spotted seals are known to be mainly fish eaters, relationships between their environment and foraging behavior are not well understood. Both sea ice and oceanographic conditions are changing in the Bering, Chukchi, and Beaufort seas, and these changes are expected to affect spotted seal distribution, available prey species, and interactions between seals and humans. Examining relationships between physical oceanography, sea ice, and seal behavior is needed to anticipate how spotted seals respond to environmental change.

Methods: Between 2016 and 2020, 23 spotted seals were equipped with Satellite Relay Data Loggers (SRDLs) with Conductivity, Temperature, and Depth (CTD) sensors capable of collecting temperature and salinity profiles as the seals dove through the water column. These instruments (referred to as CTD-SRDLs) provided animal movement and oceanographic data. Spotted seal movements, habitat use, and the dive depths targeted by seals were summarized. A state-space model was used to define seal behavioral states and explore how they related to oceanographic fields inferred from data provided by the CTD-SRDLs. The CTD-SRDLs only provided information about the oceanographic conditions seals encountered along their tracks. As such, numerical simulations from the Regional Arctic System Model were used for a broader, regional oceanographic context, and, specifically to explore the potential use of hydrographic fronts for foraging. Patterns of foraging behavior were related to prey found in seal stomachs.

Product:

Olnes, J., J. Crawford, S. Okkonen, J. Citta, L. Quakenbush, A. Von Duyke, W. Maslowski, R. Osinski, and M. Druckenmiller. In review. Oceanographic influences on spotted seal foraging in the Pacific Arctic. *Continental Shelf Research*.

Olnes, J., J. Crawford, S. Okkonen, J. Citta, L. Quakenbush, A. Von Duyke, W. Maslowski, R. Osinski, and M. Druckenmiller. 2023. Oceanographic influences on spotted seal foraging in the Pacific Arctic. Alaska Marine Science Symposium, January 23–27, Anchorage, Alaska (abstract for oral presentation).

Funding status: NPRB

Project lead: ADF&G, Justin Olnes, justin.olnes@alaska.gov

Project partners: North Slope Borough

A.3.15 (NEW PROJECT) THE TROPHIC ROLES OF ICE SEALS IN THE BERING AND ARCTIC MARINE ECOSYSTEMS OF ALASKA

Objective: Determine the seasonal and regional requirements for bearded, ringed, spotted, and ribbon seals' dominant prey species by integrating results from spring surveys of seal abundance and distribution; satellite-tracking studies of seasonal seal movements; seal prey composition studies; controlled studies of daily energy intake and metabolic rates in captive seals; energy assays of prey species, and energy budgets from closely-related seal species.

Justification: Recent extreme warm periods in the Bering and Chukchi seas have led to rapid declines in sea ice with potentially profound impacts on bearded, ringed, spotted and ribbon seals. They compose a highly abundant guild of predators, whose ecological (i.e., trophic) roles in the seasonally ice-covered waters around Alaska are undoubtedly significant, yet their impact is poorly understood. In the Bering Sea alone, the combined numbers of seals in winter and spring exceeds 1,000,000 individuals, likely consuming several million tons annually of a diverse suite of fish and invertebrate prey. Over the past decade, progress in determining the abundance, seasonal distribution, diet, and daily energy requirements has opened broad opportunities for collaboration to clarify the trophic roles of ice seals. It has become feasible to quantify their energy intake requirements and their impacts as predators. This collaboration between NMFS and six external institutions will support syntheses that for the first time, will afford meaningful inclusion of phocid seals in Ecosystem Status Reports, integrated ecosystem models, and protected species assessments for Alaska Large Marine Ecosystems.

Methods: The overall approach consists of two main components: Seal Population Energy Requirements and Seal Prey Composition.

SEAL POPULATION ENERGY REQUIREMENTS

The Population Energy Requirements component combines elements of seal abundance, seasonal distribution, and energy intake. We will use our estimates of seal abundance from aerial surveys in the Bering and Chukchi Seas to provide information on the numbers of seals and general location during April & May. The abundance and distributions from spring surveys will be

combined with spatial-seasonal utilization distributions (UDs) from satellite tracking studies.

The spatial-seasonal energy intake of seals will be estimated by incorporating individual-based gross energy intake (GEI) estimates directly measured in spotted, ringed, and bearded seals reared in captivity. These will be used as a lower bound for the expected total energy expenditure (TEE) of free-ranging seals. We will also combine them in a meta-analysis with data from analogue species to produce reasonable estimates of age-, sex-, and season-specific gross energy intake for wild individuals of all four Alaska ice seal species. These individual prey intake estimates can be apportioned over our population size and age structure estimates to determine how much energy each seal species consumes at the population level, and where and when that energy is acquired.

SEAL PREY COMPOSITION

The second main component of our approach, seal prey composition, will address the taxa and quantities of prey that meet the seal populations' energetic needs. The objective of this component is to estimate the relative mass of different prey items in the seals' diet, which can then be converted to caloric values using the AFSC-ABL prey-energy-content library. The primary seal diet data comprise the stomach contents from more than 3,500 ice seals sampled by ADF&G, NSB-DWM, and Alaska Native hunter collaborators between 2000 and 2020 at communities along the Bering and Chukchi coasts.

Prey taxa in stomachs are summarized as the counts and measurements of identifiable prey items (e.g., fish otoliths) that we will use to reconstruct species- and age-specific seasonal diet compositions. We will incorporate weight data associated with the samples: Total weight, weight of unidentifiable material ('mush'), and the weight of fishes reconstructed from the counts and sizes of identifiable parts. The overall relative mass composition of dominant fish and invertebrate prey in the sample will then be estimated from both the reconstructed fish mass composition and the approximate invertebrate mass composition.

While estimating seal prey composition is likely to be the most challenging aspect of this study, we believe that credible and highly useful estimates of ice seals' prey consumption can be made during this RWP award period by prioritizing the measurement of otoliths from the seal stomachs. The REFM Age and Growth Program is a partner for this work. More than 34,000 otoliths are available for measurement, but the actual number of measurements needed will be reduced by considering the numbers needed for adequate precision in samples that contain large numbers of small prey.

INTEGRATING THE SEAL POPULATION ENERGY REQUIREMENTS AND SEAL PREY COMPOSITION COMPONENTS

At the final stage of estimating seal prey consumption, the population energy requirements and the prey composition will be combined by using the extensive ABL library of energy content values for fish and invertebrate species. The gross energy intake requirements of individual seals (reported in calories) can be translated into absolute estimates of prey intake per seal using the species' dietary composition, paired with the existing prey-specific energy contents.

Products (planned):

Fiscal Year 2022: Developed the approach using spotted seals as the case study.

Fiscal Year 2023: Complete the spotted seal example; Submit journal article on spotted seals; develop other species examples.

Fiscal Year 2024: Submit journal article(s) for other species.

Funding status: Funded 2022-2024 under NMFS-AFSC Regional Work Plan

Project lead: NMFS AFSC Marine Mammal Laboratory, Peter Boveng, peter.boveng@noaa.gov

Project partners: NMFS AFSC Age and Growth Lab; NMFS AFSC Recruitment, Energetics & Coastal Assessment; ADF&G Arctic Marine Mammals, NSB Dept. of Wildlife Management, University of California Santa Cruz, University of British Columbia, University of San Francisco, University of Alaska Fairbanks

A.3.16 (NEW PROJECT) BERING SEA ICE SEAL SURVEYS

Objective: To estimate abundances of ribbon, spotted, bearded, and ringed seals in the Bering Sea.

Justification: Bearded, spotted, ribbon, and ringed seals are key components of Arctic marine ecosystems and they are important subsistence resources for northern coastal Alaska Native communities. Although these seals are protected under the Marine Mammal Protection Act and bearded and ringed seals are listed as threatened under the Endangered Species Act, they have not been surveyed in this area in more than a decade. Obtaining reliable abundance estimates for ice-associated seals is therefore, vital for developing sound plans for management, conservation, and responses to potential environmental impacts of oil and gas activities and climate change.

Methods: Aerial surveys for bearded, spotted, ribbon, and ringed seals will be conducted in the Bering and Sea in the spring of 2024. Surveys will be conducted using thermal imagers (to detect seals on the ice) paired with machine vision cameras (to help identify the seal to species) mounted in the belly port of a fixed-wing aircraft in the spring of 2024. This project will provide updated abundance and distribution estimates for bearded, spotted, ribbon and ringed seals in the Bering Sea for the first time in more than a decade.

Product: Comprehensive estimates of the distributions and abundances of bearded and ringed seals in the Beaufort Sea.

Funding status: Funded by NMFS/MML; U.S. Fish and Wildlife Service

Project lead: NMFS/MML, Erin Moreland, erin.moreland@noaa.gov

Project partners: U.S. Fish and Wildlife Service, U.S. Geological Survey

A.3.17 (NEW PROJECT) MONITORING BEARDED SEALS IN THE NPR-A THROUGH TAGGING AND ACOUSTICS

Objective: Enhance the baseline understanding of adult bearded seal spatial and acoustic ecology.

Justification: Rapid warming in the Arctic and subsequent loss of sea-ice is associated with ecological disruptions throughout marine and terrestrial ecosystems. Bearded seals (*Erignathus barbatus*) are ice-associated and, therefore, depend upon the sea-ice to fulfill important aspects of their life-history, such as: foraging, reproduction, molting, and predator avoidance. This reliance upon sea-ice ultimately led to their listing as “threatened” under the US Endangered Species Act (ESA). As a generalist benthic feeder, and one of two primary prey species for polar bears (*Ursus maritimus*)—also listed as “threatened” under the ESA—bearded seals form energetic linkages throughout the trophic web and are a vital component of the Arctic ecosystem.

Beyond their ecological importance, bearded seals are valued by indigenous communities in Alaska such as the Iñupiat on Alaska's North Slope, who have very strong cultural, nutritional, and economic connections to the subsistence harvest of marine mammals. For example, bearded seals are highly valued for their meat and oil, and for the raw materials (i.e., skins) they provide for the construction of umiaqs (Iñupiat: open boats) that are used to hunt bowhead whales (*Balaena mysticetus*)—an activity that is central to both Iñupiat and Yupik culture and economy. Protecting opportunities for subsistence has

economic benefits and helps to maintain the social and cultural fabric of the Inuit, for whom the harvest, gathering, and sharing of food are of paramount importance.

Despite their ecological importance and subsistence value, relatively little is known about bearded seals in the Alaskan Arctic; largely because this population is hunted, very cautious, and quite difficult to capture. As such, there is much about bearded seal ecology and behavior that remains to be learned. Because bearded seals are a highly vocal species—relying on vocalizations to attract mates, defend territories, and in other social interactions—passive acoustic survey techniques can be highly effective for investigating both basic ecology of this aquatic mammal, as well as how bearded seals respond to anthropogenic perturbations. Despite the importance of acoustic communication to bearded seals, a baseline understanding of this species' relationship with anthropogenic noise is severely lacking. As arctic sea-ice continues to decline, opportunities for industrial activities in the region continue to increase. Unmitigated anthropogenic noise associated with these activities (e.g., boat traffic, aircraft, seismic survey equipment, and industry infrastructure) may disrupt mating or other social behavior and/or the use of preferred habitat for foraging and molting, which could result in negative fitness costs for the population. Because bearded seals travel great distances annually, these impacts may impact subsistence-based communities in Alaska from the Canadian border to Bristol Bay.

Further underscoring the need for better data on bearded seals and their resilience to human activities, are plans for oil and gas development, which have the potential for negative impacts and, in turn, negatively impact subsistence. Potential impacts associated with industrial development, a lack of data to inform mitigation plans, and statutory requirements associated with managing/conserving an ESA listed species all suggest an acute need for improved knowledge about bearded seal ecology (particularly their acoustic behavior) and how they interact with their environment, including the underwater soundscape. This is key information, without which the long-term implications of chronic human activities on bearded seal ecology and behavior can neither be mitigated nor effectively managed.

This information is applicable to assessing impacts from oil and gas exploration, informing mitigation plans, and evaluating conservation efforts to ensure minimal negative effects to bearded seals, their ecosystem, and the subsistence communities that rely upon this species for their nutritional, cultural, and economic well-being.

Methods: Beginning in the early spring (Mar) and continuing into the fall (Sep), bearded seal vocalizations will be recorded at two different locations. In the Chukchi

Sea, a 4-element hydrophone array will be deployed at a location in proximity to previously deployed hydrophone arrays (i.e., near Point Barrow) to allow for a comparative analysis of contemporary and historical acoustic data collected by the North Slope Borough between 1990 and 2012. Recordings will use a 50% duty cycle, sampling rate of 48 kHz with 16-bit resolution, and a functional recording bandwidth of 20 – 23,000 Hz, thereby covering the entire frequency range of bearded seal calls. The hydrophone array will be time-aligned post deployment, thereby enabling the calls to be acoustically localized using the near-beamforming method integrated into Raven 2.0.

Acoustic recordings will be manually reviewed in Raven Pro 2.031 to annotate any bearded seal calls. Georeferenced seal calls will be recorded in a time series to establish the phenology of bearded seal acoustic repertoire that can be assessed with respect to a suite of behavioral, environmental, and physical co-variables (including ambient sound levels). Seasonal shifts in the soundscape and identification of contributors to bearded seal underwater acoustic environment will be documented by calculating broadband RMS ambient noise values in 5-minute intervals for the entirety of each deployment using the Raven-X Toolbox. Interannual variation will be assessed by comparing contemporary and historic acoustic array data (NSB unpublished data) to assess whether, to what extent, and under what conditions bearded seal vocalizations and associated behaviors have shifted.

Product: The data collection phase has not yet begun. Historical data are being analyzed.

Funding status: This work has been funded through a NPR-A grant (Grant # 22-NPRA-06).

Project lead: North Slope Borough Department of Wildlife Management, Andrew Von Duyke, andrew.vonduyke@north-slope.org

Project partners: North Slope Borough, Ice Seal Committee, Michelle Fournet (University of New Hampshire). All seal research will be conducted under NMFS permit #20466 and ADF&G Animal Care and Use Committee Protocol #0027-2017-27.

A.4 Education and outreach

B. Completed projects

In response to Project Chariot, a 14-month field study of ice-associated seals was conducted near Kivalina in the mid-1960s (Johnson et al. 1966). That study elucidated food habits, age structure, reproductive patterns, and other aspects of the basic biology of ringed, ribbon, spotted, and bearded seals.

In the mid-1970s – 1980s, the Alaska Department of Fish and Game, the University of Alaska Fairbanks, and the National Marine Fisheries Service undertook a series of studies concerning ice-associated seals and offshore oil development. They investigated feeding ecology (Lowry et al. 1978, West et al. 1979, Frost and Lowry 1980, Bukhtiyarov et al. 1984, Simpkins et al. 2001a), distribution and density (Burns and Harbo 1977, Braham et al. 1984, Frost et al. 1988, Frost et al. 2002) (Kelly et al. 2000, 2003), habitat use (Burns and Eley 1978, Burns and Frost 1979, Burns et al. 1981, Burns and Kelly 1982, Kelly and Quakenbush 1990); ; Burns et al. 1981a; Kingsley et al. 1990), diving behavior (Elsner et al. 1989, Wartzok et al. 1992, Kelly 1996, Kelly and Wartzok 1996, Simpkins et al. 2001b, Simpkins et al. 2001c), and responses to industrial development (Fay et al. 1979, Burns and Kelly 1982, Kelly et al. 1986, Frost et al. 1988, Frost and Lowry 1988, Kelly et al. 1988).

Other projects, mostly completed within the past 5-10 years, are described in more detail, below.

B.1 Population identity and status

B.1.1 TRADITIONAL ECOLOGICAL KNOWLEDGE OF SEALS IN NORTON BAY, ALASKA

Objective: Document traditional knowledge about seals in the Norton Bay area.

Justification: Knowledge of hunters and elders, of the distribution, abundance, and natural history of seals is useful in better understanding the Norton Bay region's seal populations and any changes that have occurred. Documenting this knowledge allows local residents to express their views on the status of seal populations so that their understanding and perspective can be taken into account in research and management. It also provides for collaboration between residents of seal hunting communities, scientists, and wildlife managers, that is an essential component of ensuring sustainability of the resource.



Methods: A workshop was held in Shaktoolik, Alaska, February 1-5, 1999 to interview participants.

Product:

Huntington, H. P. 2000. Traditional ecological knowledge of seals in Norton Bay, Alaska. Report submitted to the Elim-Shaktoolik-Koyuk Marine Mammal Commission and the National Marine Fisheries Service. Compiled and edited by Henry P. Huntington, translated by Clara Sookiyak.

Funding status: Funded by NMFS/NMML. Completed 2000.

Project lead: NMFS/NMML, John Bengtson, john.bengtson@noaa.gov

Project partners: NMFS/NMML, Elim-Shaktoolik-Koyuk Marine Mammal Commission

B.1.2 CORRECTION FACTOR FOR RINGED SEAL SURVEYS

Objective: Determine the proportion of local ringed seal populations included in aerial surveys and estimate the variance in that proportion.

Justification: Aerial surveys have been the primary method of estimating population size and have been

used to compare changes in densities of ringed seals over time and space (Burns and Harbo 1972, Frost et al. 1997, Frost et al. 1998, Frost et al. 1999). Survey counts cannot generate estimates of population size with correcting for the portion of the population unseen under snow and ice. Conclusions about population status based on comparisons of densities have been based on the untested assumption that the proportion of populations that are visible is constant.

Methods: Radio telemetry was used to determine the availability of ringed seals for counting during survey periods in the spring of 1999 and 2000. Each time a radio-tagged seal came out of the water, its location and whether or not it was concealed in a subnivean lair or visible on top of the snow was recorded.

Product:

Bengtson, J. L., L.M. Hiruki-Raring, M.A. Simpkins, and P.L. Boveng. 2005. Ringed and bearded seal densities in the eastern Chukchi Sea, 1999-2000. *Polar Biology* 28:833-845.

Kelly, B. P. 2005. Correction factor for ringed seal surveys in Northern Alaska. OCS Study MMS 2005. Coastal Marine Institute, University of Alaska Fairbanks.

Funding status: Funded by CMI. Completed 2004, pending publication of the manuscript.

Project lead: University of Alaska Southeast, Brendan Kelly, bkelly@nsf.gov

Project partners: NMFS/NMML

B.1.3 TIMING AND RE-INTERPRETATION OF RINGED SEAL SURVEYS

Objective: Describe inter annual variation in ringed seal behavior and its implications for interpretation of aerial survey counts. Determine the environmental factors influencing the proportion of local populations available to be counted.

Justification: Aerial surveys have been the primary method of estimating population size and have been used to compare changes in densities of ringed seals over time and space (Burns and Harbo 1972, Frost et al. 1997, Frost et al. 1998, Frost et al. 1999). The fraction of the population counted in those surveys is strongly influenced by environmental factors, especially snow conditions. Interpreting past and future survey data requires accounting for those variables.

Methods: Radio telemetry was used to determine the availability of ringed seals for counting during survey periods in the spring of 1999, 2000, 2001, 2002, and 2003.

Each time a radio-tagged seal came out of the water, its location and whether or not it was concealed in a subnivean lair or visible on top of the snow was recorded. Snow temperature, air temperature, wind speed and direction, time of day, and calendar date were used in models to predict the fraction of the population visible.

Product:

Kelly, B. P., O. R. Harding, and M. Kunasranta. 2003. Timing and re-interpretation of ringed seal surveys. p. 32-37. *In* University of Alaska Coastal Marine Institute Annual Report No. 10. OCS Study MMS 2003, University of Alaska Fairbanks and USDOI, MMS, Alaska OCS Region.

Funding status: Funded by CMI. Completed 2004, pending publication of the manuscript.

Project lead: University of Alaska Southeast, Brendan Kelly, bkelly@nsf.gov

B.1.4 DENSITIES OF RINGED AND BEARDED SEALS IN THE EASTERN CHUKCHI SEA

Objective: Determine the densities and numbers of bearded and ringed seals along the eastern Chukchi Sea coast, including the coastal zone and offshore (to 100 n mi), from just north of Bering Strait to Pt. Barrow.

Justification: These two seal species have been historically important to Arctic subsistence hunters, and ringed seals are an important prey species for polar bears. Knowledge of bearded and ringed seal population dynamics, however, is limited in Alaskan waters. Although ringed seals have been surveyed recently in portions of the Bering Sea and the Beaufort Sea, seal densities in the eastern Chukchi Sea have not been assessed since 1985-87.

Methods: Aerial line-transect surveys were flown by fixed-wing aircraft from 23 May-6 June 1999 and 21-31 May 2000. To correct for seals missed because they were in the water during surveys, the haul-out behavior of some instrumented seals was recorded by satellite telemetry. Seal densities were compared in inshore/offshore and north/south strata.

Product:

Bengtson, J. L., L.M. Hiruki-Raring, M.A. Simpkins, and P.L. Boveng. 2005. Ringed and bearded seal densities in the eastern Chukchi Sea, 1999-2000. *Polar Biology* 28:833-845.

Funding status: Funded by NMFS/NMML. Completed 2005.

Project lead: NMFS/NMML, Peter Boveng, peter.boveng@noaa.gov

B.1.5 POPULATION STRUCTURE AND SEASONAL MOVEMENTS OF RINGED SEALS

Objective: Determine the degree of fidelity to breeding sites by ringed seals and whether site fidelity reflects philopatry.

Justification: Recent observations of tagged ringed seals indicate that they maintain small breeding home ranges (averaging 1 km²) and that they use the same breeding sites in successive years. If the sites breeding seals return to are, in fact, their own natal sites, then the population likely consists of multiple demographically isolated units.

Methods: Satellite-linked transmitters will be used to follow the inter-annual movements of ringed seals. The transmitters will be attached to the seals using flipper tags, thereby allowing the seals to be tracked for periods longer than one annual molt cycle (the limitation imposed by gluing transmitters to the seals' hair). DNA collected as bits of molted skin from seals in their breeding sites will be analyzed and compared with samples collected at other breeding sites.

Movements of adult seals tracked telemetrically indicated fidelity to breeding sites by adult ringed seals but left open the question of natal philopatry. Mitochondrial and nuclear DNA were extracted from tissues (N = 358) collected at ringed seal breeding sites and used to examine population structure. Analyses of 9 microsatellite loci and a 359 bp sequence of the Cytochrome Oxidase I mtDNA locus region were consistent with ongoing gene flow between breeding sites. A history of large effective population sizes among ringed seals, however, prevented us from ruling out genetically isolated populations in which genetic drift has been weak.

Product:

Kelly, B. P., and P. L. Boveng. 2005. Ice Seal Movements and Stock Structure in a Changing Cryosphere. Semi-annual progress report to North Pacific Research Board. http://doc.nprb.org/web/05_prjs/515_pr_june05.pdf

Kelly, B. P., and P. L. Boveng. 2007. Ice Seal Movements and Stock Structure in a Changing Cryosphere. Semi-annual progress report to North Pacific Research Board. http://doc.nprb.org/web/05_prjs/515_pr_jul07.pdf

Kelly, B. P., M. Ponce, D. A. Tallmon, B. J. Swanson, and S. K. Sell. 2009. Genetic diversity of ringed seals sampled at breeding sites; implications for population structure and sensitivity to sea ice loss. University of Alaska Southeast, North Pacific Research Board 631 Final Report. 28 p.



Kelly, B. P., O. H. Badajos, M. Kunasranta, J. R. Moran, M. Martinez-Bakker, D. Wartzok, and P. Boveng. 2010. Seasonal home ranges and fidelity to breeding sites among ringed seals. *Polar Biology* 33:1095-1109.

Funding status: Funded by North Pacific Research Board and NMFS/NMML in FY2005-2007. In final write-up phase as of 2011. Completed.

Project lead: University of Alaska Southeast, Brendan Kelly, bkelly@nsf.gov

Project partners: NMFS/NMML, Ice Seal Committee, North Slope Borough, Central Michigan University

B.1.6 POPULATION STRUCTURE OF RINGED SEALS (*PHOCA HISPIDA*) IN THE CHUKCHI AND BEAUFORT SEAS

Objective: Determine the genetic diversity of ringed seals and the scale of stock structuring in Alaska.

Justification: Recent observations of tagged ringed seals indicate that they maintain small breeding home ranges (averaging 1 km²) and that they use the same breeding sites in successive years. If the sites breeding seals return to are, in fact, their own natal sites, then the population likely consists of multiple demographically isolated units. This work would expand the scope of A.1.2 by supporting sampling and analysis of DNA over a larger area.

Methods: DNA samples (mtDNA and microsatellites) will be collected from breeding ringed seals in three or more sites within Alaska and two or more sites outside of Alaska. If feasible, a sampling network will be established to involve community members in the research. Genetic diversity will be analyzed for each breeding site.

Product: Martinez-Bakker ME, Sell SK, Swanson BJ, Kelly BP, Tallmon DA (2013) Combined Genetic and Telemetry

Data Reveal High Rates of Gene Flow, Migration, and Long-Distance Dispersal Potential in Arctic Ringed Seals (*Pusa hispida*). *PLoS ONE* 8(10): e77125

Funding status: Completed.

Project lead: University of Alaska Southeast, Brendan Kelly, bkelly@nsf.gov

Project partners: Ice Seal Committee, North Slope Borough, Central Michigan Univ., Dept. Fisheries and Oceans (Canada), Finnish Game and Fisheries Research Institute

B.1.7 DENSITIES AND DISTRIBUTION OF RIBBON, SPOTTED, AND BEARDED SEALS IN THE EASTERN BERING SEA

Objective: Determine the densities and numbers of ribbon, spotted, and bearded seals in the sea ice of the Bering Sea in spring time.

Justification: The Bering Sea Ecosystem Study (BEST) and the Bering Sea Integrated Ecosystem Research Program (BS-IERP) are major collaborative programs funded by NSF and NPRB, respectively, to better understand the Bering Sea ecosystem from top (humans) to bottom (climate and primary production). Because seals are important upper predators in this system that represent a direct link to the human component, it is essential to understand the trophic links that involve seals. Models used to investigate hypotheses about this system cannot be parameterized for seals without estimates of fundamental quantities such as densities, which are currently lacking.

Methods: Aerial line-transect surveys will be flown by helicopter from a U.S. Coast Guard icebreaker in spring of 2007 and 2008. The aerial survey effort will be supplemented by line-transect observations from the icebreaker and from a NOAA Fisheries research vessel. To correct for seals missed because they are in the water during surveys, the haul-out behavior of seals is being quantified in related studies using satellite telemetry.

Product:

Cameron, M.F and P.L. Boveng. 2007. Abundance and Distribution Surveys for Ice Seals Aboard the USCG Healy and the Oscar Dyson, 10 April – 18 June 2007. Alaska Fisheries Science Center Quarterly Research Reports. April – June 2007. <http://www.afsc.noaa.gov/Quarterly/amj2007/divrptsNMML3.htm>

Boveng, P.L., J.M. London and M.F. Cameron. 2007. Telemetry of ice seals captured during the USCG Healy and Oscar Dyson research cruises in the eastern Bering Sea. Alaska Fisheries Science Center Quarterly Research Reports. April – June 2007. <http://www.afsc.noaa.gov/Quarterly/amj2007/divrptsNMML4.htm>

Ver Hoef, J.M., M.F. Cameron, P.L. Boveng, J.M. London, E.E. Moreland. 2013. A spatial hierarchical model for abundance of three ice-associated seal species in the eastern Bering Sea. *Statistical Methodology*. 17: 46-66.

Conn, P. B., B. T. McClintock, M. F. Cameron, D. S. Johnson, E. E. Moreland, P. L. Boveng. 2013 Accommodating species identification errors in transect surveys. *Ecology*. 94 (11): 2607-2618.

Funding status: Funded by NMFS/NMML and NSF 2007-2011. Completed 2011.

Project lead: NMFS/NMML, Peter Boveng, peter.boveng@noaa.gov

B.1.8 BEAUFORT SEA ICE SEAL SAMPLING AND ARCHIVAL PROJECT

Objective: This Project will archive full biological sample sets from subsistence harvested ice seals in the communities of Barrow, Nuiqsut, and Kaktovik, Alaska. Samples will be analyzed in cooperation with the Alaska Department of Fish and Game Marine Mammal Program and some tissues stored at the University of Alaska Museum of the North. This is first year of the project with long-term expectations of developing an annual program to obtain future, long-term data and information on the health of ice seal populations.

Justification: Seals are a key ecological component of the Arctic and are heavily relied upon by polar bears and northern indigenous people for food. Measurable impacts from climate changes affecting ice and foraging habitat, and offshore oil and gas exploration and development affecting health and movements of seals may be attained from tissue sampling. Some past data from the 1970s and 1980s may be used for temporal health comparisons.

Methods: Seal hunting households are instructed in tissue sampling and measurements and given sample kits and data-forms. Samples are frozen and sent to Fairbanks for processing and long-term storage.

Product: Samples were collected from Kaktovik and Barrow, and data were stored in ADF&G's database.

Funding status: Completed

Project lead: ADF&G

Project partners: Alaska Nanuuq Commission, NSB Wildlife Management, Local Tribes

B.2 Mortality and harvest

B.2.1 BERING STRAIT SEAL HARVEST SURVEY 2002

Objective: Estimate the harvest of ice seals in the Bering Strait Region of Alaska

Justification: Ice seal harvest information has been sporadic and lacking for the Bering Strait region of Alaska.

Methods: A multi-page survey questionnaire was developed to assess ice seal harvests by age class, sex, and month of harvest. Surveyors attempted to census an entire community but generally the participation rate ranged from 10% to 64%. Results included seals harvested by species, by village, by month and struck and lost estimates. The villages included Brevig Mission, Elim, Gambell, Golovin, Shaktoolik, Saint Michael, Savoonga, Stebbins, Teller, and Wales.

Product: A currently unpublished report housed in Kawerak, Inc. has been compiled and used to assist the Kawerak, Inc., Subsistence Program to better understand ice seal subsistence harvests of Bering Strait region communities.

Funding status: Completed year??

Project lead: Kawerak, Inc., Lily Ray-Gadamus, ss.pi@kawerak.org

Project partners: NOAA/NMFS

B.2.2 NUTRIENTS AND CONTAMINANTS IN SPOTTED SEAL BASED FOODS, AND ASSESSMENT OF RISKS AND BENEFITS TO HUMAN CONSUMERS

Objective:

Justification:

Methods:

Product:

Moses, S.K., A.V. Whiting, G.R. Bratton, R.J. Taylor, T.M. O'Hara. 2009. Inorganic nutrients and contaminants in subsistence species of Alaska: linking wildlife and human health. *International Journal of Circumpolar Health*. Vol. 68(1):53-74.

Moses, S.K., A.V. Whiting, D.C.G. Muir, X. Wang, T.M. O'Hara. 2009. Organic nutrients and contaminants in subsistence species of Alaska: concentrations and relationship to food preparation method. *International Journal of Circumpolar Health*. Vol. 68(4): 354-371.

Hueffer, K., C.L. Lieske, L.M. McGilvary, R.F. Hare, D.L. Miller, T.M. O'Hara. 2011. *Streptococcus phocae* isolated from a spotted seal (*Phoca largha*) with pyometra in Alaska. *Journal of Zoo and Wildlife Medicine*. 42(1): 108-112.

Funding status: Project completed 2009

Project lead: Todd O'Hara

Project partners: Ice Seal Committee

B.3 Habitat and climate change

B.3.1 ICE SEAL HABITAT USE AND SELECTION NEAR ST. LAWRENCE ISLAND

Objective: Evaluate the habitat use of ice seals near St. Lawrence Island to determine whether species associate with certain ice conditions or prefer to remain near rich foraging grounds.

Justification: The design and interpretation of aerial surveys for estimating the density and abundance of ice seals, is improved by knowing the habitats (e.g., ice types and concentrations) preferred by the different species of ice seals.

Methods: Aerial line-transect surveys were conducted from helicopters supported by the U.S. Coast Guard icebreaker Polar Star. Seal densities were compared in areas of differing ice concentration, floe sizes, and benthic productivity. Evidence of interactions and segregation among seal species were examined.

Product:

Simpkins, M. A., L. M. Hiruki-Raring, G. Sheffield, J. M. Grebmeier, and J. L. Bengtson. 2003. Habitat selection by ice-associated pinnipeds near St. Lawrence Island, Alaska. *Polar Biology* 26(9):577-586.

Funding status: Funded by the National Science Foundation and the NMML. Completed, 2003.

Project lead: NMFS/NMML, Peter Boveng, peter.boveng@noaa.gov

Project partners: ADF&G, Diomed Observatory, National Science Foundation

B.3.2 ICE SEAL CONTAMINANT LEVEL ASSESSMENT IN TISSUES CONSUMED BY HUMANS

Objective: Determine the levels of trace elements in tissues of ice seals harvested for subsistence.

Justification: Some trace elements (cadmium, lead, and mercury) are toxic to marine mammals and humans. People who rely on marine mammals are concerned about the safety of their food.

Methods: Liver, kidney, and blubber samples are collected during the subsistence harvest. Concentrations of trace elements (cadmium, silver, copper, zinc, total mercury, and methyl mercury) were determined in tissues of bearded, ringed, and spotted seals from Alaska and Canada. Age and trophic level were investigated to learn more about the pathways and biomagnification of trace elements among species.

Product:

Reports to the Ice Seal Committee, Village IRAs, State of Alaska Department of Health and Social Services, and scientific publications:

Dehn, L. A., G. Sheffield, E. H. Follmann, L. K. Duffy, V. M. Woshner, and T. M. O'Hara. 2003. Age and diet related distribution of heavy metals in renal and hepatic tissue of ringed, bearded, and spotted seals harvested in Alaska. Proceedings of the 15th Conference of the Biology of Marine Mammals, 14-19 December 2003. (abstract)

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.

Funding status: Funded by Cooperative Institute for Arctic Research, NSB/DWM, IAB and Department of Wildlife and Biology UAF, USGS, BASC, and NSF. Completed.

Project lead: UAF, Todd O'Hara, fftmo@uaf.edu

Project partners: ADF&G, Village IRAs, local hunters

B.3.3 MOVEMENTS, HABITAT USE, AND FORAGING BEHAVIOR OF RINGED SEALS IN THE CHUKCHI AND BERING SEAS

Objective: To document the seasonal movements, foraging behavior, and important habitats of spotted and ringed seals in Kotzebue Sound, the Chukchi Sea, and the Bering Sea.

Justification: This work has expanded upon the existing collaboration between Kotzebue IRA, ADF&G, and NMFS by taking advantage of opportunities to study spotted and ringed seals when they are captured incidentally to the capture efforts of the bearded seal project, B.3.2.

Methods: Spotted and ringed seals are captured in large-mesh tangle nets, instrumented with satellite-linked Depth Recorders (SDRs) and then released. Information on the seal's movements and diving behavior are transmitted back to researchers via the ARGOS satellite system and analyzed for relationships with bathymetry, sea ice, and other environmental features.

Product: Crawford, J.A., K.J. Frost, L.T. Quakenbush, and A. Whiting. 2011. Different habitat use strategies by subadult and adult ringed seals (*Phoca hispida*) in the Bering and Chukchi seas. Polar Biology 35:241-255.

Funding status: Funded by USFWS Tribal grant. 2005-2011.

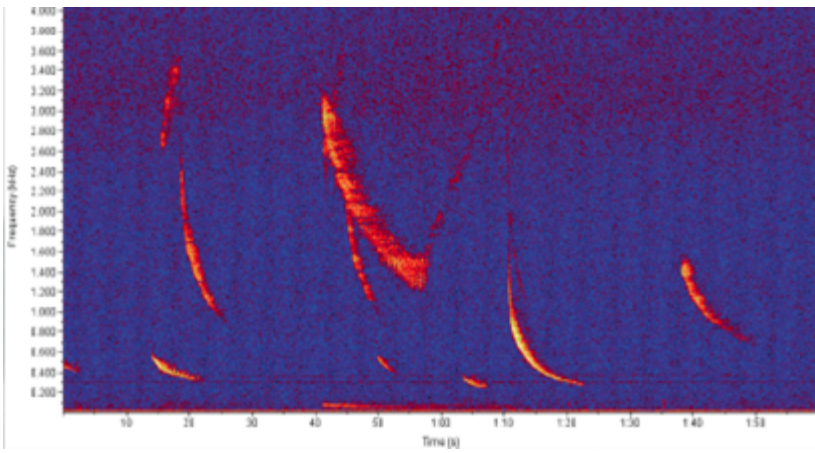
Project lead: Kathy Frost and Alex Whiting

Project partners: Kotzebue IRA, ADF&G, NMFS/NMML

B.3.4 YEAR-ROUND ACOUSTIC DETECTION OF BEARDED SEALS

Objective: (1) Evaluate seasonal occurrence of vocalizing bearded seals within the Bering, Chukchi and Beaufort Seas (BCB) using three years of passive acoustic monitoring data; (2) characterize and identify the implications variable sea ice conditions and changing water temperatures have had on the distribution of vocalizing bearded seals in the BCB using vocal presence as a means to assess presence; (3) examine geographic variation by comparing call types during the spring months from all regions within the BCB.

Justification: Dramatic shifts in Arctic climate have led to changes in sea ice distribution, extent, and timing that pose substantial adaptation challenges for Arctic species. Ice obligate species like the bearded seal are inherently vulnerable to environmental change, relying on seasonal sea ice as a platform for pupping and molting. During mating season, while female bearded seals haul out on ice floes and migrate northward with the retreating ice edge, males produce underwater vocal displays to present their reproductive condition. Preliminary analysis has revealed year-round vocal presence in the Beaufort Sea, which was once believed to be a spring phenomenon. With this new insight, it is clear that passive acoustic monitoring can be employed as an effective method to examine bearded seal distribution, migration patterns, and population structure year-round. This research will help to develop a more complete understanding for



bearded seal ecology through the analysis of year-round passive acoustic data and changing sea ice conditions from 2008 – 2011. By comparing call types within and between regions, we can determine population structure and seasonal movement that will address issues concerning impacts reduced sea ice will have on population dynamics. Establishing a year-round understanding for bearded seal behavior will provide baseline data to detect future changes as a consequence of climate variability.

Methods: Passive acoustic data in the BCB was previously collected by the NMML NOAA and the UW APL. Hydrophones, (Multi-electronique Aural M2s), were used to make yearlong recordings of underwater sounds during a three-year period from 2008 to 2011. Instruments were deployed in 10 locations throughout the BCB: four in the Bering Sea, two in the Chukchi Sea, and four in the Beaufort Sea. The instruments were suspended 5 m above the seafloor at varying depths: the Bering Sea hydrophones were moored in ~70 m of water, the Chukchi Sea ~40 m and the Beaufort Sea hydrophones were moored at depths ranging from 60-180 m. Hydrophones in each location were set to record for one year from deployment and retrieved a year later. Each instrument recorded on a set duty cycle (e.g. 9 min on/20 min off) and at sample rates of either 8192 Hz or 16384 Hz for an entire year.

The acoustic data has been analyzed, using Ishmael, a bioacoustics software (Mellinger 2001), for the presence of sounds typically associated with bearded seals. Data was observed in the form of spectrograms, or a visual representation of sound, where frequency is plotted as a function of time. Call presence was based on daily proportions of hours per day with calls out of the total hours recorded at each site. Bearded seal vocal presence was examined and compared within and between each region of the BCB to assess distribution (based on vocal presence) between 2008 and 2011.

Bearded seal presence was then compared with mean sea ice concentration from year-round acoustic data collected between 2008 and 2011. Data to calculate mean sea ice concentration at each mooring was obtained from the National Snow and Ice Data Center (NSIDC, [http://](http://nsidc.org/data/collections.html)

nsidc.org/data/collections.html). All mooring locations for each year (2008-2011) were surrounded by a 20 km buffer where associated sea ice concentration data within the buffer were averaged for a given day. Mean daily sea ice concentration for each day was then compared to bearded seal vocal presence to examine how variations in sea ice presence affect bearded seal distribution within and between locations in the BCB.

Geographic variation will be examined within the BCB by comparing call types observed during the spring in each region during a single year (2011). For high quality calls, key features will be extracted from each including: start frequency, duration, frequency change from start to end of the call, frequency range from the minimum to the maximum of the call, modulation, and presence or absence of harmonic bands. Mean values and standard deviations of all parameters will be calculated for each call type to facilitate comparison with previously described calls and categorization of new calls.

Following the initial classification, vocal parameters will be examined with classification trees using R (www.R-project.org). Once the call types are determined and separated out for each region, classification trees will be used to compare bearded seal vocalizations geographically between each region. The repertoire analysis will allow us to determine if distinct subpopulations exist within the study area. The presence of distinct subpopulations may have implications for independent management strategies when considering the impacts of diminishing sea ice within the BCB and may lead to a better understanding of bearded seal ecology.

Product: One manuscript has been published in Polar Biology and a second manuscript has been drafted comparing the regional variability of bearded seal year-round vocal activity in the BCB relative to changing environmental conditions (MacIntyre et al. in prep). A third manuscript will also be produced from this research which will examine geographic variation in the BCB by comparing call types produced during the spring months.

MacIntyre, K. Q., K. M. Stafford, C. L. Berchok, P. L. Boveng. 2013. Year-round acoustic detection of bearded seals (*Erignathus barbatus*) in the Beaufort Sea relative to changing environmental conditions, 2008–2010. *Polar Biology* **36**: 1161-1173

Funding status: Completed

Project lead: NMFS/NMML, Kalyne MacIntyre, kalyne.macintyre@noaa.gov

Project partners: UW APL, UW SAFS

B.3.5 MOVEMENTS, HABITAT USE, AND FORAGING BEHAVIOR OF YOUNG-OF-THE-YEAR BEARDED SEALS IN THE CHUKCHI AND BERING SEAS

Objective: To document the seasonal movements, foraging behavior, and important habitats of young-of-the-year bearded seals in Kotzebue Sound, the Chukchi Sea and Bering Sea.

Justification: Bearded seals are an important subsistence resource, a key ecological component of the arctic marine ecosystem and vulnerable to climate change because of their strong association with sea ice. Their seasonal movements, habitat use, and diving behavior have never been documented in Alaskan waters.

Methods: In 2004-2006, 26 (13 female and 13 male) young bearded seals were captured in Kotzebue Sound using large-mesh tangle nets. The seals were instrumented with Satellite-linked Data Recorders (SDRs) and then released. Information on the seals' movements and diving behavior were transmitted back to researchers via the ARGOS satellite system and analyzed to: 1) provide haul-out correction factors for past and future abundance and distribution sightings surveys, 2) assess the seasonal movements and patterns of distribution and diving/foraging behavior, 3) identify and determine the priority of importance for specific marine habitats associated with key ice seal life history events such as breeding, pup rearing, and foraging and molting, and 4) describe seal dive depths and durations. With the field work, data collection and analyses complete, research manuscripts are being prepared and finalized for publication in peer-reviewed journals. This project involved direct collaboration between subsistence hunters and scientists, especially in capturing and tagging seals.

Product:

Cameron, M., Frost, K., VerHoef, J., Breed, G., Whiting, A., Goodwin, J., and Boveng, P. 2018. Habitat selection and seasonal movements of young bearded seals in the Bering Sea. *PLoS ONE* 13(2): e0192743. <https://doi.org/10.1371/journal.pone.0192743>.

Breed, G., Cameron, M., VerHoef, J., Boveng, P., Whiting, A., and Frost, K., 2018. Seasonal sea ice dynamics drive movement and migration of juvenile bearded seals (*Erignathus barbatus*). *Marine Ecology Progress Series*. 600:223-237. <https://doi.org/10.3354/meps12659>

Citta, J., Lowry, L., Quakenbush, L., Kelly, B., Fischbach, A., London, J., Jay, C., Frost, K., O'Corry Crowe, G., Crawford, J., Boveng, P., Cameron, M., Von Duyke, A., Nelson, M., Harwood, L., Richard, P., Suydam, R., Heide-Jorgensen, M., Hobbs, R., Litovka, D., Whiting, A., Marcoux, M., Kennedy, A., George, J., Orr, J., Gray, T. -2018. A multi-species synthesis of satellite telemetry data in the Pacific Arctic (1987–2015): Overlap of marine mammal distributions and core use areas (SOAR II). *Deep Sea Research II*

Cameron, M. 2007. Habitat use and seasonal movements of bearded seals in Kotzebue Sound, Alaska. *AFSC Quarterly Research Reports* (Oct.-Dec. 2006).

Cameron, M.F. 2006. Habitat use and seasonal movements of bearded seals in Kotzebue Sound, Alaska. *AFSC Quarterly Research Reports* (Oct.-Dec. 2005).

Cameron, M.F. 2005. Habitat use and seasonal movements of bearded seals in Kotzebue Sound, Alaska. *AFSC Quarterly Research Reports* (Oct.-Dec. 2004).

Funding status: Funded by USFWS Tribal Wildlife Grant and NMFS/MML

Project lead: Alaska Marine Ecosystems Research, Kathy Frost, kjfrost@hawaii.rr.com

Project partners: Kotzebue IRA, ADF&G, NMFS/MML, Ice Seal Committee, Minerals Management Service

B.3.6 MOVEMENTS, HABITAT USE, AND FORAGING BEHAVIOR OF RINGED, BEARDED, AND SPOTTED SEALS

Objective: To document the seasonal movements, foraging behavior, and important habitats of ringed, bearded, and spotted seals in the Beaufort, Chukchi, and Bering Seas using satellite telemetry and ocean sensing technology and to collect traditional ecological knowledge regarding seals and other marine mammals.

Justification: Ringed, bearded, and spotted seals are highly valued subsistence resources for western and northern Alaska coastal communities. To better understand how shipping and oil and gas activities affect seals and how mitigation measures may be of use, more information is needed regarding seasonal movements, diving and haul-out behavior, site fidelity, and the relationship of oceanographic conditions and important habitats.

Methods: Ringed, bearded, and spotted seals are captured in large-mesh tangle nets, instrumented with satellite-linked Depth Recorders (SDRs), long-term flipper tags, or CTD tags and then released. Seal locations, hauling out behavior, diving behavior, and oceanic conditions

such as salinity and temperature are transmitted back to researchers via the ARGOS satellite system and analyzed for movements, site fidelity, and relationships with bathymetry, sea ice, and other environmental features.

Product:

Huntington, H.P., L.T. Quakenbush, and M. Nelson. 2016. Effects of changing sea ice on marine mammals and subsistence hunters in northern Alaska from traditional knowledge interviews. *Biology Letters* <http://dx.doi.org/10.1098/rsbl.2016.0198>

Huntington, H.P., L.T. Quakenbush, and M. Nelson. 2017. Evaluating the effects of climate change on indigenous marine mammal hunting in northern and western Alaska using traditional knowledge. *Frontiers in Marine Science* 4:319. [Doi:10.3389/fmars.2017.00319](https://doi.org/10.3389/fmars.2017.00319)

Crawford, J.A., Frost, K.J., Quakenbush, L.T., Whiting, A. 2012. Different habitat use strategies by subadult and adult ringed seals (*Phoca hispida*) in the Bering and Chukchi seas. *Polar Biology* 35:241-255

Crawford, J.A., Frost, K.J., Quakenbush, L.T., Whiting, A. 2012. Seasonal and diel differences in dive and haul-out behavior of adult and subadult ringed seals (*Pusa hispida*) in the Bering and Chukchi seas. *Polar Biology* 42:65-80

Quakenbush, L., Crawford J. 2019. Ice seal movements and foraging: village-based satellite tracking and collection of traditional ecological knowledge regarding ringed and bearded seals. Annual report to BOEM No. M13PC00015.

Quakenbush, L. 2020. Movements and habitat use of Pacific Arctic seals and whales via satellite telemetry and ocean sensing. Final report to the Office of Naval Research No. N00014-16-3019.

Olness, J., J. Crawford, J.J. Citta, M.L. Druckenmiller, A.L. Von Duyke, and L. Quakenbush. 2020. Movement, diving, and haul-out behaviors of bearded seals in the Bering, Chukchi, and Beaufort seas, 2014–2018. *Polar Biology* [doi: 10.1007/s00300-020-02710-6](https://doi.org/10.1007/s00300-020-02710-6)

Olness, J., G.A. Breed, M.L. Druckenmiller, J.J. Citta, J.A. Crawford, A.L. Von Duyke, and L. Quakenbush. Juvenile bearded seal response to a decade of sea ice change in the Bering, Chukchi, and Beaufort seas. *In press*. *Marine Ecology Progress Series*.

Von Duyke, A.L., D.C. Douglas, J.K. Herreman, and J.A. Crawford. 2020. Ringed seal (*Pusa hispida*) seasonal movements, diving, and haul-out behavior in the Beaufort, Chukchi, and Bering seas. *Ecology and Evolution* [doi:10.1002/ece3.6302](https://doi.org/10.1002/ece3.6302)

Funding status: Funded by NMFS prior to 2013, BOEM 2013–2019 and ONR 2016–2019. This project has ended but publications are being finalized.

Project lead: ADF&G, Lori Quakenbush

Project partners: North Slope Borough, Ice Seal Committee, Native Village of Kotzebue, Huntington Consulting, NMFS Marine Mammal Lab.

B.3.7 FIRST DOCUMENTATION OF OIL FOULING IN SUBSISTENCE-HARVESTED RINGED (PHOCA HISPIDA) AND SPOTTED (PHOCA LARGHA) SEALS IN BERING STRAIT

Objective: Document the chemical contamination, gross necropsy, and histological findings for oiled ice seals harvested for subsistence in the Bering Strait region

Justification: The Bering Strait is a narrow waterway that divides Alaska from Russia and forms the only maritime transportation corridor for shipping routes between the Pacific and Arctic oceans. Concurrently, reliance on marine resources harvested in this region remains essential to the human population. Decreasing ice conditions herald not only ecosystem changes but increased opportunities for industrialized maritime use in the Bering Strait.

During 2012–2014, oil spills of unknown origin were detected in the Bering Strait region by the subsistence harvest of oiled ice seals [spotted (*Phoca largha*; n=4); ringed (*Phoca hispida*; n=1)] near Shishmaref and Saint Lawrence Island.

Methods: PAH concentrations determined from various tissues of 5 seals collected in the Bering Strait region during 2012–2014 as well as an unoiled and oiled harbor seal collected during the 1989 Exxon Valdez Oil Spill (EVOS) in Prince William Sound, Alaska. All results expressed in ng/g, wet weight. Results include the sum of low molecular weight PAHs containing 2–3 ring compounds (LMWAH) and the sum of high molecular weight PAHs containing 4–5 ring compounds (HMWAH).

Product:

Stimmelmayer, R., G.M. Ylitalo, G. Sheffield, K. Beckmen, K. Burek-Huntington, V. Metcalf, and T. Rowles. 2018. Oil Fouling in Three Subsistence-Harvested Ringed (*Phoca hispida*) and Spotted seals (*Phoca largha*) from the Bering Strait region, Alaska: Polycyclic Aromatic Hydrocarbon Bile and Tissue Levels and Pathological Findings. *Marine Pollution Bulletin* 130 (2018):311–323. <https://doi.org/10.1016/j.marpolbul.2018.02.040>

Sheffield, G., R. Stimmelmayer, V. Metcalf, G. Ylitalo, K. Burek, T. Rowles, and T. Hepa. 2015. Oil fouling in subsistence harvested ringed (*Phoca hispida*) and spotted seals (*Phoca largha*) in the Bering Strait region: 2012 and 2014. Oral presentation. 2015 May 18-22: Effects of Oil on Wildlife Conference, Anchorage, Alaska.

Sheffield, G., V. Metcalf, R. Stimmelmayer, G. Ylitalo, K. Burek, K. Beckmen, and T. Rowles. 2014. First documentation of oil fouling in subsistence harvested ringed (*Phoca hispida*) and spotted seals (*Phoca largha*) in the Bering Strait region – Fall 2012. Poster presentation. 2014 Jan 20-24: Alaska Marine Science Symposium, Anchorage, Alaska.

Ice Seal Committee meeting (2013)

Funding status: Funded

Project lead: Eskimo Walrus Commission, UAF-Marine Advisory Program, and NSB Dept. of Wildlife Management

Project partners: Gay Sheffield, Vera Metcalf, Raphaela Stimmelmayer, Gina Ylitalo, Kathy Burek Huntington, Kimberlee Beckmen, Teri Rowles, Taqulik Hepa

B.4 Education and Outreach

B.4.1 KAWERAK ICE SEAL AND WALRUS PROJECT, 2010-2014

Objective: Document traditional knowledge of ice seals and walruses in the Bering Strait Region of Alaska, including important habitat areas, local management traditions, and cultural importance.

Justification: Bering Strait tribes have detailed knowledge of ice seals and walruses, and a long history of subsistence use.

Methods: Participatory research design. Semi-structured interviews and focus groups with a purposive sample of local experts. Interviews included mapping as well narrative traditional knowledge. Participating communities were Diomedes, King Island, Savoonga, Nome, Elim, Koyuk, Shaktoolik, Saint Michael and Stebbins.

Product:

Gadamus, L. and J. Raymond-Yakoubian. 2015. Qualitative participatory mapping of seal and walrus harvest and habitat areas: documenting indigenous knowledge, preserving local values, and discouraging map misuse. *International Journal of Applied Geospatial Research*. 6(1): 76-93.

Gadamus, L. 2013. Linkages between human health and ocean health: a participatory climate change vulnerability assessment for marine mammal harvesters. *International Journal of Circumpolar Health*. 72: 20715.

A map atlas “Seal and Walrus Harvest and Habitat Areas for Nine Bering Strait Region Communities”

Two books: Seal and Walrus Hunting Safety and Traditions of Respect

A policy document: “Policy-Based recommendations from Kawerak’s Ice Seal and Walrus Project”

A synthesis document in collaboration with Oceana: “Bering Strait Marine Life and Subsistence Use Data Synthesis”

Two articles have been submitted for publication. One on the use of traditional knowledge in habitat delineation, and one on local values associated with seal and walrus harvest and management.

A collaboration with Audubon Alaska to do an analysis of vessel traffic in the Bering Strait which includes spatial data from this project

<http://www.kawerak.org/socialsci.html>

Funding status: Completed 2014

Project lead: Kawerak Social Science Program, socsci@kawerak.org

Project partners: Ice Seal Committee, Eskimo Walrus Commission, the communities of Diomedes, King Island, Savoonga, Nome, Elim, Koyuk, Shaktoolik, Saint Michael, and Stebbins

B.4.2 TRADITIONAL HUNTING WORKBOOK – ICE SEALS

Objective: A workbook on traditional ice-seal hunting in the Yukon-Kuskokwim region will be produced that can be used by teachers in the region. Printing of the workbook will require additional funds.

Justification: Young hunters need to know the traditional ways of hunting, the tools used in hunting, and the ways to prepare seals.

Methods: Produce outline and draft workbook for review by hunters and elders.

Product: Workbook is completed and being used for teaching in the Yukon-Kuskokwim and Kawerak regions and as a template for a beluga hunting book by the Alaska Beluga Whale Committee.



Funding status: Funded 2005-2006 by the Ice Seal Committee and NMFS, Alaska Region.

Project lead: Lori Quakenbush and Mike Taras

Project partners: ADF&G, NMFS/NMML, IUM, Ice Seal Committee

Literature cited

- Allen, J. A. 1880. History of North American pinnipeds: a monograph of the walruses, sea-lions, sea-bears and seals of North America. U.S. Department of the Interior, U.S. Government Printing Office, Washington, D.C. 785 p.
- Boas, F. 1888. The central eskimo. Pages 401-650 Bull. Amer. Ethnol. 1884-85.
- Braham, H. W., J. J. Burns, G. A. Fedoseev, and B. D. Krogman. 1984. Habitat partitioning by ice-associated pinnipeds: distribution and density of seals and walruses in the Bering Sea, April 1976 Pages 25-47 in F. H. Fay and G. A. Fedoseev, editors. Soviet-American Cooperative Research on Marine Mammals. Volume 1 - Pinnipeds. NOAA Technical Report NMFS 12. U.S. Department of Commerce, NOAA, Washington, DC.
- 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 55-60 in F. H. Fay and G. A. Fedoseev, editors. Soviet-American Cooperative Research on Marine Mammals. Volume 1 - Pinnipeds. U.S. Department of Commerce, Washington, DC.
- Burns, J. J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi Seas. Journal of Mammalogy 51:445-454.
- 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*). Pages 99-160 in Environmental Assessment of the Alaskan Continental Shelf. Annual Reports of Principal Investigators for the year ending March 1978. Volume 1. Receptors--Mammals-Birds. U.S. Department of Commerce, NOAA and U.S. Department of the Interior, Bureau of Land Management, Boulder, CO.
- Burns, J. J., and K. J. Frost. 1979. The natural history and ecology of the bearded seal, *Erignathus barbatus*. Alaska Department of Fish and Game. 77 p.
- Burns, J. J., and S. J. Harbo. 1972. An aerial census of ringed seals, northern coast of Alaska. Arctic 25:179-290.
- Burns, J. J., and S. J. Harbo. 1977. An aerial census of spotted seal, *Phoca vitulina largha*, and walruses, *Odobenus rosmarus*, in the ice front of Bering Sea. Pages 58-132 in Environmental Assessment of the Alaskan Continental Shelf. Quarterly Reports of Principal Investigators April-June 1977. Volume 1. U.S. Department of Commerce, NOAA and the U.S. Department of Interior, Bureau of Land Management, Boulder, CO.
- Burns, J. J., and B. P. Kelly. 1982. Studies of ringed seals in the Alaskan Beaufort Sea during winter: impacts of seismic exploration. Alaska Department of Fish and Game, Annual Report. 57 p.
- Burns, J. J., L. H. Shapiro, and F. H. Fay. 1981. Ice as marine mammal habitat in the Bering Sea. Pages 781-797 in D. W. Hood and J. A. Calder, editors. The Eastern Bering Sea Shelf: Oceanography and Resources. Volume Two. U.S. Department of Commerce, NOAA, U.S. Department of Interior, Office of Marine Pollution Assessment, and Bureau of Land Management, Washington, D.C.
- Cox, S. L., and A. Spiess. 1980. Dorset settlement and subsistence in Northern Labrador. Arctic 33:659-669.
- DeMaster, D. P., and R. Davis, editors. 1996. A report on the workshop on the use of ice-associated seals in the Bering and Chukchi Seas as indicators of environmental change. Seattle, WA. 1-13 p.
- Elsner, R., D. Wartzok, N. B. Sonafrank, and B. P. Kelly. 1989. Behavioral and physiological reactions of Arctic seals during under-ice pilotage. Canadian Journal of Zoology 67:2506-2513.
- Fay, F. H. 1974. The role of ice in the ecology of marine mammals of the Bering Sea. Pages 383-399 in D. W. Hood and E. J. Kelley, editors. Oceanography of the Bering Sea. Institute of Marine Science, Hakodate, Japan.
- Fay, F. H., R. A. Dieterich, L. M. Shults, N. K. Murray, A. Hoover, and B. P. Kelly. 1979. Morbidity and mortality of marine mammals. Pages 1-34 in Environmental Assessment of the Alaskan Continental Shelf. Annual Reports of Principal Investigators for the Year Ending March 1979. Volume 1. Receptors--Mammals-Birds. U.S. Department of Commerce, NOAA and U.S. Department of the Interior, Bureau of Land Management, Boulder, CO.

- Ferguson, S. H., I. Stirling, and P. McLoughlin. 2005. Climate change and ringed seal (*Phoca hispida*) recruitment in western Hudson Bay. *Marine Mammal Science* 21:121-135.
- Freeman, M. M. R. 1984. Contemporary Inuit exploitation of the sea-ice environment. Pages 73-96 in A. Cooke and E. Van Alstine, editors. *Sikumiut: The People Who Use Sea Ice*. Canadian Arctic Resources Committee, Ottawa, Canada.
- Frost, K. J., L. Lowry, F., R. J. Gilbert, and J. Burns, J. 1988. Ringed seal monitoring: relationships of distribution and abundance to habitat attributes and industrial activities. Department of the Interior, Department of Commerce, Final Report, 1998. 101 p.
- 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. 1988. Effects of industrial activities on ringed seals in Alaska, as indicated by aerial surveys. Port and ocean engineering under arctic conditions. Vol. II. Symp. on noise and marine mammals.
- Frost, K. J., L. F. Lowry, C. Hessinger, G. Pendleton, D. DeMaster, and S. Hills. 1998. Monitoring distribution and abundance of ringed seals in northern Alaska, Interim report, April 1997 - March 1998. U.S. Department of the Interior, Minerals Management Service.
- Frost, K. J., L. F. Lowry, C. Hessinger, G. W. Pendleton, D. P. DeMaster, and S. Hills. 1999. Monitoring distribution and abundance of ringed seals in northern Alaska. State of Alaska, Department of Fish and Game, Juneau, Alaska. vii, 37, [36] p. p.
- Frost, K. J., L. F. Lowry, and S. Hills. 1997. Monitoring distribution and abundance of ringed seals in northern Alaska Alaska Department of Fish and Game Quarterly Report April-June 1997. 11 p.
- Frost, K. J., L. F. Lowry, G. Pendleton, and H. R. Nute. 2002. Monitoring distribution and abundance of ringed seals in northern Alaska. Alaska Department of Fish and Game, Final Report of OCS Study MMS 2002-043 66 p.
- Hall, C. F. 1866. Arctic researches and life among the Esquimaux: being the narrative of an expedition in search of Sir John Franklin, in the years 1860, 1861, and 1862. Harper and Brothers Publishing, New York, NY. 595 p.
- Huntington, H. P., editor. 2000. Traditional ecological knowledge of seals in Norton Bay, Alaska. Huntington Consulting, Eagle River, AK. 21 p.
- 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, editors. *Environment of the Cape Thompson Region, Alaska*. U.S. Atomic Energy Commission, Oak Ridge, TN.
- Kelly, B. P. 1988a. Bearded seal, *Erignathus barbatus*. Pages 77-94 in J. W. Lentifer, editor. *Selected Marine Mammal Species of Alaska: Species Accounts with Research and Management Recommendations*. Marine Mammal Commission, Washington, D.C.
- Kelly, B. P. 1988b. Ribbon seal, *Phoca fasciata*. Pages 95-106 in J. W. Lentifer, editor. *Selected Marine Mammal Species of Alaska: Species Accounts with Research and Management Recommendations*. Marine Mammal Commission, Washington, D.C.
- Kelly, B. P. 1988c. Ringed seal, *Phoca hispida*. Pages 57-75 in J. W. Lentifer, editor. *Selected Marine Mammal Species of Alaska: Species Accounts with Research and Management Recommendations*. Marine Mammal Commission, Washington, D.C.
- Kelly, B. P. 1996. Live capture of ringed seals in ice-covered waters. *Journal of Wildlife Management* 60:678-684.
- Kelly, B. P. 2001. Climate change and ice breeding pinnipeds. Pages 43-55 in G.-R. Walther, C. A. Burga, and P. J. Edwards, editors. "Fingerprints" of Climate Change -- Adapted Behavior and Shifting Species Ranges. Kluwer Academic / Plenum Publishers, New York, NY.
- Kelly, B. P., O. H. Badajos, M. Kunnsaranta, and J. Moran. 2006. Timing and re-interpretation of ringed seal surveys. Coastal Marine Institute University of Alaska Fairbanks, Final Report. 60 p.
- Kelly, B. P., J. J. Burns, and L. T. Quakenbush. 1988. Responses of ringed seals (*Phoca hispida*) to noise disturbance. Pages 27-38 in W. M. Sackinger, M. O. Jeffries, J. L. Imm, and S. D. Treacy, editors. *Port and Ocean Engineering Under Arctic Conditions, Volume II, Symposium on Noise and Marine Mammals*, Fairbanks, Alaska.
- Kelly, B. P., and L. T. Quakenbush. 1990. Spatiotemporal use of lairs by ringed seals (*Phoca hispida*). *Canadian Journal of Zoology* 68:2503-2512.
- Kelly, B. P., L. T. Quakenbush, and J. R. Rose. 1986. Ringed seal winter ecology and effects of noise disturbance. Pages 447-536 in *Outer Continental Shelf Environmental Assessment Program. Final Reports of Principal Investigators, Volume 61*. Minerals Management Service, Alaska Outer Continental Shelf Office, Anchorage, AK.
- Kelly, B. P., and D. Wartzok. 1996. Ringed seal diving behavior in the breeding season. *Canadian Journal of Zoology* 74:1547-1555.
- Krupnik, I. I. 1978. A quantitative appraisal of the traditional economy of the Asiatic Eskimos. Pages 26-39 in *Problems of Ethnography and Ethnic Anthropology*, Moscow, Russia. (Translated from Russian by B. A. and F. H. Fay, 1985, 11 p.)

- Lowry, L. F., K. J. Frost, and J. J. Burns. 1978. Food of ringed seals and bowhead whales near Point Barrow, Alaska. *Canadian Field-Naturalist* 92:67-70.
- Lowry, L. F., K. J. Frost, and J. J. Burns. 1980a. Trophic relationships among ice-inhabiting phocid seals and functionally related marine mammals in the Chukchi Sea. Alaska Department of Fish and Game, Final Report of Chukchi Sea Activities. 58 p.
- Lowry, L. F., K. J. Frost, and J. J. Burns. 1980b. Variability in the diet of ringed seals, *Phoca hispida*, in Alaska. *Canadian Journal of Fisheries and Aquatic Sciences* 37:2254-2261.
- Mineev, V. N. 1975. Regulation of pinniped hunting in Soviet waters. Biology of the Seal. Proceedings of a Symposium held in Guelph 14-17 August 1972. Rappports et Proces-verbaux des Réunions. Conseil International pour l'Exploration de la Mer. 169:550-551.
- Mineev, V. N. 1984. Protection and regulation of the harvest of marine mammals in the Bering and Chukchi seas. Pages 76-78 in L. A. Popov, editor. Scientific Investigations of the Marine Mammals of the North Pacific Ocean in 1982/83. VNIRO, Moscow, Russia. (Translated from Russian by S. Pearson, 6 p.)
- Murdoch, J. 1885. Part IV -- Natural History, I. -- Mammals. Pages 92-103 in P. H. Ray, editor. Report of the International Polar Expedition to Point Barrow, Alaska. The Resolution of the House of Representatives of December 11, 1884. 48th Congress, 2nd Session, House Executive Document 44. Government Printing Office, Washington, D.C.
- Nelson, E. W., and F. W. True. 1887. Mammals of the northern Alaska. Pages 227-293 in H. W. Henshaw, editor. Report upon natural history collections made in Alaska between the years 1877 and 1881. Washington: Government printing office, Washington, D.C.
- Nelson, R. K. 1969. Hunters of the northern ice. University of Chicago Press, Chicago, Illinois. 429 p.
- Quakenbush, L. T. 1988. Spotted seal: *Phoca largha*. Pages 107-124 in J. W. Lentfer, editor. Selected Marine Mammals of Alaska: Species Accounts with Research and Management Recommendations. Marine Mammal Commission, Washington, DC.
- Rozanov, M. P. 1931. Harvest of marine mammals on the Chukchii Peninsula. *Soviet North* 6:44-59. (Translated from Russian by B. A. and F. H. Fay, 1984)
- Shustov, A. P. 1965. The effect of sealing on the state of the population of Bering Sea ribbon seals. *Izvestiya TINRO* 59:173-178. (Translated from Russian, 11 p.)
- Shustov, A. P. 1972. On the condition of the stocks and the distribution of true seals and walruses in the North Pacific (Abstract). Pages 146-147 in V. A. Arsen'ev, editor. Fifth All-Union Conference on Studies of Marine Mammals, Makhachkala, USSR. Akad. Nauk. SSSR. (Translated from Russian by F.H. Fay, University of Alaska, Fairbanks, AK, 2 p.)
- Simpkins, M. A., B. P. Kelly, and D. Wartzok. 2001a. Three-dimensional analysis of search behaviour by ringed seals. *Animal Behaviour* 62:67-72.
- Simpkins, M. A., B. P. Kelly, and D. Wartzok. 2001b. Three-dimensional diving behaviors of ringed seals (*Phoca hispida*). *Marine Mammal Science* 17:909-925.
- Simpkins, M. A., B. P. Kelly, and D. Wartzok. 2001c. Three-dimensional movements within individual dives by ringed seals (*Phoca hispida*). *Canadian Journal of Zoology* 79:1455-1464.
- Smith, T. G., and L. A. Harwood. 2001. Observations of neonate ringed seals, *Phoca hispida*, after early break-up of the sea ice in Prince Albert Sound, Northwest Territories, Canada, spring 1998. *Polar Biology* 24:215-219.
- Stirling, I., and T. G. Smith. 2004. Implications of warm temperatures, and an unusual rain event for the survival of ringed seals on the coast of southeastern Baffin Island. *Arctic* 57:59-67.
- Twiss, J. R., R. J. Hofman, and J. W. Lentfer. 1988. Introduction. Pages pp. 1-16 in J. W. Lentfer, editor. Selected marine mammals of Alaska. Species account with research and management recommendations. Mar. Mammal Commn, Washington, D. C., USA.
- Tynan, C. T., and D. P. DeMaster. 1997. Observations and predictions of Arctic climatic change: potential effects on marine mammals. *Arctic* 50:308-322.
- Wartzok, D., R. Elsner, H. Stone, B. P. Kelly, and R. W. Davis. 1992. Under-ice movements and the sensory basis of hole finding by ringed and Weddell seals. *Canadian Journal of Zoology* 70:1712-1722.
- Wenzel, G. 1984. Archaeological evidence for prehistoric Inuit use of the sea-ice environment. Pages 41-60 in A. Cooke and E. Van Alstine, editors. Sikumuit: The People Who Use the Sea Ice. Canadian Arctic Resources Committee, Ottawa, Canada.
- West, G. C., J. J. Burns, and M. Modafferi. 1979. Fatty acid composition of blubber from the four species of Bering Sea phocid seals. *Canadian Journal of Zoology* 57:189-195.
- Whiting, A., and K. J. Frost. 2007. Kotzebue Sound bearded seal tagging project. Kotzebue IRA, Kotzebue, AK. Accessed June 2011 at http://www.kotzebueira.org/current_projects.html.

