The Northern Fur Seal

Bibliography

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Background & Scope

The goal of this bibliography is to update 2006's *The Northern Fur Seal (*Callorhinus ursinus*): A Bibliography*, published as AFSC Processed Report 2006-05. This bibliography is intended to provide a review of the scientific literature from 2006 to the present. The starting point for compiling this review was an EndNote library provided by Sonja Kromann of the National Marine Mammal Laboratory. The listed sources are organized alphabetically by the lead author's last name.

"Northern fur seals are members of the 'eared seal' family (Otariidae). Northern fur seals, like all marine mammals, are protected under the Marine Mammal Protection Act. The Pribilof Islands/eastern Pacific stock is listed as depleted under the MMPA. In 1988, the Pribilof Islands population was designated as a depleted stock under the MMPA because it had declined by more than 50 percent from its estimated population of 2.1 million seals in the 1950s. Trends in abundance since the designation of the eastern Pacific stock are different for individual islands and even breeding areas." - NMFS

Sources Reviewed

The following databases were used to identify sources: Science Direct, Clarivate Analytics' Web of Science: Science Citation Index Expanded and Social Science Index; EBSCO Academic Search Complete and Environment Complete; ProQuest Aquatic Sciences and Fisheries Abstracts; NOAA Institutional Repository; BioDiversity Heritage Library; BioOne Complete; and JSTOR.

References

Aalderink, M. T., Nguyen, H. P., Kass, P. H., Arzi, B., & Verstraete, F. J. M. (2015). Dental and Temporomandibular Joint Pathology of the Northern Fur Seal (*Callorhinus ursinus*). *Journal of Comparative Pathology, 152*(4), 325-334. https://doi.org/10.1016/j.jcpa.2015.02.002

Skulls from 145 northern fur seals (*Callorhinus ursinus*) were examined macroscopically according to predefined criteria. The museum specimens were acquired from strandings along the west coast of the USA between 1896 and 2008. Seventy-one skulls (49.0%) were from male animals, 56 (38.6%) from female animals and 18 (12.4%) from animals of unknown sex. Their age varied from juvenile to adult, with 58 adult animals (40.0%) and 87 juvenile animals (60.0%). The majority of teeth were available for examination (95.1%); 3.4% of teeth were artefactually absent, 0.8% were deemed absent due to acquired tooth loss and 0.6% were deemed congenitally absent. Males were no more likely than females to have either acquired tooth loss ($P = 0.054$) or congenitally absent teeth ($P = 0.919$). Adults had significantly more acquired tooth loss than juveniles ($P = 0.0099$). Malformations were seen in 11 teeth (0.2% of all 4,699 teeth available for examination). Two roots, instead of the typical one root, were found on 14 teeth (0.3%). Supernumerary teeth were associated with 14 normal teeth (0.3%) in eight specimens (5.5% of the total number of specimens). A total of 22 persistent deciduous teeth were found, 19 of which were associated with the maxillary canine teeth. Attrition/abrasion was seen on 194 teeth (3.9%); the canine teeth were most often affected, accounting for 39.7% of all abraded teeth. Adults were found to have a greater prevalence of abraded teeth than juveniles ($P < 0.0001$). No significant difference was found in the appearance of attrition/abrasion between males and females ($P = 0.072$). Tooth fractures were found in 24 specimens (16.6%), affecting a total of 54 teeth (1.1%). Periapical lesions were found in two skulls (1.4%). None of the specimens showed signs of enamel hypoplasia. About a fifth (18.6%) of alveoli, either with or without teeth, showed signs of alveolar bony changes consistent with periodontitis. A total of 108 specimens (74.5%) had at least one tooth associated with mild periodontitis. Lesions consistent with temporomandibular joint osteoarthritis (TMJ-OA) were found in 29 specimens (20.0%). Both periodontal disease and TMJ-OA were significantly more common in adults than in juveniles ($P < 0.0001$). Periodontitis was found to be more common in males than in females ($P < 0.012$). Although the significance of the high incidence of periodontitis and TMJ-OA in the northern fur seal remains unknown, the occurrence and severity of these diseases found in this study may play an important role in this species morbidity and mortality.

Adamantopoulou, S., Androukaki, E., Dendrinos, P., Kotomatas, S., Paravas, V., Psaradellis, M., . . . Karamanlidis, A. A. (2011). Movements of Mediterranean Monk Seals (*Monachus monachus*) in the Eastern Mediterranean Sea. *Aquatic Mammals, 37*(3), 256-261. https://doi.org/10.1578/AM.37.3.2011.256

Pinnipeds (the carnivorans in the families Otariidae, Odobenidae, and Phocidae) are mammals that spend their lives in both terrestrial and aquatic envi-ronments; thoroughly studying activity patterns in both environments is essential to fully understand their biology and consequently to define effective management and conservation actions (Harwood & Croxall, 1988; Thompson, 1989; Thompson et al., 2001). Studying individual activity patterns of seals at sea (i.e., estimating movements, calculating dive depth, identifying feeding locations, etc.) has relied mainly on telemetry and tagging; both methodolo-gies have been applied successfully for a wide range of geographical locations and species (e.g., Grey seals [*Halichoerus grypus*], McConnell et al., 1999; Hooded seals [*Cystophora cristata*], Hammill, 1993;

Northern fur seals [*Callorhinus ursinus*], Ream et al., 2005; South African fur seals [*Arctocephalus pusillus pusillus*], Oosthuizen, en, 1991; Southern elephant seals *[Mirounga leonina*], McConnell et al., 2002; Bester, 2006) and also included endangered species such as the Hawaiian monk seal (*Monachus schauinslandi*; Henderson & Johanos, 1988; Parrish et al., 2002).

Adams, G. P., Ward Testa, J., Goertz, C. E. C., Ream, R. R., & Sterling, J. T. (2007). Ultrasonographic Characterization of Reproductive Anatomy and Early Embryonic Detection in the Northern Fur Seal (*Callorhinus ursinus*) in the Field. *Marine Mammal Science, 23*(2), 445-452. https://doi.org/10.1111/j.1748-7692.2007.00104.x

The article presents a study on the characterization of reproductive anatomy and early embryonic detection in the northern fur seal or *Callorhinus ursinus* using ultrasonography in Saint Paul Island, Alaska. The study's aim is to determine the feasibility of transrectal ultrasonography for assessing the reproductive status of female northern fur seals in the wild and to provide preliminary description of the reproductive tract and early embryo in situ. Subjects used were female northern fur seals of adult size, where ultrasonography was performed by an experienced operator with the use of a portable ultrasound unit. An overview of the results of the study is offered.

Allen, B. M., & Angliss, R. P. (2012). *Alaska Marine Mammal Stock Assessments, 2011*. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from http://www.nmfs.noaa.gov/pr/pdfs/sars/ak2011.pdf

On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new sections. This new regime replaced the interim exemption that has regulated fisheries-related incidental takes since 1988. Section 117, Stock Assessments, required the establishment of three regional scientific review groups to advise and report on the status of marine mammal stocks within Alaska waters, along the Pacific Coast (including Hawaii), and the Atlantic Coast (including the Gulf of Mexico). This report provides information on the marine mammal stocks of Alaska under the jurisdiction of the National Marine Fisheries Service. Each stock assessment includes, when available, a description of the stock's geographic range, a minimum population estimate, current population trends, current and maximum net productivity rates, optimum sustainable population levels and allowable removal levels, and estimates of annual human-caused mortality and serious injury through interactions with commercial fisheries and subsistence hunters. These data will be used to evaluate the progress of each fishery towards achieving the MMPA's goal of zero fishery-related mortality and serious injury of marine mammals.

Allen, B. M., & Angliss, R. P. (2013). *Alaska Marine Mammal Stock Assessments, 2012*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-245. Retrieved from https://repository.library.noaa.gov/view/noaa/4379

On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). I nteractions between marine mammals and commercial fisheries are addressed under three new sections. This new regime replaced the interim exemption that has regulated fisheriesrelated incidental takes since 1988. Section 117, Stock Assessments, required the

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Allen, B. M., & Angliss, R. P. (2014). *Alaska Marine Mammal Stock Assessments, 2013*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-277. Retrieved from https://repository.library.noaa.gov/view/noaa/4778

On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new sections. This new regime replaced the interim exemption that has regulated fisheriesrelated incidental takes since 1988. Section 117, Stock Assessments, required the establishment of three regional scientific review groups to advise and report on the status of marine mammal stocks within Alaska waters, along the Pacific Coast (including Hawaii), and the Atlantic Coast (including the Gulf of Mexico). This report provides information on the marine mammal stocks of Alaska under the jurisdiction of the National Marine Fisheries Service

Allen, B. M., & Angliss, R. P. (2015). *Alaska Marine Mammal Stock Assessments, 2014*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-301. http://doi.org/10.7289/V5NS0RTS

On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new sections. This new regime replaced the interim exemption that has regulated fisheries-related incidental takes since 1988. Section 117, Stock Assessments, required the establishment of three regional scientific review groups to advise and report on the status of marine mammal stocks within Alaska waters, along the Pacific Coast (including Hawaii), and the Atlantic Coast (including the Gulf of Mexico). This report provides information on the marine mammal stocks of Alaska under the jurisdiction of the National Marine Fisheries Service. Each stock assessment includes, when available, a description of the stock's geographic range, a minimum population estimate, current population trends, current and maximum net productivity rates, optimum sustainable population levels and allowable removal levels, and estimates of annual human-caused mortality and serious injury through interactions with commercial fisheries and subsistence hunters. These data will be used to evaluate the progress of each fishery towards achieving the MMPA's goal of zero fishery-related mortality and serious injury of marine mammals.

Allen, B. M., Angliss, R. P., & Wade, P. R. (2011). *Alaska Marine Mammal Stock Assessments, 2010*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-223. Retrieved from https://repository.library.noaa.gov/view/noaa/3836

On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new sections. This new regime replaced the interim exemption that has regulated fisheriesrelated incidental takes since 1988. Section 117, Stock Assessments, required the establishment of three regional scientific review groups to advise and report on the status of marine mammal stocks within Alaska waters, along the Pacific Coast (including Hawaii), and the Atlantic Coast (including the Gulf of Mexico). This report provides information on the marine mammal stocks of Alaska under the jurisdiction of the National Marine Fisheries Service. Each stock assessment includes, when available, a description of the stock's geographic range, a minimum population estimate, current population trends, current and maximum net productivity rates, optimum sustainable population levels and allowable removal levels, and estimates of annual human-caused mortality and serious injury through interactions with commercial fisheries and subsistence hunters. These data will be used to evaluate the progress of each fishery towards achieving the MMPA's goal of zero fishery-related mortality and serious injury of marine mammals.

Allen, B. M., Angliss, R. P., Wade, P. R., Perez, M. A., Fritz, L. W., Rugh, D. J., . . . Zerbini, A. N. (2010). *Alaska Marine Mammal Stock Assessments, 2009*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-206. http://doi.org/10.7289/V5/TM-AFSC-206

On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new sections. This new regime replaced the interim exemption that has regulated fisheriesrelated incidental takes since 1988. Section 117, Stock Assessments, required the establishment of three regional scientific review groups to advise and report on the status of marine mammal stocks within Alaska waters, along the Pacific Coast (including Hawaii), and the Atlantic Coast (including the Gulf of Mexico). This report provides information on the marine mammal stocks of Alaska under the jurisdiction of the National Marine Fisheries Service.

Angliss, R. P., Allen, B. M., Wade, P. R., Perez, M. A., Clapham, P., Fritz, L. W., . . . Zerbini, A. N. (2009). *Alaska Marine Mammal Stock Assessments, 2008*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-193. http://doi.org/10.7289/V5/TM-AFSC-193

On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new sections. This new regime replaced the interim exemption that has regulated fisheriesrelated incidental takes since 1988. Section 117, Stock Assessments, required the establishment of three regional scientific review groups to advise and report on the status of marine mammal stocks within Alaska waters, along the Pacific Coast (including Hawaii), and the Atlantic Coast (including the Gulf of Mexico). This report provides information on the marine mammal stocks of Alaska under the jurisdiction of the National Marine Fisheries Service.

Angliss, R. P., Outlaw, R. B., Wade, P. R., Perez, M. A., Clapham, P., Fritz, L. W., . . . Zerbini, A. N. (2007). *Alaska Marine Mammal Stock Assessments, 2006*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-168. http://doi.org/10.7289/V5/TM-AFSC-168

On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new sections. This new regime replaced the interim exemption that has regulated fisheriesrelated incidental takes since 1988. Section 117, Stock Assessments, required the establishment of three regional scientific review groups to advise and report on the status of marine mammal stocks within Alaska waters, along the Pacific Coast (including Hawaii), and the Atlantic Coast (including the Gulf of Mexico). This report provides information on the marine mammal stocks of Alaska under the jurisdiction of the National Marine Fisheries Service.

Angliss, R. P., Outlaw, R. B., Wade, P. R., Perez, M. A., Clapham, P., Fritz, L. W., . . . Zerbini, A. N. (2008). *Alaska Marine Mammal Stock Assessments, 2007*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-180. http://doi.org/10.7289/V5/TM-AFSC-180

On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new sections. This new regime replaced the interim exemption that has regulated fisheriesrelated incidental takes since 1988. Section 117, Stock Assessments, required the establishment of three regional scientific review groups to advise and report on the status of marine mammal stocks within Alaska waters, along the Pacific Coast (including Hawaii), and the Atlantic Coast (including the Gulf of Mexico). This report provides information on the marine mammal stocks of Alaska under the jurisdiction of the National Marine Fisheries Service.

Arnason, U., Gullberg, A., Janke, A., Kullberg, M., Lehman, N., Petrov, E. A., & Vainola, R. (2006). Pinniped Phylogeny and a New Hypothesis for Their Origin and Dispersal. *Molecular Phylogenetics and Evolution, 41*(2), 345-354. https://doi.org/10.1016/j.ympev.2006.05.022

The relationships and the zoogeography of the three extant pinniped families, Otariidae (sea lions and fur seals), Odobenidae (one extant species, the walrus), and Phocidae (true seals), have been contentious. Here, we address these topics in a molecular study that includes all extant species of true seals and sea lions, four fur seals and the walrus. Contrary to prevailing morphological views the analyses conclusively showed monophyletic Pinnipedia with a basal split between Otarioidea (Otariidae + Odobenidae) and Phocidae. The northern fur seal was the sister to all remaining otariids and neither sea lions nor arctocephaline fur seals were recognized as monophyletic entities. The basal Phocidae split between Monachinae (monk seals and southern true seals) and Phocinae (northern true seals) was strongly supported. The phylogeny of the Phocinae suggests that the ancestors of Cystophora (hooded seal) and the Phocini (e.g. harp seal, ringed seal) adapted to Arctic conditions and ice-breeding before 12 MYA (million years ago) as supported by the white natal coat of these lineages. The origin of the endemic Caspian and Baikal seals was dated well before the onset of major Pleistocene glaciations. The current findings, together with recent advances in pinniped paleontology, allow the proposal of a new hypothesis for pinniped origin and early dispersal. The hypothesis posits that pinnipeds originated on the North American continent with early otarioid and otariid divergences taking place in the northeast

Pacific and those of the phocids in coastal areas of southeast N America for later dispersal to colder environments in the N Atlantic and the Arctic Basin, and in Antarctic waters.

Augusteyn, R. C. (2014). Growth of the Eye Lens: I. Weight Accumulation in Multiple Species. *Molecular Vision, 20*, 410-426. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3976689/pdf/mv-v20-410.pdf

Purpose: To examine the accumulation of wet and/or dry weight in the ocular lens as a function of age in different species. Methods: Wet weights and/or fixed dry weights were obtained from measurements in the author's laboratory and from the literature for over 14,000 lenses of known-ages, representing 130 different species. Various algorithms were tested to determine the most suitable for describing the relationship between lens weight and age. Results: For 126 of the species examined, lens growth is continuous throughout life but asymptotic and can be reasonably described with a single logistic equation, W=W-m e(-(k/A)), where W is lens wet or dry weight; Wm is the maximum asymptotic weight, k is the logistic growth constant and A is the time from conception. For humans, elephants, hippopotami, minks, wild goats and woodchucks, lens growth appears to be biphasic. No gender differences could be detected in the lens weights for 70 species but male lenses are reportedly 10% larger than those of females in northern fur seals and pheasants. Dry weight accumulation is faster than that for wet weight in all species except birds and reptiles where the rates are the same. Low lens growth rates are associated with small animals with short gestation periods and short life spans. Conclusions: Lens growth is continuous throughout life and, for most species, is independent of gender. For most, growth takes place through a monophasic asymptotic mode and is unaffected by events such as hibernation. This makes lens weight measurement a reliable tool for age determination of species culled in the wild. Compaction of the growing lens generates different properties, appropriate to an animal's lifestyle. How these events are controlled remains to be established.

Baker, J. D. (2007). Post-Weaning Migration of Northern Fur Seal *Callorhinus ursinus* Pups from the Pribilof Islands, Alaska. *Marine Ecology Progress Series, 341*, 243-255. https://doi.org/10.3354/meps341243

The post-weaning migration of northern fur seal *Callorhinus ursinus* pups from the Pribilof Islands in the eastern Bering Sea was investigated using satellite-linked dive recorders deployed in November 1996 and 1997, with tracking duration ranging up to more than 6 mo. Prior to abruptly departing on the migration by early December, pups did not stray far from their natal islands. After a median travel time of 17 d, most pups transited various Aleutian Island passes, though 3 animals remained in the Bering Sea until at least late January. Pups that left the Bering Sea subsequently dispersed into a vast area of the North Pacific some 2500 km wide from the central Aleutians to the Gulf of Alaska and 1000 km from 60 to 45 degrees N. Most pups remained in offshore pelagic areas; however, 3 individuals also spent time over continental shelf waters. While the spatial dispersion and habitats used by migrating pups varied considerably, their diving behavior was remarkably consistent. All migrating pups dove largely during the night, and during evening and morning hours, but practically ceased diving during the day, suggesting they foraged on vertically migrating prey that is unattainable or too costly to reach during daytime. Dives were typically shallow and brief; 77 reached depths less than 10 m, and 81 % lasted less than 1 min. Wide dispersal presents a potential selective mechanism for differential survival, in that benefits (food availability) and risks (storms, predation, and, potentially, fishery interactions) likely vary considerably across the oceanic habitats occupied by these naive foragers on their first migration.

Balsiger, J. W. (2014). *Final Supplemental Environmental Impact Statement Management of the Subsistence Harvest of Northern Fur Seals on St. George Island, Alaska August 2014*. National Marine Fisheries Service Alaska Region. Retrieved from https://repository.library.noaa.gov/view/noaa/19161

The National Marine Fisheries Service (NMFS) proposes to improve the management of the subsistence harvest for the Eastern Pacific stock of northern fur seals (*Callorhinus ursinus*). NMFS, in conjunction with the Pribilof Island Aleut Community of St. George Island, Traditional Council, is proposing new management measures that (1) provide harvest flexibility, (2) use both Alaska Native and scientific experience to develop best harvest practices, and (3) create firm regulatory measures to conserve the fur seal population and maintain sustainable subsistence harvest on St. George Island consistent with the community's subsistence needs. NMFS and the Traditional Council would continue to co-manage the harvest consistent with new regulatory controls to reduce the accidental killing of females, reduce localized harvest pressures, and prohibit harvest at small breeding areas. The new subsistence management regime would maintain the existing range of permissible subsistence harvest, allow a portion of the harvest to be comprised of young of the year male fur seals consistent with traditional practices, reduce impacts to females, reduce harassment to non-target seals, and schedule harvesting to promote scientific coordination and monitoring.

Barta, J. L., Monroe, C., Crockford, S. J., & Kemp, B. M. (2014). Mitochondrial DNA Preservation across 3000-Year-Old Northern Fur Seal Ribs Is Not Related to Bone Density: Implications for Forensic Investigations. *Forensic Science International, 239*, 11-18. https://doi.org/10.1016/j.forsciint.2014.02.029

While recent forensic research has focused on determining which skeletal elements are superior in their preservation of DNA over the long term, little focus has been placed on measuring intra-element variation. Moreover, there is a general belief that dense (cortical) bone material will contain betterpreserved DNA than does spongy (cancellous) bone. To address these ideas, quantitative PCR was used to estimate the degree of mitochondrial DNA (mtDNA) preservation variance across sections of 19 northern fur seal ribs (*Callorhinus ursinus*) that date to similar to 3000 years before present. Further, we developed a measure called the "density index" that was used to gauge the relative densities of the rib sections studied here to determine if density was an appropriate predictor of preservation. The average preservation among the samples was significantly different (ANOVA, p = 1.9 X 10 (9)) with only 15% of the total variance observed within samples. However, 12 of the 19 specimens (similar to 63.2%) exhibited at least an order of magnitude difference in mtDNA preservation across the whole. Regression of the amount of mtDNA extracted per gram of bone material against the density index of the bone from which it was extracted demonstrates no relationship between these variables (R-2 = 0.03, p = 0.28).

Barta, J. L., Monroe, C., & Kemp, B. M. (2013). Further Evaluation of the Efficacy of Contamination Removal from Bone Surfaces. *Forensic Science International, 231*(1-3), 340-348. https://doi.org/10.1016/j.forsciint.2013.06.004

Studies of low copy number (LCN) and degraded DNA are prone to contamination from exogenous DNA sources that in some cases out-compete endogenous DNA in PCR amplification, thus leading to false positives and/or aberrant results. Particularly problematic is contamination that is inadvertently deposited on the surfaces of bones through direct handling. Whereas some previous studies have shown that contamination removal is possible by subjecting samples to sodium hypochlorite prior to DNA extraction, others caution that such treatment can destroy a majority of the molecules endogenous to the sample. To further explore this topic, we experimentally contaminated ancient northern fur seal (*Callorhinus ursinus*) ribs with human DNA and treated them with sodium hypochlorite to remove that contamination. Our findings are consistent with previous studies that found sodium hypochlorite to be highly efficient (similar to 81-99%) at contamination removal; however, there emerged no treatment capable of removing 100% of the contamination across all of the experiments. Moreover, the ability to estimate the degree of damage to endogenous northern fur seal molecules was compromised due to the inherent variability of preserved mtDNA across the bones, and the presence of co-extracted PCR inhibitors.

Battaile, B. C., Nordstrom, C. A., Liebsch, N., & Trites, A. W. (2015). Foraging a New Trail with Northern Fur Seals (*Callorhinus ursinus*): Lactating Seals from Islands with Contrasting Population Dynamics Have Different Foraging Strategies, and Forage at Scales Previously Unrecognized by Gps Interpolated Dive Data. *Marine Mammal Science, 31*(4), 1494-1520. https://doi.org/10.1111/mms.12240

We reconstructed the foraging tracks of lactating northern fur seals (*Callorhinus ursinus*) from two eastern Bering Sea islands (St. Paul Island and Bogoslof Island) using linear interpolation between GPS locations recorded at a maximum of four times per hour and compared it to tri-axial accelerometer and magnetometer data collected at 16 Hz to reconstruct pseudotracks between the GPS fixes. The high-resolution data revealed distances swum per foraging trip were much greater than the distances calculated using linearly interpolated GPS tracks (1.5 times further for St. Paul fur seals and 1.9 times further for Bogoslof fur seals). First passage time metrics calculated from the high resolution data revealed that the optimal scale at which the seals searched for prey was 500 m (radius of circle searched) for fur seals from St. Paul Island that went off-shelf, and 50 m for fur seals from Bogoslof Island and surprisingly, 50 m for fur seals from St. Paul that foraged on-shelf. These area-restricted search scales were significantly smaller than those calculated from GPS data alone (12 km for St. Paul and 6 km for Bogoslof) indicating that higher resolution movement data can reveal novel information about foraging behaviors that have important ecological implications.

Battaile, B. C., Sakamoto, K. Q., Nordstrom, C. A., Rosen, D. A. S., & Trites, A. W. (2015). Accelerometers Identify New Behaviors and Show Little Difference in the Activity Budgets of Lactating Northern Fur Seals (*Callorhinus ursinus*) between Breeding Islands and Foraging Habitats in the Eastern Bering Sea. *PLoS One, 10*(3) https://doi.org/10.1371/journal.pone.0118761

We tagged 82 lactating northern fur seals (*Callorhinus ursinus*) with tri-axial accelerometers and magnetometers on two eastern Bering Sea islands (Bogoslof and St. Paul) with contrasting population trajectories. Using depth data, accelerometer data and spectral analysis we classified time spent diving (30%), resting (similar to 7%), shaking and grooming their pelage (9%), swimming in the prone position (similar to 10%) and two types of previously undocumented rolling behavior (29%), with the remaining time (similar to 15%) unspecified. The reason for the extensive rolling behavior is not known. We

ground-truthed the accelerometry signals for shaking and grooming and rolling behaviors and identified the acceleration signal for porpoising by filming tagged northern fur seals in captivity. Speeds from GPS interpolated data indicated that animals traveled fastest while in the prone position, suggesting that this behavior is indicative of destination-based swimming. Very little difference was found in the percentages of time spent in the categorical behaviors with respect to breeding islands (Bogoslof or St. Paul Island), forager type (cathemeral or nocturnal), and the region where the animals foraged (primarily on-shelf <200m, or off-shelf > 200m). The lack of significant differences between islands, regions and forager type may indicate that behaviors summarized over a trip are somewhat hardwired even though foraging trip length and when and where animals dive are known to vary with island, forager type and region.

Battaile, B. C., & Trites, A. W. (2013). Linking Reproduction and Survival Can Improve Model Estimates of Vital Rates Derived from Limited Time-Series Counts of Pinnipeds and Other Species. *PLoS One, 8*(11) https://doi.org/10.1371/journal.pone.0077389

We propose a method to model the physiological link between somatic survival and reproductive output that reduces the number of parameters that need to be estimated by models designed to determine combinations of birth and death rates that produce historic counts of animal populations. We applied our Reproduction and Somatic Survival Linked (RSSL) method to the population counts of three species of North Pacific pinnipeds (harbor seals, Phoca vitulina richardii (Gray, 1864); northern fur seals,*Callorhinus ursinus* (L., 1758); and Steller sea lions, Eumetopias jubatus (Schreber, 1776))-and found our model outperformed traditional models when fitting vital rates to common types of limited datasets, such as those from counts of pups and adults. However, our model did not perform as well when these basic counts of animals were augmented with additional observations of ratios of juveniles to total non-pups. In this case, the failure of the ratios to improve model performance may indicate that the relationship between survival and reproduction is redefined or disassociated as populations change over time or that the ratio of juveniles to total non-pups is not a meaningful index of vital rates. Overall, our RSSL models show advantages to linking survival and reproduction within models to estimate the vital rates of pinnipeds and other species that have limited time-series of counts.

Belonovich, O. A. (2011). *Northern Fur Seals* (Callorhinus ursinus) *of the Commander Islands: Summer Feeding Trips, Winter Migrations and Interactions with Killer Whales* (Orcinus orca). Texas A&M University, Retrieved from http://oaktrust.library.tamu.edu/handle/1969.1/ETD-TAMU-2011-08-9320

The northern fur seal (NFS) population on the Pribilof Islands (PI) is currently declining while the population on the Commander Islands (CI which includes Bering and Medny Islands) is stable. The reasons for the different population trajectories remain unknown. Comparing differences in behavioral ecology and predation pressure between these two populations could provide an explanation. This study examined lactating NFS female behavior to determine: 1) summer foraging patterns (trip duration, trip direction, dive depth) of animals from two nearby rookeries on Bering Island, 2) winter migration from Medny and Bering Islands relative to patterns of ocean productivity, and 3) the potential impact of killer whale predation on population dynamics. Data were collected from 2003 to 2010 using visual observations and telemetry. Twenty-one satellite transmitters, 29 time-depth recorders and 17 geolocation recorders were deployed. Shore-based observations of killer whale predation and photo-identification were conducted near the CI rookeries in 1999-2010. During lactation, both mean foraging

trip duration and mean maximum diving depth (3.4 plus or minus 1.3 days and 17.7 plus or minus 6.8 m, respectively) for NFS adult females (n = 28) did not significantly change among years. Although foraging areas of NFS from the two rookeries on Bering Island overlapped, the mean direction of travel from Severo-Zapadnoe rookery was significantly ($p<0.01$) different compared with Severnoe rookery. The foraging patterns suggested that these females had a reliable food source that did not change despite potential environmental changes or the effects of fisheries. During their winter migration, NFS females from the CI traveled to the Transition Zone Chlorophyll Front (32 degree N-42 degree N) in the North Pacific Ocean. Their winter migration routes and the location of overwinter foraging areas were positively correlated with high ocean productivity (near surface chlorophyll a concentration). Over 82% (n=17) of these females spent 3-8 months near the eastern coast of Hokkaido, Japan and followed the coastal high productivity areas on their way back to the CI. Transient killer whales in groups of 2-12 individuals were repeatedly observed preying mostly on NFS males during the summer. The simulation model showed little impact on population dynamics as long as male fur seals were the primary prey. However, if the number of killer whales increased or they changed their diet to include females and pups, then the NFS population on the CI could decline. The winter migration of NFS from CI and PI are similar. Lactating NFS from the PI exhibit greater summer foraging effort (longer average trip duration and bout duration; greater number of deep dives) compared with females from the CI.

Belonovich, O. A., Fomin, S. V., Burkanov, V. N., Andrews, R. D., & Davis, R. W. (2016). Foraging Behavior of Lactating Northern Fur Seals (*Callorhinus ursinus*) in the Commander Islands, Russia. *Polar Biology, 39*(2), 357-363. https://doi.org/10.1007/s00300-015-1786-9

We characterized the foraging behavior and habitat associations of lactating female northern fur seals (*Callorhinus ursinus*) from two of four rookeries comprising the stable population on the Commander Islands (CI). The CI females included in the study were from Severo-Zapadnoe rookery (SZR in 2008 and 2009) and Servernoe rookery (SR in 2009) which are 16 km apart on the northern tip of Bering Island (BI). We used satellite-linked tags and time-depth recorders to track the animals at sea and record dive behavior. For SZR females, the average foraging trip duration, mean dive depth, and maximum travel distance for both years were 3.4 +/- A 1.42 days, 16 +/- A 9.8 m, and 85 +/- A 59.6 km, respectively. The same measures for SR females were 4.4 +/- A 1.90 days, 20 +/- A 9.7 m, and 159 +/- A 70.8 km, respectively. The mean duration of foraging trips, mean number of bouts per trip and trip duration, mean direction of foraging trips, and size of foraging areas were significantly different between females from SR and SZR. Foraging trips of females from neither rookery were associated with high chl-a concentration. Overall, females on the CI appeared to expend less time and energy during foraging trips than females on the Pribilof Islands, and this may explain why the latter population is declining while the CI population is stable.

Benoit-Bird, K. J., Battaile, B. C., Heppell, S. A., Hoover, B., Irons, D., Jones, N., . . . Trites, A. W. (2013). Prey Patch Patterns Predict Habitat Use by Top Marine Predators with Diverse Foraging Strategies. *PLoS One, 8*(1) https://doi.org/10.1371/journal.pone.0053348

Spatial coherence between predators and prey has rarely been observed in pelagic marine ecosystems. We used measures of the environment, prey abundance, prey quality, and prey distribution to explain the observed distributions of three co-occurring predator species breeding on islands in the southeastern Bering Sea: black-legged kittiwakes (Rissa tridactyla), thick-billed murres (Uria lomvia), and northern fur seals (*Callorhinus ursinus*). Predictions of statistical models were tested using movement

patterns obtained from satellite-tracked individual animals. With the most commonly used measures to quantify prey distributions - areal biomass, density, and numerical abundance - we were unable to find a spatial relationship between predators and their prey. We instead found that habitat use by all three predators was predicted most strongly by prey patch characteristics such as depth and local density within spatial aggregations. Additional prey patch characteristics and physical habitat also contributed significantly to characterizing predator patterns. Our results indicate that the small-scale prey patch characteristics are critical to how predators perceive the quality of their food supply and the mechanisms they use to exploit it, regardless of time of day, sampling year, or source colony. The three focal predator species had different constraints and employed different foraging strategies - a shallow diver that makes trips of moderate distance (kittiwakes), a deep diver that makes trip of short distances (murres), and a deep diver that makes extensive trips (fur seals). However, all three were similarly linked by patchiness of prey rather than by the distribution of overall biomass. This supports the hypothesis that patchiness may be critical for understanding predator-prey relationships in pelagic marine systems more generally.

Benoit-Bird, K. J., Battaile, B. C., Nordstrom, C. A., & Trites, A. W. (2013). Foraging Behavior of Northern Fur Seals Closely Matches the Hierarchical Patch Scales of Prey. *Marine Ecology Progress Series, 479*, 283-302. https://doi.org/10.3354/meps10209

Marine prey often occur in hierarchical mosaics whereby small, high-density patches are nested inside of larger, lower density aggregations. We tested the extent to which the foraging behavior of a marine predator (northern fur seal *Callorhinus ursinus*) could be explained by the hierarchical patch structure of a dominant prey species (juvenile walleye pollock Theragra chalcogramma) in the eastern Bering Sea. Comparing the movements of satellite-tracked fur seals with ship-based acoustic surveys of prey revealed that fur seals did not randomly search for prey, but instead showed deviations in the distribution of step-lengths (distances between their foraging patches) corresponding to the distances between aggregations of prey. Scales of prey distribution varied between Bering Sea shelf and deep-water slope habitats, while spatial scale distributions of fur seals showed corresponding changes, indicating that their search strategies were not innate patterns decoupled from the environment. Fur seals tended to avoid the smallest prey patches in both shelf and slope habitats. They also avoided prey patches that were separated by large distances. Fur seals responded to several levels of prey patchiness simultaneously, resulting in strong correlations between predator and prey over the entire range of aggregation scales observed in juvenile pollock. Our results indicate that, despite having a varied diet, fur seal foraging paths were defined by juvenile pollock aggregations. The presence of hierarchical, scale-dependent aggregation in both predator and prey provides new insights into fur seal behavior and a means to predict the dynamics of their interactions with prey.

Bergfelt, D. R., Steinetz, B. G., Dunn, J. L., Atkinson, S., Testa, J. W., & Adams, G. P. (2010). Validation of a Homologous Canine Relaxin Radioimmunoassay and Application with Pregnant and Non-Pregnant Northern Fur Seals (*Callorhinus ursinus*). *General and Comparative Endocrinology, 165*(1), 19-24. https://doi.org/10.1016/j.ygcen.2009.05.017

The primary objectives of this study were to validate a canine relaxin RIA for use in *otariids* and *phocids* and consider practical applications. For 6 captive Northern fur seal females, serum samples were grouped and examined according to pregnancy (n = 13), post-partum (n = 8) and non-pregnancy (n = 6), and, for 2 captive Northern fur seal males, serum samples were grouped and examined together

regardless of age (2 mo-15 yrs, n = 6). Placental tissue was available for examination from one Northern fur seal, Steller sea lion and harbor seal. The validation process involved several steps using an acid-acetone extraction process to isolate a relaxin-containing fraction in pools of serum from each group of fur seals and placental tissue from each seal species. A relaxin-like substance was detected in extracts of pregnant, non-pregnant and male serum and placental tissue in a dose-responsive manner as increasing volumes of respective extracts or amounts of canine relaxin were introduced into the assay. In raw serum samples, mean immuno-reactive relaxin concentrations were higher ($P < 0.05$) during pregnancy than post-partum and non-pregnancy, and lower ($P < 0.05$) in male than female fur seals. During pregnancy, mean serum concentrations of relaxin progressively increased ($P < 0.05$) over Months 4-10 and, in serial samples collected from the same fur seals before and after parturition, mean concentrations were higher ($P < 0.06$) pre-partum than post-partum. In conclusion, validation of a homologous canine relaxin RIA for use in otariids and phocids resulted in the discovery of a relaxin-like substance in extracted and raw serum and placental tissue from Northern fur seals, a Steller sea lion and harbor seal. Distinctly higher immuno-reactive concentrations during pregnancy indicated the potential for relaxin to serve as a hormonal marker to differentiate between pregnant and non-pregnant or pseudopregnant pinnipeds.

Berta, A., Churchill, M., & Boessenecker, R. W. (2018). The Origin and Evolutionary Biology of Pinnipeds: Seals, Sea Lions, and Walruses. In *Annual Review of Earth and Planetary Sciences.* R. Jeanloz & K. H. Freeman (Eds.), (Vol. 46, pp. 203-228) https://doi.org/10.1146/annurev-earth-082517-010009

The oldest definitive pinniped fossils date from approximately 30.6-23 million years ago (Ma) in the North Pacific. Pinniped monophyly is consistently supported; the group shares a common ancestry with arctoid carnivorans, either ursids or musteloids. Crown pinnipeds comprise the Otariidae (fur seals and sea lions), Odobenidae (walruses), and Phocidae (seals), with paraphyletic "enaliarctines" falling outside the crown group. The position of extinct Desmatophocidae is debated; they are considered to be closely related to both otariids and odobenids or, alternatively, to phocids. Both otariids and odobenids are known from the North Pacific, diverging approximately 19 Ma, with phocids originating in the North Atlantic or Paratethys region 19-14 Ma. Our understanding of pinniped paleobiology has been enriched by studies that incorporate anatomical and behavioral data into a phylogenetic framework. There is now evidence for sexual dimorphism in the earliest pinnipeds, heralding polygynous breeding systems, followed by increased body sizes, diving capabilities, and diverse feeding strategies in later-diverging phocid and otarioid lineages.

Boessenecker, R. W. (2011). New Records of the Fur Seal *Callorhinus* (*Carnivora: otariidae*) from the Plio-Pleistocene Rio Dell Formation of Northern California and Comments on Otariid Dental Evolution. *Journal of Vertebrate Paleontology, 31*(2), 454-467. https://doi.org/10.1080/02724634.2011.550362

New fossils representing two species of the fur seal Callorhinus are reported from the uppermost Pliocene to lower Pleistocene Rio Dell Formation of northern California. The finds include latest Pliocene-earliest Pleistocene dentaries and postcrania of Callorhinus gilmorei, and a partial dentary of early Pleistocene age identified as Callorhinus sp. The aforementioned material is ascribed to C. gilmorei due to the incipient single-rooted condition of the p1-2, retention of double-rooted p3-m1, and overall small size. The dentary identified as Callorhinus sp. exhibits a more derived pattern of tooth

morphology, including single-rooted p1-p4 (and double-rooted m1), larger size than C. gilmorei, and in the size range of extant *Callorhinus ursinus* (which typically exhibit fused roots on all postcanine teeth). Fusion of postcanine roots began with the p2 and continued posteriorly, and is likely an adaptation to accommodate crowded teeth anteriorly in the jaws. Callorhinus gilmorei has previously been reported from the upper Pliocene of southern California and Japan, and this new record extends the range of this taxon further north in the Northeast Pacific. Callorhinus sp. is the most complete pinniped fossil to be described from the early Pleistocene of the Northeast Pacific. The wide biogeographic range of Callorhinus during the Pliocene and Pleistocene documents the persistence of this taxon, potentially as a Pliocene-Holocene anagenetic lineage. This highlights the antiquity of the Callorhinus lineage, which has persisted in the Northeast Pacific since the Pliocene, establishing it as the oldest and earliest diverging crown otariid.

Boltnev, A. I. (2017). Intraspecific R / K-Selection in the Northern Fur Seal. *Trudy VNIRO, 168*, 4-13. Retrieved from http://www.vniro.ru/files/trydi_vniro/archive/tv_2017_t_168_article_1.pdf

We tested the hypothesis of intraspecific ecological life strategies in animals, which are expressed in a complex of ecological and physiological adaptations to the environment, related to the features of obtaining energy from the environment and its utilization for the maintenance of life and the reproduction of descendants. For this purpose, we used archival materials on the biology of northern fur seals collected by us at the Northern rookery of Bering Island in 1982–1998. We analyzed the individual variability of the dimensions and weight parameters of newborn seals, the connection of the size and weight parameters of newborn seals with maternal weight and maternal age and birthdate and also with the cost of reproduction in females which were estimated as the ratio of the puppy's weight to the mother's mass. Based on the results of the analysis, a hypothesis of intraspecific r/K-selection in animals was expressed. As with interspecies comparison, intraspecific r-strategists mature earlier, they are smaller than K-strategists, also they have a higher contribution to descendants, but a short life expectancy compared to K-strategists. All the signs of r-strategists are aimed at higher productivity, while for K-strategists all the signs are aimed at more efficient use of resources. Since the K-strategy is effective in a competitive environment with a reduced feed base, and the r-strategy - in conditions of a good fodder base at a low population density, long-term fluctuations of the habitat (fodder base) will cause cyclic dynamic of population structure of the species which will presented by the ratio of animals with different life strategies.

Braje, T. J., & DeLong, R. L. (2009). Ancient Sea Mammal Exploitation on the South Coast of San Miguel Island. In *Proceedings of the Seventh California Islands Symposium, Oxnard, California, February 5 - 8, 2008.* C. C. Damiani & D. K. Garcelon (Eds.), (pp. 43-52). Arcata, CA: Institute for Wildlife Studies. Retrieved from http://www.iws.org/CISProceedings/7th_CIS_Proceedings/Braje_and_DeLong.pdf

Archaeological evidence suggests that pinnipeds and sea otters have long been important dietary and raw material resources for Channel Islanders. Excavations at a village site on the south coast of San Miguel Island, CA-SMI-232, provide evidence of sea mammal hunting at about 1200 cal BP. Detailed analysis demonstrates that Guadalupe fur seals were the focus of Late Holocene hunters, with lesser numbers of California sea lions, harbor seals, and sea otters. Since federal protection and the subsequent rebound in populations after historic over-hunting, tens of thousands of pinnipeds haul out each year on San Miguel Island beaches and rocky outcrops. Today, breeding populations are dominated

by northern elephant seals, California sea lions, northern fur seals, and harbor seals with occasional visits by Steller's sea lion and Guadalupe fur seals. The archaeological record suggests a complex picture of local pinniped population dynamics that has been severely altered by historic exploitation, and perhaps by large-scale prehistoric hunting. In this paper, we present zooarchaeological evidence of pinniped hunting from CASMI- 232 and document significant changes between prehistoric and modern pinniped communities on San Miguel Island.

Braje, T. J., & Rick, T. C. (Eds.). (2011). *Human Impacts on Seals, Sea Lions, and Sea Otters : Integrating Archaeology and Ecology in the Northeast Pacific*. Berkeley, CA: University of California Press. Retrieved from https://www.ucpress.edu/book/9780520267268/human-impacts-on-seals-sea-lions-and-sea-otters

For more than ten thousand years, Native Americans from Alaska to southern California relied on aquatic animals such as seals, sea lions, and sea otters for food and raw materials. Archaeological research on the interactions between people and these marine mammals has made great advances recently and provides a unique lens for understanding the human and ecological past. Archaeological research is also emerging as a crucial source of information on contemporary environmental issues as we improve our understanding of the ancient abundance, ecology, and natural history of these species. This groundbreaking interdisciplinary volume brings together archaeologists, biologists, and other scientists to consider how archaeology can inform the conservation and management of pinnipeds and other marine mammals along the Pacific Coast.

Breiwick, J. M. (2013). *North Pacific Marine Mammal Bycatch Estimation Methodology and Results, 2007-2011*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-260. Retrieved from http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-260.pdf

Analyses of North Pacific marine mammal bycatch data for the period 1989-2006 have been made by Perez (2003, 2006, Unpubl.) based on Structured Query Language scripts. A change in the structure of the Oracle database maintained by the Fisheries Monitoring and Analysis (FMA) Division of the Alaska Fisheries Science Center in 2008 required that analysis programs be rewritten. The present analysis, for the period 2007-2011, was undertaken using the R programming language (R Core Team 2012). Bycatch estimates were calculated for each of 23 groundfish trawl, longline, and pot fisheries in Alaska using the FMA observer data and the total fishery data from the Catch Accounting System of the Alaska Regional Office of the National Marine Fisheries Service. Fisheries were determined by the target species, gear type, and area. The weight of all groundfish caught in a haul was used as a measure of effort. The total number of hauls was unknown for each fishery. The ratio of sampled groundfish weight to number of sampled hauls was assumed to be equal to the ratio of total groundfish weight for the fishery to the total number of hauls in the fishery. The observed bycatch of all marine mammal species for the years 20072011 was 16, 38, 20, 23 and 32, respectively. An additional 12 marine mammal mortalities were observed but were not used to estimate total marine mammal mortality because they occurred in hauls with unknown effort. The estimated bycatch of all marine mammals for these years was 31.8, 42.9, 21.1, 28.6 and 38.4, respectively. The following marine mammal species were bycaught during 2007-2011: bearded seal, harbor seal, northern elephant seal, northern fur seal, Steller (northern) sea lion, ribbon seal, ringed seal, spotted seal (larga seal), unidentified pinniped, walrus, Dall's porpoise, gray whale, harbor porpoise, humpback whale, killer whale and sperm whale. Annual bycatch (killed or seriously injured) estimates were calculated for each marine mammal stock in each fishery for the 5 year period.

These estimates are used to assess and manage marine mammal stocks and for classification of commercial fisheries.

Browne, P., Conley, A. J., Spraker, T., Ream, R. R., & Lasley, B. L. (2006). Sex Steroid Concentrations and Localization of Steroidogenic Enzyme Expression in Free-Ranging Female Northern Fur Seals (*Callorhinus ursinus*). *General and Comparative Endocrinology, 147*(2), 175-183. https://doi.org/10.1016/j.ygcen.2005.12.019

Recent precipitous population declines in northern fur seal (*Callorhinus ursinus*) and other Alaskan pinniped populations are due in part to reduced fecundity and have emphasized deficits in basic reproductive knowledge of these species. Following estrus and mating, fertilized female pinnipeds experience an obligatory delayed implantation lasting several months and non-pregnant (pseudo pregn ant) females are indistinguishable by sex steroid levels during this time. The current study examined circulating steroid concentrations and ovarian expression of key steroid-synthesizing enzymes in northern fur seals to identify changes associated with embryonic implantation, data necessary for estimating early pregnancy rates of the Population. Blood samples were collected from 84 female fur seals captured on an Alaskan rookery from October 15 to November 30, a period spanning the end of the delay and subsequent uterine implantation of the fertilized blastocyst in this species. Concentrations of progesterone, estradiol, and estrone measured in blood collected during boreal fall were contrasted with samples collected during late summer from post-ovulatory females and males. Serum sex steroids were also related to ovarian expression of key enzymes responsible for androgen (17 alpha-hydroxylase/17,20-lyase, cytochrome b5, and 3 beta-hydroxysteroid dehydrogenase) and estrogen (aromatase cytochrome P450) synthesis. Enzymes necessary for androgen synthesis were highly expressed in ovaries, and accordingly, endocrine profiles were expanded to include DHEA, androstenediol, androstenedione, and testosterone. Estradiol concentrations were universally low and free and conjugated estrone were the primary circulating estrogens in fur seal sera. No implantation-associated peak was identified for estrogens or progesterone and mean values of progesterone and estrone were actually greater in female serum samples collected during summer than fall. However, there was a significant positive relationship between fall sampling date and testosterone concentration. Additionally, DHEA concentrations in females were lower in samples collected during the implantation period than during the summer embryonic delay. These data suggest androgens may play a substantial regulatory role in the embryonic delay of northern fur seals.

Call, K. A., & Ream, R. R. (2012). Prey Selection of Subadult Male Northern Fur Seals (*Callorhinus ursinus*) and Evidence of Dietary Niche Overlap with Adult Females During the Breeding Season. *Marine Mammal Science, 28*(1), 1-15. https://doi.org/10.1111/j.1748-7692.2011.00463.x

During the breeding season northern fur seals (*Callorhinus ursinus*) congregate on the Pribilof Islands in large numbers creating the potential for intraspecific competition. Due to the declining trend in the Pribilof Islands population of fur seals, it is important to understand how prey resources are partitioned among the population. Fur seals exhibit a high degree of sexual dimorphism resulting in energetic differences among age and sex classes. Therefore, we hypothesized that subadult male and adult female fur seals would differ in the type and size of prey consumed. We examined the diets of subadult male (age 2–8; mean mass 28–176 kg) and adult female (age ≥ 3 yr; mean mass 13–50 kg) seals on St. Paul Island from 1992 to 2000. Prey remains found in fecal samples were compared using niche overlap indices. There was nearly complete dietary niche overlap between subadult male and adult female fur

seals. Walleye pollock (*Theragra chalcogramma*), Pacific salmon (*Oncorhynchus* spp.), Pacific herring (*Clupeia pallasi)*, and cephalopods were common prey items found in the diets of both groups. We found differences in the size of pollock consumed and that geographic location of sample collection may be important in determining diet differences. Our results indicate high levels of dietary overlap among subadult male and adult female fur seals.

Call, K. A., Ream, R. R., Johnson, D., Sterling, J. T., & Towell, R. G. (2008). Foraging Route Tactics and Site Fidelity of Adult Female Northern Fur Seal (*Callorhinus ursinus*) around the Pribilof Islands. *Deep-Sea Research Part II-Topical Studies in Oceanography, 55*(16-17), 1883-1896. https://doi.org/10.1016/j.dsr2.2008.04-022

This study examines foraging route choices and foraging site fidelity of 39 lactating adult northern fur seals (*Callorhinus ursinus*) at six rookeries on the Pribilof Islands. Satellite transmitters were deployed on seals at St. Paul (n = 19) and St. George (n = 20) Islands during the 2004 breeding season. A total of 167 complete foraging trips were identified, with individuals making 2-8 consecutive trips each. Foraging trip directional bearing, total distance traveled, maximum distance traveled, trip duration, and relative search effort were used to make comparisons among islands, rookeries, and individuals. The amount of time individuals spent in each of five hydrographic domains (inner shelf, middle shelf, outer shelf, shelf break, and oceanic) were important factors in determining foraging strategies. These domains are related to the bathymetry of the continental shelf, have predictable temperature, salinity, and current structures, and were used to define foraging habitat differences within and among individuals and rookeries. Based on cluster analysis and model results, we distinguished three types of individual foraging route tactics. Identifying variability in foraging route choices at the rookery and individual level is important for understanding the ability of northern fur seals to adapt to changes in environmental conditions and prey distributions.

Carretta, J. V. (2006). *U.S. Pacific Marine Mammal Stock Assessments, 2005*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-388. Retrieved from https://repository.library.noaa.gov/view/noaa/3480

Under the 1994 amendments to the Marine Mammal Protection Act (MMPA), the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) are required to publish Stock Assessment Reports for all stocks of marine mammals within U.S. waters, to review new information every year for strategic stocks and every three years for non-strategic stocks, and to update the stock assessment reports when significant new information becomes available. This report presents revised stock assessments for 5 Pacific marine mammal stocks under NMFS jurisdiction: 1) the California stock of harbor seals 2) Hawaiian monk seal 3) Eastern North Pacific humpback whale 4) Hawaii false killer whale 5) Southern Resident killer whale and 6) the California/Oregon/Washington stock of short-finned pilot whale. Information on the remaining 56 Pacific region stocks is reprinted without revision in this report and also appears in the 2004 reports (Carretta et al. 2005). Stock Assessments for Alaskan marine mammals are published by the National Marine Mammal Laboratory (NMML) in a separate report. The five revised stock assessments in this report include those studied by the Southwest Fisheries Science Center (SWFSC, La Jolla, California), the Pacific Islands Fisheries Science Center (PIFSC, Honolulu, Hawaii), the National Marine Mammal Laboratory (NMML, Seattle, Washington), and the Northwest Fisheries Science Center in Seattle, WA. Staff of the Northwest Fisheries Science Center prepared the report on the Eastern North Pacific Southern Resident killer whale. Pacific Islands Fisheries Science

Center staff prepared the report on the Hawaiian monk seal. Southwest Fisheries Science Center staff prepared stock assessments for the remaining four stocks. Updated estimates of abundance are available for California harbor seals (Lowry et al. 2005), Eastern North Pacific humpback whales (Calambokidis et al. 2004), Southern Resident killer whales, and Hawaiian monk seals. Updated calculations of potential biological removal (PBR) are available for California harbor seals, Eastern North Pacific humpback whales, and Hawaiian false killer whales.

Carretta, J. V., Forney, K. A., Lowry, M. S., Barlow, J., Baker, J., Hanson, B., . . . Muto, M. (2009). *U.S. Pacific Marine Mammal Stock Assessments, 2008*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-434. Retrieved from https://repository.library.noaa.gov/view/noaa/3922

Under the 1994 amendments to the Marine Mammal Protection Act (MMPA), the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) are required to publish Stock Assessment Reports for all stocks of marine mammals within U.S. waters, to review new information every year for strategic stocks and every three years for non-strategic stocks, and to update the stock assessment reports when significant new information becomes available. This report presents revised stock assessments for 27 Pacific marine mammal stocks under NMFS jurisdiction, including 9 “strategic” stocks and 18 “non-strategic” stocks (see summary table). New abundance estimates are available for 20 stocks, including 5 endangered species of large whales, the Hawaiian monk seal, and southern resident killer whales. Information on the remaining 37 Pacific region stocks will be reprinted without revision in the final 2008 reports and currently appears in the 2007 reports (Carretta et al. 2007). Stock Assessments for Alaskan marine mammals are published by the National Marine Mammal Laboratory (NMML) in a separate report. Pacific region stock assessments include those studied by the Southwest Fisheries Science Center (SWFSC, La Jolla, California), the Pacific Islands Fisheries Science Center (PIFSC, Honolulu, Hawaii), the National Marine Mammal Laboratory (NMML, Seattle, Washington), and the Northwest Fisheries Science Center (NWFSC, Seattle, WA). Northwest Fisheries Science Center staff prepared the report on the Eastern North Pacific Southern Resident killer whale. Pacific Islands Fisheries Science Center staff prepared the report on the Hawaiian monk seal. Southwest Fisheries Science Center staff prepared stock assessments for the remaining 25 stocks, which include 22 U.S. west coast cetacean stocks and three stocks of false killer whales (Hawaii Insular, Hawaii Pelagic, and Palmyra Atoll). Recently completed sea otter stock assessment reports produced by the U.S. Fish and Wildlife Service have been included as Appendix 4 to the Pacific stock assessment reports.

Carretta, J. V., Forney, K. A., Lowry, M. S., Barlow, J., Baker, J., Hanson, B., & Muto, M. (2007). *U.S. Pacific Marine Mammal Stock Assessments, 2007*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-414. Retrieved from https://repository.library.noaa.gov/view/noaa/3591

Under the 1994 amendments to the Marine Mammal Protection Act (MMPA), the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) are required to publish Stock Assessment Reports for all stocks of marine mammals within U.S. waters, to review new information every year for strategic stocks and every three years for non-strategic stocks, and to update the stock assessment reports when significant new information becomes available. This report presents revised stock assessments for 29 Pacific marine mammal stocks under NMFS jurisdiction, including 9 “strategic” stocks and 20 “non-strategic” stocks (see summary table). appears in the 2006 reports (Carretta et al.

2007). Information on the remaining 32 Pacific region stocks is reprinted without revision in this report and also Stock Assessments for Alaskan marine mammals are published by the National Marine Mammal Laboratory (NMML) in a separate report. The 29 revised stock assessments in this report include those studied by the Southwest Fisheries Science Center (SWFSC, La Jolla, California), the Pacific Islands Fisheries Science Center (PIFSC, Honolulu, Hawaii), the National Marine Mammal Laboratory (NMML, Seattle, Washington), and the Northwest Fisheries Science Center in Seattle, WA. Northwest Fisheries Science Center staff prepared the report on the Eastern North Pacific Southern Resident killer whale. Washington coast harbor seal stock. National Marine Mammal Laboratory staff prepared the report for the Oregon and Pacific Islands Fisheries Science Center staff prepared the report on the Hawaiian monk seal. Southwest Fisheries Science Center staff prepared stock assessments for the remaining 26 stocks, which include 22 U.S. west coast cetacean stocks, two stocks of false killer whales (Hawaii and Palmyra Atoll), the California sea lion, and northern elephant seal.

Carretta, J. V., Forney, K. A., Lowry, M. S., Barlow, J., Baker, J. D., Johnston, D., . . . Carswell, L. (2010). *U.S. Pacific Marine Mammal Stock Assessments, 2009*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-453. Retrieved from https://repository.library.noaa.gov/view/noaa/3915

Under the 1994 amendments to the Marine Mammal Protection Act (MMPA), the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) are required to publish Stock Assessment Reports for all stocks of marine mammals within U.S. waters, to review new information every year for strategic stocks and every three years for non-strategic stocks, and to update the stock assessment reports when significant new information becomes available. This report presents revised stock assessments for 11 Pacific marine mammal stocks under NMFS jurisdiction, including six "strategic" and five "non-strategic" stocks (see summary table in Appendix 3.). A new stock assessment for humpback whales in American Samoa waters is included in the Pacific reports for the first time. New or revised abundance estimates are available for nine stocks, including The 'Northern Oregon/Washington Coast Stock' Information on the remaining Pacific region stocks Eastern North Pacific blue whales, American Samoa humpback whales, five U.S. west coast harbor porpoise stocks, the Hawaiian monk seal, and southern resident killer whales.

Carretta, J. V., Forney, K. A., Lowry, M. S., Barlow, J., Baker, J. D., Johnston, D., . . . Hill, M. C. (2011). *U.S. Pacific Marine Mammal Stock Assessments, 2010*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-476. Retrieved from https://repository.library.noaa.gov/view/noaa/3923

Under the 1994 amendments to the Marine Mammal Protection Act (MMPA), the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) are required to publish Stock Assessment Reports for all stocks of marine mammals within U.S. waters, to review new information every year for strategic stocks and every three years for non-strategic stocks, and to update the stock assessment reports when significant new information becomes available. The 2010 Pacific marine mammal stock assessments include revised stock assessments for 63 Pacific marine mammal stocks under NMFS jurisdiction, including 12 "strategic" stocks, 48 "non-strategic" stocks, and three stocks of unknown status (see summary table in Appendix 3). Information on the remaining 12 Pacific region stocks is reprinted without revision in the final 2010 reports and currently appears in the 2009 reports (Carretta et al. 2010). Twelve new stock assessments in the Pacific Islands region are included in the

2010 Pacific stock assessments for the first time, including six spinner dolphin stocks, four bottlenose dolphin stocks, one false killer whale stock, and one rough-toothed dolphin stock. New or revised abundance estimates are available for 41 stocks. Where available, information on subspecies designations has been included in these reports to reflect local taxonomic and conservation issues (Perrin 2009). Information updates for longline fisheries in the Pacific Islands region are also included in a fishery description appendix. Stock Assessments for Alaska region marine mammals are published by the National Marine Mammal Laboratory (NMML) in a separate report. USFWS sea otter stock assessments are included as Appendix 4 of this document. Pacific region stock assessments include those studied by the Southwest Fisheries Science Center (SWFSC, La Jolla, California), the Pacific Islands Fisheries Science Center (PIFSC, Honolulu, Hawaii), the National Marine Mammal Laboratory (NMML, Seattle, Washington), and the Northwest Fisheries Science Center (NWFSC, Seattle, WA).

Carretta, J. V., Forney, K. A., Muto, M., Barlow, J., Baker, J. D., Hanson, B., & Lowry, M. S. (2007). *U.S. Pacific Marine Mammal Stock Assessments 2006*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-398. Retrieved from https://repository.library.noaa.gov/view/noaa/3500

Under the 1994 amendments to the Marine Mammal Protection Act (MMPA), the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) are required to publish Stock Assessment Reports for all stocks of marine mammals within U.S. waters, to review new information every year for strategic stocks and every three years for non-strategic stocks, and to update the stock assessment reports when significant new information becomes available. This report presents revised stock assessments for 9 Pacific marine mammal stocks under NMFS jurisdiction: 1) San Miguel Island northern fur seal, 2) Hawaiian monk seal, 3) Oregon/Washington coast harbor porpoise, 4) Washington Inland Waters harbor porpoise, 5) California coastal bottlenose dolphin, 6) Southern Resident killer whale, 7) Hawaii bottlenose dolphin, 8) Hawaii false killer whale, and 9) Hawaii short-finned pilot whale. Information on the remaining xx Pacific region stocks is reprinted without revision in this report and also appears in the 2005 reports (Carretta et al. 2006). Stock Assessments for Alaskan marine mammals are published by the National Marine Mammal Laboratory (NMML) in a separate report. The 9 revised stock assessments in this report include those studied by the Southwest Fisheries Science Center (SWFSC, La Jolla, California), the Pacific Islands Fisheries Science Center (PIFSC, Honolulu, Hawaii), the National Marine Mammal Laboratory (NMML, Seattle, Washington), and the Northwest Fisheries Science Center in Seattle, WA. Northwest Fisheries Science Center staff prepared the report on the Eastern North Pacific Southern Resident killer whale. National Marine Mammal Laboratory staff prepared the reports for San Miguel Island northern fur seal, and Oregon and Washington harbor porpoise stocks. Pacific Islands Fisheries Science Center staff prepared the report on the Hawaiian monk seal. Southwest Fisheries Science Center staff prepared stock assessments for California coastal bottlenose dolphin, Hawaii false killer whale, Hawaii short-finned pilot whale, and Hawaii bottlenose dolphin.

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K. K., Muto, M., Lowry, M. S., . . . Hill, M. C. (2012). *U.S. Pacific Marine Mammal Stock Assessments, 2011*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-488. Retrieved from https://repository.library.noaa.gov/view/noaa/4506

Under the 1994 amendments to the Marine Mammal Protection Act (MMPA), the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) are required to publish Stock Assessment Reports for all stocks of marine mammals within U.S. waters, to review new information

every year for strategic stocks and every three years for non-strategic stocks, and to update the stock assessment reports when significant new information becomes available. The 2011 Pacific marine mammal stock assessments include revised stock assessments for nine Pacific marine mammal stocks under NMFS jurisdiction, including four "strategic" stocks (Hawaiian monk seal, Southern Resident killer whale, Hawaii Insular false killer whale, Hawaii Pelagic false killer whale), and five "non-strategic" stocks (California sea lion, California harbor seal, Northern Oregon/Washington coast harbor porpoise, Washington Inland waters harbor porpoise, and Palmyra Atoll false killer whale). New information on a population viability analysis for the stock of Hawaii Insular false killer whale is presented. NMFS has received a petition to list this stock as endangered under the ESA. A Take Reduction Team was established in 2010 with the goal of reducing mortality and serious injury in the Hawaii Pelagic, Hawaii Insular, and Palmyra stocks of false killer whale (75 FR 2853, 19 January 2010). Information on the remaining 66 Pacific region stocks can be found in the final 2010 reports (Carretta et al. 2011). New abundance estimates are available for five stocks (California sea lion, California harbor seal, Hawaiian monk seal, Southern Resident killer whale, and Hawaii Insular false killer whale). Updated information on human-caused mortality is presented for the two harbor porpoise stocks and the three stocks of false killer whale. Stock Assessments for Alaska region marine mammals are published by the National Marine Mammal Laboratory (NMML) in a separate report. Pacific region stock assessments include those studied by the Southwest Fisheries Science Center (SWFSC, La Jolla, California), the Pacific Islands Fisheries Science Center (PIFSC, Honolulu, Hawaii), the National Marine Mammal Laboratory (NMML, Seattle, Washington), and the Northwest Fisheries Science Center (NWFSC, Seattle, WA). Draft versions of the 2011 stock assessment reports were reviewed by the Pacific Scientific Review Group.

Carretta, J. V., Forney, K. A., Oleson, E. M., Weller, D. W., Lang, A. e. R., Baker, J. D., . . . Brownell, R. L. (2019). *U.S. Pacific Marine Mammal Stock Assessments: 2018*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-617. https://doi.org/10.25923/x17q-2p43

Pacific region stock assessments include those studied by the Southwest Fisheries Science Center (SWFSC, La Jolla, CA), the Pacific Islands Fisheries Science Center (PIFSC, Honolulu, HI), the National Marine Mammal Laboratory (NMML, Seattle, WA), and the Northwest Fisheries Science Center (NWFSC, Seattle, WA). The 2018 Pacific marine mammal stock assessments include revised reports for 16 Pacific marine mammal stocks under NMFS jurisdiction, including 7 "strategic" stocks: Hawaiian monk seal, Eastern North Pacific blue whale, Western North Pacific gray whale, California/Oregon/Washington humpback whale, California/Oregon/Washington fin whale, Eastern North Pacific sei whale and Southern Resident killer whale. New abundance estimates are available for 8 stocks: California sea lions, Hawaiian monk seals, Eastern North Pacific Offshore killer whales, Southern Resident killer whales, Eastern North Pacific gray whales, Western North Pacific gray whales, California/Oregon/Washington humpback whales, and Hawaii Island spinner dolphins. Information on sea otters, manatees, walrus, and polar bears are published separately by the US Fish and Wildlife Service.

Carretta, J. V., Helker, V. T., Muto, M., Greenman, J., Wilkinson, K., Lawson, D. D., . . . Jannot, J. E. (2019). *Sources of Human-Related Injury and Mortality for U.S. Pacific West Coast Marine Mammal Stock Assessments, 2013-2017*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-616. https://doi.org/10.25923/j6bk-xt87

This report contains human-caused injury and mortality records of pinnipeds and cetaceans that occur in U.S. west coast waters for the period 2013-2017, for those species evaluated in Pacific region marine

mammal stock assessment reports (SARs) (Carretta et al. 2016a). Mortality records, while included in this report, were not a part of the SI/NSI status evaluation that included only live animals. Subsistence and directed takes (i.e., gray whales taken by Russian natives) are not reported here but are reported in SARs published by NMFS. Previous serious injury and mortality records, including cases from 2007 through 2016, are published in previous reports (Carretta et al. 2013, 2014, 2015b, 2016b, 2017, 2018). Sources of injury data include strandings, disentanglement networks, the public, researchers, and fishery observer programs. Stranding data include records of injured marine mammals at sea and ashore. Injury sources include, but are not limited to, vessel strikes, gillnet entanglement, pot and trap gear entanglement, shootings, marine debris entanglement, research-related injuries/deaths, hook and line fishery interactions, and entrainment in power plant water intakes. Most records originate from stranding networks in California, Oregon, and Washington, though a few Alaska records of Eastern North Pacific gray whales (Eschrichtius robustus) are included, because this population is assessed in the Pacific region SARs and occurs along the U.S. west coast. Other marine mammals, such as Steller sea lions (Eumetopias jubatus), occur in California, Oregon, and Washington waters, but they are assessed in Alaska region SARs (Muto et al. 2016) and are not included in this report. Injury determinations for Pacific region species/stocks in the central Pacific from Hawaii westward are also included in separate reports (Bradford and Forney 2014).

Carretta, J. V., Muto, M., Greenman, J., Wilkinson, K. M., Lawson, D. D., Viezbicke, J., & Jannot, J. E. (2017). *Sources of Human-Related Injury and Mortality for U.S. Pacific West Coast Marine Mammal Stock Assessments, 2011-2015*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-579. http://doi.org/10.7289/V5/TM-SWFSC-579

This report contains human-caused injury and mortality records of pinnipeds and cetaceans that occur in U.S. west coast waters for the period 2011-2015, for those species evaluated in Pacific region marine mammal stock assessment reports (SARs) (Carretta et al. 2016a). Mortality records, while included in this report, were not a part of the SI/NSI status evaluation that included only live animals. Subsistence and directed takes (i.e., gray whales taken by Russian natives) are not reported here but are reported in SARs published by NMFS. Previous records, including cases from 2007 through 2010, are published in previous reports (Carretta et al. 2013, 2014, 2015b, 2016b).

Carretta, J. V., Muto, M., Greenman, J., Wilkinson, K. M., Viezbicke, J., Lawson, D. D., . . . Jannot, J. E. (2018). *Sources of Human-Related Injury and Mortality for U.S. Pacific West Coast Marine Mammal Stock Assessments, 2012-2016*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-601. Retrieved from https://repository.library.noaa.gov/view/noaa/18081

This report contains human-caused injury and mortality records of pinnipeds and cetaceans that occur in U.S. west coast waters for the period 2012-2016, for those species evaluated in Pacific region marine mammal stock assessment reports (SARs) (Carretta et al. 2016a). Mortality records, while included in this report, were not a part of the SI/NSI status evaluation that included only live animals. Subsistence and directed takes (i.e., gray whales taken by Russian natives) are not reported here but are reported in SARs published by NMFS. Previous serious injury and mortality records, including cases from 2007 through 2015, are published in previous reports (Carretta et al. 2013, 2014, 2015b, 2016b, 2017).

Carretta, J. V., Muto, M., Wilkin, S. M., Greenman, J., Wilkinson, K. M., DeAngelis, M., . . . Jannot, J. E. (2016). *Sources of Human-Related Injury and Mortality for U.S. Pacific West Coast Marnine Mammal Stock Assessments, 2010-2014*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-554. http://doi.org/10.7289/V5/TM-SWFSC-554

This report contains human-caused injury and mortality records of pinnipeds and cetaceans that occur in U.S. west coast waters for the period 2010-2014, for those species evaluated in Pacific region marine mammal stock assessment reports (SARs) (Carretta et al. 2015a). Mortality records, while included in this report, were obviously not evaluated for SI/NSI status. Subsistence and directed takes (i.e., gray whales taken by Russian natives) are not reported here but are reported in SARs published by NMFS. Previous records, including cases from 2007 through 2009, are published in previous reports (Carretta et al. 2013a, 2014, 2015b). Sources of injury data include strandings, disentanglement networks, the public, researchers, and fishery observer programs. Stranding data includes records of injured marine mammals at sea and ashore. Injury sources include, but are not limited to, vessel strikes, gillnet entanglement, pot and trap gear entanglement, shootings, marine debris entanglement, researchrelated injuries/deaths, hook and line fishery interactions, and power plant water intake entrainment. Most records originate from stranding networks in California, Oregon, and Washington, though a few Alaska records of Eastern North Pacific gray whales (Eschrichtius robustus) are included, because this population is assessed in the Pacific region SARs and occurs along the U.S. west coast. Other marine mammals, such as Steller sea lions (Eumetopias jubatus), occur in California, Oregon, and Washington waters, but they are assessed in Alaska region SARs (Allen and Angliss 2014) and are not included in this report. Injury determinations for Pacific region species/stocks in the central Pacific from Hawaii westward are also included in separate reports (Bradford and Forney 2014).

Carretta, J. V., Muto, M., Wilkin, S. M., Greenman, J., Wilkinson, K. M., DeAngelis, M., . . . Jannot, J. E. (2015). *Sources of Human-Related Injury and Mortality for U.S. Pacific West Coast Marine Mammal Stock Assessments, 2009-2013*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-548. http://doi.org/10.7289/V5/TM-SWFSC-548

This report contains updated records of human-caused injury and mortality to pinnipeds and cetaceans from 2009 to 2013 for marine mammal populations that occur in U.S. west coast waters and which are evaluated in Pacific region marine mammal stock assessment reports (SARs) (Carretta et al. 2013a, 2013b). Mortality records, while included in this report, were obviously not evaluated for SI/NSI status. Subsistence and directed takes (i.e., gray whales taken by Russian natives) are not reported here but are reported in SARs published by NMFS. Previous records, including cases from 2007 and 2008, are published in previous reports (Carretta et al. 2013a, 2014). Sources of injury data include strandings, disentanglement networks, and fishery observer programs. Stranding network data includes records of injured marine mammals at sea and ashore reported by the public, as well as researchers. Injury sources include, but are not limited to, vessel strikes, gillnet entanglement, pot and trap gear entanglement, shootings, marine debris entanglement, research-related injuries/deaths, hook and line fishery interactions, and power plant water intake entrainment. Most records originate from stranding networks in California, Oregon, and Washington, though a few Alaska records of Eastern North Pacific gray whales (Eschrichtius robustus) are included, because this population is assessed in the Pacific region SARs and occurs along the U.S. west coast. Other marine mammals, such as Steller sea lions (Eumetopias jubatus), occur in California, Oregon, and Washington waters, but they are assessed in Alaska region SARs (Allen and Angliss 2014) and are not included in this report. Injury determinations for

Pacific region species/stocks in the central Pacific from Hawaii westward are also included in separate reports.

Carretta, J. V., Oleson, E. M., Baker, J. D., Weller, D. W., Lang, A. e. R., Forney, K. A., . . . Brownell, R. L. (2016). *U.S. Pacific Marine Mammal Stock Assessments, 2015*. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-561. http://doi.org/10.7289/V5/TM-SWFSC-561

The 2015 Pacific marine mammal stock assessments include revised reports for eight Pacific marine mammal stocks under NMFS jurisdiction, including five "strategic" stocks: Hawaiian monk seal, Southern Resident killer whale, Eastern North Pacific blue whale, Main Hawaiian Islands Insular false killer whale, and Hawaii Pelagic false killer whale. New abundance estimates are available for three stocks in the Pacific Islands region (Hawaiian monk seal, Hawaii Pelagic and Northwestern Hawaiian Islands false killer whales) and two U.S. west coast stocks (Southern Resident killer whale and California northern fur seal). The stock range and boundaries of the three Hawaiian stocks of false killer whales, which have overlapping ranges, were recently reevaluated based on new information on the occurrence and movements of each stock (Bradford et al. 2015). New information on fisheryrelated serious injury and mortality of false killer whales has also been updated. A stock assessment report for the Eastern Tropical Pacific stock of Bryde's whale has been reinstated into the Pacific reports in response to a regular and increasing presence of this species in southern California waters (Kerosky et al. 2012, Smultea et al. 2012). The Eastern Tropical Pacific Bryde's whale report last appeared in the Pacific stock assessments in 2007. The genus of Hawaiian monk seal has been updated from Monachus to Neomonachus to reflect recent genetic and skull morphology data (Scheel et al. 2014). The report for Eastern North Pacific blue whales includes significant new information on historic whaling removals, the population's status relative to carrying capacity, and risk of ship strikes to the population (Monnahan et al. 2014, 2015). This is a working document and individual stock assessment reports will be updated as new information on marine mammal stocks and fisheries becomes available. Background information and guidelines for preparing stock assessment reports are reviewed in Wade and Angliss (1997). The authors solicit any new information or comments which would improve future stock assessment reports.

Colegrove, K. M., Gulland, F. M. D., Naydan, D. K., & Lowenstine, L. J. (2009). The Normal Genital Tract of the Female California Sea Lion (*Zalophus californianus*) : Cyclic Changes in Histomorphology and Hormone Receptor Distribution. *Anatomical Record-Advances in Integrative Anatomy and Evolutionary Biology, 292*(11), 1801-1817. https://doi.org/10.1002/ar.21009

Changes in reproductive tract histomorphology, and estrogen (ER(X) and progesterone receptor (PR) expression throughout the breeding cycle were evaluated in free-ranging stranded female California sea lions (*Zalophus californianus*). Hormone receptor expression in the ovaries, uterus, cervix, and vagina was evaluated using an immunohistochemical technique with monoclonal antibodies. During a large portion of the cycle, ovaries contained both a corpora lutea (CL) and follicles in varying stages of development. In the periods of pupping and estrus during June and July, and in the spring morphologic features of the endometrium suggested estrogen influence. There were areas of squamous differentiation in the pseudostratified columnar epithelium of the cervix and vagina in some animals during estrus and in the spring. Estrogen receptor immunohistochemical scores were highest during pupping and estrus and in the spring and lowest during embryonic diapause. Cyclic changes in uterine PR expression throughout the cycle were minimal. Both ER alpha and PR were expressed in epithelial

and stromal cells throughout the cervix and vagina, however, receptor expression was typically higher in the stroma. Stromal cell hormone receptors may play an important role in epithelial responses to circulating sex hormones. The results of this investigation add to the general knowledge of California sea lion reproduction and establish baseline information on reproductive tract hormone receptors that will aid in determining the factors involved in urogenital cancer development in sea lions.

Colitz, C. M. H., Renner, M. S., Manire, C. A., Doescher, B., Schmitt, T. L., Osborn, S. D., . . . Rudnick, J. C. (2010). Characterization of Progressive Keratitis in Otariids. *Veterinary Ophthalmology, 13*, 47-53. https://doi.org/10.1111/j.1463-5224.2010.00811.x

Objective To characterize a form of progressive keratitis that occurs commonly in otariids. Materials and methods One hundred and thirteen captive otariids were evaluated by ophthalmologic examination and digital photography. Results Forty-six females and 67 males were in the reference population, average age of 14 years. California sea lions predominated (n = 100); there were also six Steller sea lions, five brown fur seals, one Guadalupe fur seal and one northern fur seal. Three stages of progressive keratitis are described. Overall, 64.6% animals and 142 eyes from 113 animals (62.8%) were affected with one of three stages. The mildest form, Stage 1 keratitis, occurred in 78 of 226 eyes (34.5%); the intermediate Stage 2 keratitis occurred in 30 of 226 eyes (13.3%); and the most severe, Stage 3 keratitis, occurred in 34 of 226 eyes (15%). All but six animals had bilateral disease. Animals with Stage 1 keratitis were significantly younger than those in more advanced stages. Discussion 'Otariid Keratitis' occurs in all populations of eared seals evaluated. A large-scale epidemiological study is ongoing to identify the risk factors that contribute to this disease. Exposure to chronic sunlight appears to be an important risk factor as shade diminishes clinical signs; animals kept out of sunlight the majority of the time have less severe clinical signs. Age may be important since exposure accumulates with aging. Progression of the disease is also associated with secondary opportunistic bacterial and fungal infections. The surface immune system may be imbalanced contributing to these infections and progression.

Committee on the Status of Endangered Wildlife in Canada (Ed.) (2006). *Cosewic Assessment and Update Status Report on the Northern Fur Seal,Callorhinus Ursinus, in Canada.* Ottawa: Committee on the Status of Endangered Wildlife in Canada. Retrieved from http://dsp-psd.pwgsc.gc.ca/Collection/CW69-14-74-2006E.pdf

This report of the Committee on the Status of Endangered Wildlife in Canada gives information on the northern fur seal species, its distribution, habitat, biology, population sizes and trens, limiting factors and threats, special significance, and protective status designations in Canada and abroad.

Cortés-Hinojosa, G., Gulland, F. M. D., DeLong, R., Gelatt, T., Arecher, L., & Wellehan, J. F. X., Jr. (2016). A Novel Gammaherpesvirus in Northern Fur Seals (*Callorhinus ursinus*) Is Closely Related to the California Sea Lion (*Zalophus californianus*) Carcinoma-Associated Otarine Herpesvirus-1. *Journal of Wildlife Diseases, 52*(1), 88-95. https://doi.org/10.7589/2015-03-060

Otarine herpesvirus 1 (OtHV1) is strongly associated with California sea lion (CSL, Zalophus californianus) urogenital carcinoma, the most common cancer documented in marine mammals. In addition to CSL, OtHV1 has also been found in association with carcinoma in South American fur seals (Arctocephalus australis), demonstrating it can infect related species. Northern fur seals (NFS,*Callorhinus ursinus*) are

sympatric with CSL, and copulation between these species has been observed; yet, there are no reports of urogenital carcinoma in NFS. We describe a new Otarine herpesvirus found in vaginal swabs from NFS, herein called OtHV4. Partial sequencing of the polymerase gene and the glycoprotein B gene revealed OtHV4 is closely related to OtHV1, with 95% homology in the region of polymerase sequenced, and phylogenetic analyses demonstrate that they are sister taxa. An OtHV4-specific hydrolysis probe quantitative PCR was developed and validated, and its use on vaginal swabs revealed 16 of 50 (32%) wild adult female NFS were positive for OtHV4. The identification of a virus highly similar to the carcinoma-associated OtHV1 in a sympatric species without carcinoma suggests that comparative genomics of OtHV1 and OtHV4 may identify candidate viral oncogenes.

Dalton, A. J. M., Rosen, D. A. S., & Trites, A. W. (2014). Broad Thermal Capacity Facilitates the Primarily Pelagic Existence of Northern Fur Seals (*Callorhinus ursinus*). *Marine Mammal Science, 30*(3), 994-1013. https://doi.org/10.1111/mms.12103

Thermoregulatory capacity may constrain the distribution of marine mammals despite having anatomical and physiological adaptations to compensate for the thermal challenges of an aquatic lifestyle. We tested whether subadult female northern fur seals (*Callorhinus ursinus*) experience increased thermoregulatory costs in water temperatures potentially encountered during their annual migration in the Bering Sea and North Pacific Ocean. Metabolic rates were measured seasonally in 6 captive female northern fur seals (2.75-3.5 yr old) in ambient air and controlled water temperatures of 2 degrees C, 10 degrees C, and 18 degrees C. Rates of oxygen consumption in ambient air (1 degrees C-18 degrees C) were not related to environmental temperature except below 2.5 degrees C (winter only). However, metabolism was significantly higher during the fall seasonal trials (September-October) compared to other times of year, perhaps due to the costs of molting. The fur seals appeared thermally neutral in all seasons for all water temperatures tested (2 degrees C-18 degrees C) except during the summer when metabolic rates were higher in the 2 degrees C water. Comparing this broad thermal neutral zone to the average sea surface temperatures potentially encountered during annual migrations indicates wild fur seals can likely exploit a large geographic area without added thermal metabolic costs.

Dalton, A. J. M., Rosen, D. A. S., & Trites, A. W. (2014). Season and Time of Day Affect the Ability of Accelerometry and the Doubly Labeled Water Methods to Measure Energy Expenditure in Northern Fur Seals (*Callorhinus ursinus*). *Journal of Experimental Marine Biology and Ecology, 452*, 125-136. https://doi.org/10.1016/j.jembe.2013.12.014

Estimates of energy expenditure for free-ranging animals are essential to answering a range of fundamental questions in animal biology, but are challenging to obtain and difficult to validate.We simultaneously employed three methods to measure the energy expenditure of 6 captive female northern fur seals (*Callorhinus ursinus*) during 5-day trials across 4 seasons: respirometry (oxygen consumption), doubly labeled water (DLW), and accelerometry. The DLWmethod estimated that the fur seals expended 13.1 ± 16.5% more energy than indicated by the more direct measures of oxygen consumption. Accelerometry failed to predict the average massspecific rate of oxygen consumption ($\dot{V}$O2DEE) within the individual seasons over entire 5-day trials. However, on a finer time scale (15 or 60 min) and adjusted for time of day, accelerometry estimated energy expenditure within an average difference of 5.4 ± 29.3% (60 min intervals) and 13.8 ± 39.5% (15 min intervals) of respirometry measured values. Our findings suggest that accelerometers have the potential to bemore effective than the DLWmethod for measuring energy expenditure of free-ranging animals. However, rates of oxygen

consumption varied with season, independent of overall activity. Seasonal effects (and time of day for accelerometry) must therefore be accounted for when estimating energy expenditure from measures of DLW and acceleration of free-swimming northern fur seals. Such corrections required for estimating energy expenditures in northern fur seals have implications for using accelerometers and DLW to estimate the energy expenditure of other species.

Dalton, A. J. M., Rosen, D. A. S., & Trites, A. W. (2015). Resting Metabolic Rate and Activity: Key Components of Seasonal Variation in Daily Energy Expenditure for the Northern Fur Seal (*Callorhinus ursinus*). *Canadian Journal of Zoology, 93*(8), 635-644. https://doi.org/10.1139/cjz-2014-0313

Seasonal changes in daily energy expenditure (DEE) and its key underlying components (costs of resting metabolic rate (RMR), thermoregulation, activity, and growth) were measured to determine seasonal energy requirements, bioenergetic priorities, and potential times of year when unpredicted episodes of nutritional stress would have their greatest effect on female northern fur seals (*Callorhinus ursinus* (L., 1758)). The mean (+/- SD) DEE of six captive juvenile female fur seals was 527.8 +/- 65.7 kJ.kg(-1).d(-1) and fluctuated seasonally (lower during summer and winter, and up to 20% greater in spring and fall). RMR also changed significantly with season and was higher in the fall (potentially due to moulting or anticipated migratory activity). However, changes in RMR did not follow the same seasonal trend as those of DEE. The largest component of DEE was RMR (similar to 80%, on average), followed by the cost of activity (which may have driven some of the seasonal variations in DEE). In contrast, the energetic costs associated with growth and thermoregulation appeared negligible within the scope of overall energy expenditures. Elevated innate costs of RMR and higher growth rates in the fall and summer, respectively, suggest that inadequate nutrition could comparatively have greater negative effects on female fur seals during these seasons.

DeLong, R. L., Orr, A. J., Jenkinson, R. S., & Lyons, E. T. (2009). Treatment of Northern Fur Seal (*Callorhinus ursinus*) Pups with Ivermectin Reduces Hookworm-Induced Mortality. *Marine Mammal Science, 25*(4), 944-948. https://doi.org/10.1111/j.1748-7692.2008.00274.x

The article focuses on the role of ivermectin to treat hookworm disease among infant northern fur seal to prevent pups mortality. Ivermectin is a broad-spectrum antiparasitic drug utilized for controlling arthropods and nematodes in domestic animals. Accordingly, hookworm infections are transmitted to pups through the milk of the mother and are thought to last for up to three months. It states that hookworm infections were almost complete clearance during the single dose trial of ivermectin.

DeMaster, D. P., Trites, A. W., Clapham, P., Mizroch, S., Wade, P., Small, R. J., & Ver Hoef, J. (2006). The Sequential Megafaunal Collapse Hypothesis: Testing with Existing Data. *Progress in Oceanography, 68*(2-4), 329-342. https://doi.org/10.1016/j.pocean.2006.02.007

Springer et al. [Springer, A.M., Estes, J.A., van Vliet, G.B., Williams, T.M., Doak, D.F., Danner, E.M., Forney, K.A., Pfister, B., 2003. Sequential megafaunal collapse in the North Pacific Ocean: an ongoing legacy of industrial whaling? Proceedings of the National Academy of Sciences 100 (21), 12,223–12,228] hypothesized that great whales were an important prey resource for killer whales, and that the removal of fin and sperm whales by commercial whaling in the region of the Bering Sea/Aleutian Islands (BSAI) in

the late 1960s and 1970s led to cascading trophic interactions that caused the sequential decline of populations of harbor seal, northern fur seal, Steller sea lion and northern sea otter. This hypothesis, referred to as the Sequential Megafaunal Collapse (SMC), has stirred considerable interest because of its implication for ecosystem-based management. The SMC has the following assumptions: (1) fin whales and sperm whales were important as prey species in the Bering Sea; (2) the biomass of all large whale species (i.e., North Pacific right, fin, humpback, gray, sperm, minke and bowhead whales) was in decline in the Bering Sea in the 1960s and early 1970s; and (3) pinniped declines in the 1970s and 1980s were sequential. We concluded that the available data are not consistent with the first two assumptions of the SMC. Statistical tests of the timing of the declines do not support the assumption that pinniped declines were sequential. We propose two alternative hypotheses for the declines that are more consistent with the available data. While it is plausible, from energetic arguments, for predation by killer whales to have been an important factor in the declines of one or more of the three populations of pinnipeds and the sea otter population in the BSAI region over the last 30 years, we hypothesize that the declines in pinniped populations in the BSAI can best be understood by invoking a multiple factor hypothesis that includes both bottom–up forcing (as indicated by evidence of nutritional stress in the western Steller sea lion population) and top–down forcing (e.g., predation by killer whales, mortality incidental to commercial fishing, directed harvests). Our second hypothesis is a modification of the top–down forcing mechanism (i.e., killer whale predation on one or more of the pinniped populations and the sea otter population is mediated via the recovery of the eastern North Pacific population of the gray whale). We remain skeptical about the proposed link between commercial whaling on fin and sperm whales, which ended in the mid-1960s, and the observed decline of populations of northern fur seal, harbor seal, and Steller sea lion some 15 years later.

Dickerson, B. R., Ream, R. R., Vignieri, S. N., & Bentzen, P. (2010). Population Structure as Revealed by mtDNA and Microsatellites in Northern Fur Seals,*Callorhinus ursinus*, Throughout Their Range. *PLoS One, 5*(5), 1-9. https://doi.org/10.1371/journal.pone.0010671

Background: The northern fur seal (*Callorhinus ursinus*; NFS) is a widely distributed pinniped that has been shown to exhibit a high degree of philopatry to islands, breeding areas on an island, and even to specific segments of breeding areas. This level of philopatry could conceivably lead to highly genetically divergent populations. However, northern fur seals have the potential for dispersal across large distances and have experienced repeated rapid population expansions following glacial retreat and the more recent cessation of intensive harvest pressure. Methodology/Principal Findings: Using microsatellite and mitochondrial loci, we examined population structure in NFS throughout their range. We found only weak population genetic structure among breeding islands including significant F-ST and Phi(ST) values between eastern and western Pacific islands. Conclusions: We conclude that insufficient time since rapid population expansion events (both post glacial and following the cessation of intense harvest pressure) mixed with low levels of contemporary migration have resulted in an absence of genetic structure across the entire northern fur seal range.

Donohue, M. J., Masura, J., Gelatt, T., Ream, R., Baker, J. D., Faulhaber, K., & Lerner, D. T. (2019). Evaluating Exposure of Northern Fur Seals, *Callorhinus ursinus,* to Microplastic Pollution through Fecal Analysis. *Marine Pollution Bulletin, 138*, 213-221. https://doi.org/10.1016/j.marpolbul.2018.11.036

Environmental microplastics are widely documented in marine life and bioaccumulation may present risks to marine predators. Investigations of microplastics in marine mammals are increasing, though none have examined animals routinely consumed by humans. Here, we investigate microplastic exposure in the northern fur seal (Callorhinus *ursinus*), a species consumed by humans, using fecal material. We examined 44 feces (scat) at sites encompassing the seals' eastern Pacific range. Multiple contamination control measures were implemented, including field and laboratory controls. Fragments were the most common microplastic recovered, in 55% (24/44) of scat and no controls (range 1 to 86 fragments/scat, mean 16.6, sd 19.1). Microplastic fibers were recovered from 41% of scats (18/44), though some controls contained fibers confounding fiber results. Fecal analysis documented northern fur seal exposure to microplastics throughout their eastern Pacific range.

Dowd, M., & Joy, R. (2011). Estimating Behavioral Parameters in Animal Movement Models Using a State-Augmented Particle Filter. *Ecology, 92*(3), 568-575. https://doi.org/10.1890/10-0611.1

Data on fine-scale animal movement are being collected worldwide, with the number of species being tagged and the resolution of data rapidly increasing. In this study, a general methodology is proposed to understand the patterns in these high-resolution movement time series that relate to marine animal behavior. The approach is illustrated with dive data from a northern fur seal (*Callorhinus ursinus*) tagged on the Pribilof Islands, Alaska, USA. We apply a state-space model composed of a movement model and corresponding high-resolution vertical movement data. The central goal is to estimate parameters of this movement model, particularly their variation on appropriate time scales, thereby providing a direct link to behavior. A particle filter with state augmentation is used to jointly estimate the movement parameters and the state. A multiple iterated filter using overlapping data segments is implemented to match the parameter time scale with the behavioral inference. The time variation in the auto-covariance function facilitates identification of a movement model, allows separation of observation and process noise, and provides for validation of results. The analysis yields fitted parameters that show distinct time-evolving changes in fur seal behavior over time, matching well what is observed in the original data set.

Duncan, C., Dickerson, B., Pabilonia, K., Miller, A., & Gelatt, T. (2014). Prevalence of *Coxiella burnetii* and *Brucella* spp. In Tissues from Subsistence Harvested Northern Fur Seals (*Callorhinus ursinus*) of St. Paul Island, Alaska. *Acta Veterinaria Scandinavica, 56* https://doi.org/10.1186/s13028-014-0067-x

The northern fur seal (*Callorhinus ursinus*) is an important cultural and nutritional resource for the Aleut community on St. Paul Island Alaska. In recent years, an increasing number of zoonotic pathogens have been identified in the population, but the public health significance of these findings is unknown. To determine the prevalence of Coxiella burnetii and Brucella spp. in northern fur seal tissues, eight tissue types from 50 subsistence-harvested fur seals were tested for bacterial DNA by real-time polymerase chain reaction. Findings: Of the 400 samples tested, only a single splenic sample was positive for Brucella spp. and the cycle threshold (ct) value was extremely high suggesting a low concentration of DNA within the tissue. C. burnetii DNA was not detected. Conclusions: Findings suggest that the risk of humans contracting brucellosis or Q fever from the consumption of harvested northern fur seals is low.

Duncan, C., Goldstein, T., Hearne, C., Gelatt, T., & Spraker, T. (2013). Novel Polyomaviral Infection in the Placenta of a Northern Fur Seal (*Callorhinus ursinus*) on the Pribilof Islands, Alaska, USA. *Journal of Wildlife Diseases, 49*(1), 163-167. https://doi.org/10.7589/2012-04-101

Viruses of the family Polyomaviridae infect a wide variety of avian and mammalian hosts with a broad spectrum of outcomes including asymptomatic infection, acute systemic disease, and tumor induction. In 2010, intranuclear viral inclusion bodies were identified in trophoblasts of a single northern fur seal (NFS; *Callorhinus ursinus*) placenta from a presumed healthy birth on St. Paul Island, Alaska. On transmission electron microscopy, virions were approximately 40 nm in diameter and were arranged in paracrystalline arrays within the nucleus. The tissue was positive for the polyomaviral major capsid gene (VP1) by PCR, and the sequenced product revealed a novel Orthopolyomavirus. Twenty-nine additional NFS placentas, devoid of viral inclusions on histologic examination, were tested for polyomavirus by PCR; all were negative. The significance of this novel virus for the infected animal is unknown, but the virus does not appear to be very prevalent within the placentas from newborn northern fur seal pups.

Duncan, C., Kersh, G. J., Spraker, T., Patyk, K. A., Fitzpatrick, K. A., Massung, R. F., & Gelatt, T. (2012). *Coxiella burnetii* in Northern Fur Seal (*Callorhinus ursinus*) Placentas from St. Paul Island, Alaska. *Vector-Borne and Zoonotic Diseases, 12*(3), 192-195. https://doi.org/10.1089/vbz.2011.0715

The decline in the number of northern fur seal (NFS; *Callorhinus ursinus*) pups on St. Paul Island, Alaska, has led to multidisciplinary research, including investigation into issues of reproductive health and success. Given the recent identification of Coxiella burnetii in the placenta of two other marine mammal species, NFS placentas were collected from Reef rookery on St. Paul Island, Alaska, during the 2010 pupping season, examined histologically, and tested for C. burnetii using polymerase chain reaction (PCR). Of 146 placentas examined, gram-negative intratrophoblastic bacteria that were positive for C. burnetii on immunohistochemistry were observed in 5 (3%) placentas. Placental infection was usually devoid of associated inflammation or significant ancillary pathology. One hundred nine (75%) of the placentas were positive for C. burnetii on PCR. C. burnetii is globally distributed and persists for long periods in the environment, providing ample opportunity for exposure of many species. The significance of this finding for the declining fur seal population, potential human exposure and infection, and impact on other sympatric marine mammal or terrestrial species is unclear; further investigation into the epidemiology of Coxiella in the marine ecosystem is warranted.

Duncan, C., Savage, K., Williams, M., Dickerson, B., Kondas, A. V., Fitzpatrick, K. A., . . . Kersh, G. J. (2013). Multiple Strains of *Coxiella burnetii* Are Present in the Environment of St. Paul Island, Alaska. *Transboundary and Emerging Diseases, 60*(4), 345-350. https://doi.org/10.1111/j.1865-1682.2012.01353.x

In 2010, Coxiella burnetii was identified at a high prevalence in the placentas of Northern fur seals (*Callorhinus ursinus*) collected at a single rookery on St. Paul Island Alaska; an area of the United States where the agent was not known to be present. As contamination was hypothesized as a potential cause of false positives, but nothing was known about environmental C.burnetii in the region, an environmental survey was conducted to look for the prevalence and distribution of the organism on the island. While environmental prevalence was low, two strains of the organism were identified using PCR targeting the COM1 and IS1111 genes. The two strains are consistent with the organism that has been increasingly identified in marine mammals as well as a strain type more commonly found in terrestrial

environments and associated with disease in humans and terrestrial animals. Further work is needed to elucidate information regarding the ecology of this organism in this region, particularly in association with the coastal environment.

Duncan, C. G., Tiller, R., Mathis, D., Stoddard, R., Kersh, G. J., Dickerson, B., & Gelatt, T. (2014). *Brucella* Placentitis and Seroprevalence in Northern Fur Seals (*Callorhinus Ursinus*) of the Pribilof Islands, Alaska. *Journal of Veterinary Diagnostic Investigation, 26*(4), 507-512. https://doi.org/10.1177/1040638714532647

Brucella species infect a wide range of hosts with a broad spectrum of clinical manifestations. In mammals, one of the most significant consequences of Brucella infection is reproductive failure. There is evidence of Brucella exposure in many species of marine mammals, but the outcome of infection is often challenging to determine. The eastern Pacific stock of northern fur seals (NFSs, *Callorhinus ursinus*) has declined significantly, spawning research into potential causes for this trend, including investigation into reproductive health. The objective of the current study was to determine if NFSs on St. Paul Island, Alaska have evidence of Brucella exposure or infection. Archived DNA extracted from placentas (n = 119) and serum (n = 40) samples were available for testing by insertion sequence (IS) 711 polymerase chain reaction (PCR) and the Brucella microagglutination test (BMAT), respectively. As well, placental tissue was available for histologic examination. Six (5%) placentas were positive by PCR, and a single animal had severe placentitis. Multilocus variable number tandem repeat analysis profiles were highly clustered and closely related to other Brucella pinnipedialis isolates. A single animal was positive on BMAT, and 12 animals had titers within the borderline range; 1 borderline animal was positive by PCR on serum. The findings suggest that NFSs on the Pribilof Islands are exposed to Brucella and that the organism has the ability to cause severe placental disease. Given the population trend of the NFS, and the zoonotic nature of this pathogen, further investigation into the epidemiology of this disease is recommended.

Eldridge, K. A. (2016). An Analysis of Archaeofauna Recovered from a Russian Period Camp on St. Paul Island, Pribilof Islands, Alaska. *Arctic Anthropology, 53*(2), 33-51. https://doi.org/10.3368/aa.53.2.33

This paper examines the history of the early Russian-American settlement of Zapadni (XPI-007) on St. Paul Island in the Pribilofs. An analysis of faunal remains recovered from the site during archaeological work done in association with The St. Paul History and Archaeology Project, led by Douglas Veltre and Allen McCartney in 2000 and 2001, supplements oral and written historical records. These well-preserved archaeofauna provide insight into the ethnic identity of the Unangaŷ laborers who harvested northern fur seals (*Callorhinus ursinus*) near the site between AD 1787 and the early 1800s and a glimpse at the beginning of the creolization that affected both Unangaŷ and Russian individuals. Although a small number of domesticated specimens were identified, the Zapadni faunal assemblage demonstrates the maintenance of traditional Unangaŷ foodways during a time of intense colonialism and shows the overwhelming importance of northern fur seal pups as a subsistence resource.

Etnier, M. A. (2007). Defining and Identifying Sustainable Harvests of Resources: Archaeological Examples of Pinniped Harvests in the Eastern North Pacific. *Journal for Nature Conservation, 15*(3), 196-207. https://doi.org/10.1016/j.jnc.2007.04.003

Archaeologists and resource managers are starting to recognize the value of studying ancient cultures for examples of how resources have, and have not, been sustainably utilized in the past as a way of understanding current trends in environmental degradation. These studies do not provide sweeping generalizations about aboriginal resource use but, rather, identify the range of conditions under which sustainable harvests may be possible. The hypothesis of sustainable harvests must be tested using variables that can be measured equally well in ancient (e.g., archaeological) and modern contexts. These factors are carefully considered in this analysis of pinniped (seal and sea lion) remains from two archaeological sites on the eastern North Pacific (ENP) coast, where pinnipeds have been hunted for millennia. Reconstruction of the age composition, or harvest profile, of *Callorhinus ursinus* at the Ozette Village Site, Washington, shows that males and females of all ages were harvested, and supports the hypothesis that it was done so sustainably for over 500 years. After this period of apparent stability, C. ursinus abandoned local breeding colonies in the early historic period. In contrast, harvests of this species at the Moss Landing Hill Site, California, primarily targeted young of the year, and sub-adult and adult females. While this harvest is also inferred to have targeted a local breeding colony, C. ursinus appear to have been extirpated nearly 2000 years earlier at Moss Landing than at Ozette. The causes of these extirpations are not known, but the timing does not correspond well with known climatic changes, suggesting that subsistence, and perhaps commercial, hunting may have played a role. These examples underscore the need to recognize that patterns of resource use are highly variable - different cultures have had varying levels of effects on economically important species, and these effects have varied temporally, spatially, and taxonomically.

Fadely, B., Fritz, L., Ream, R., Towell, R., Sterling, J., Stinchcomb, C., . . . Gelatt, T. (2006). *Contrasting Western Steller Sea Lion and Northern Fur Seal Population Trends in Alaska*. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from https://www.afsc.noaa.gov/Quarterly/jfm2006/jfm06feat.pdf

The western stock of Steller sea lion (Eumetopias jubatus) and the northern fur seal (*Callorhinus ursinus*) are sympatric over large portions of their ranges in Alaskan waters, and both have declined substantially over the past 30 years. These population declines have resulted in a listing of 'endangered' for the western Steller sea lion under the Endangered Species Act, and of 'depleted' for the northern fur seal under the Marine Mammal Protection Act. Though both share some common traits, significant differences exist in body size (northern fur seals are much smaller than similarly aged Steller sea lions), life history traits, and in how each utilizes the marine environment. Exploring the interrelationship among these traits and environmental variables may help elucidate underlying environmental or anthropogenic factors affecting survival and reproductive rates, and hence population trends, of these two species. This article presents results of the most recently completed Steller sea lion and northern fur seal abundance surveys and examine their population trends from 1976 through 2005.

Fadely, B. S., Wieting, D., Fritz, L. W., & Adams, T. C. (2014). *Environmental Assessment for Issuance of Permits to Take Steller Sea Lions by Harassment During Surveys Using Unmanned Aerial Systems*. National Marine Fisheries Service Office of Protected Resources. Retrieved from https://repository.library.noaa.gov/view/noaa/4951

The National Marine Fisheries Service (NMFS) proposes to issue permits to take Steller sea lions for research, including during surveys using unmanned aerial systems (UAS). The effects of various research methods on Steller sea lions were evaluated in a Programmatic Environmental Impact Statement on the

Steller Sea Lion and Northern Fur Seal Research Programs (PEIS; NMFS 2007). That PEIS included analysis of the effects of aerial surveys using manned aircraft and did not consider the effects of UAS because they were not a proposed survey method at the time the PEIS was prepared. This EA supplements the analysis in that PEIS to evaluate the effects of takes by surveys using UAS. It also evaluates new information on the status of the species as it relates to the effects of permit issuance.

Fahlman, A., Loring, S. H., Johnson, S. P., Haulena, M., Trites, A. W., Fravel, V. A., & Van Bonn, W. G. (2014). Inflation and Deflation Pressure-Volume Loops in Anesthetized Pinnipeds Confirms Compliant Chest and Lungs. *Frontiers in Physiology, 5* https://doi.org/10.3389/fphys.2014.00433

We examined structural properties of the marine mammal respiratory system, and tested Scholander's hypothesis that the chest is highly compliant by measuring the mechanical properties of ther espiratory system in five species of pinniped under anesthesia (Pacific harbor seal, Phoca vitulina; northern elephant seal, Mirounga angustirostris; northern fur seal *Callorhinus ursinus*; California sea lion, Zalophusc alifornianus; and Steller sea lion ,Eumetopias jubatus). We found that the chest wall compliance (CCW) of all five species was greater than lung compliance (airways and alveoli, C_L)as predicted by Scholander, which suggests that the chest provides little protection against alveolar collapse or lung squeeze. We also found that specific respiratory compliance was significantly greater in wild animals than in animals raised in an aquatic facility. While differences in ages between the two groups may affect this incidental finding, it is also possible that lung conditioning in free-living animals may increase pulmonary compliance and reduce the risk of lung squeeze during diving. Overall, our data indicate that compliance of excised pinniped lungs provide a good estimate of total respiratory compliance.

Fisheries and Oceans Canada. (2012). *Recovery Potential Assessment for the Northern Fur Seal (Callorhinus Ursinus) in Canadian Waters.* CSAS, Vancouver, BC (Canada) Retrieved from http://waves-vagues.dfo-mpo.gc.ca/Library/347547.pdf

When the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designates an aquatic species as threatened or endangered, Fisheries and Oceans Canada (DFO), as the responsible jurisdiction under the Species at Risk Act (SARA), is required to undertake a number of actions. Many of these actions require scientific information on the current status of the species, population or designable unit, threats to its survival and recovery, and the feasibility of its recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) that is conducted shortly after the COSEWIC assessment. This timing allows for the consideration of peer-reviewed scientific analyses into SARA processes including recovery planning. In November 2010, COSEWIC determined that northern fur seals in Canada were threatened. The reason for the designation was that pup production on the Pribilof Islands, the largest breeding site and origin of the majority of animals migrating through Canadian waters, had declined by 38% over the last 30 years (3 generations). COSEWIC could not determine the cause of the decline, but noted it had persisted for the past 45 years. This RPA provides information and scientific advice required to meet various requirements under SARA, including public consultations, decisions regarding the listing of northern fur seals in Canadian waters under SARA, and developing a recovery strategy should the species be legally listed.

Flanary, J. R., Reiner, J. L., Helke, K. L., Kucklick, J. R., Gulland, F. M. D., & Becker, P. R. (2012). P6—Measurements of Perfluorinated Compounds in Plasma of Northern Fur Seals (*Callorhinus ursinus*) and a Preliminary Assessment of Their Relationship to Peroxisome Proliferation and Blood Chemistry Parameters. *Reproductive Toxicology*, *33*(4), 601. https://doi.org/10.1016/j.reprotox.2011.11.040

Perfluorinated compounds (PFCs) are known to exhibit toxicological effects in laboratory animals and may pose a risk of adverse effects in marine mammals. With some of the highest concentrations of PFCs measured in marine mammals from the Arctic, it is important to understand their distribution in Arctic species. In this study we report concentrations of thirteen perfluorinated compounds measured in northern fur seal (*Callorhinus ursinus*) plasma from animals harvested on St. Paul Island, Alaska in 2006 and 2007. Perfluoroundecanoic acid (PFUnA) was the most abundant compound with a median concentration of 5.5 ng/g ranging from 1.2 to 16.8 ng/g, followed by perfluorononanoic acid (PFNA) at 3.3 ng/g (1.3 to 9.6 ng/g) and perfluorooctane sulfonate (PFOS) at 3.0 ng/g (0.9 to 18.6 ng/g). Interestingly, PFOS is not the most abundant compound as it is in most environmental studies, suggesting a different source or preferential metabolism of the C11 and C9 carboxylic acid compounds. The results reported here demonstrate that several perfluorinated compounds are at measurable quantities in the northern fur seal, with some PFCs being measured for the first time in this species. We also determined that peroxisome counts and blood chemistry parameters were not significantly correlated to concentrations of perfluorinated compounds measured in the plasma. This suggests the levels of PFCs in this population are too low to induce peroxisome proliferation or to affect other blood chemistry markers.

Fowler, C. W., Jewell, T. E., & Lee, M. V. (2009). *Harvesting Young-of-the-Year from Large Mammal Populations: An Application of Systemic Management*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-192. Retrieved from http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-192.pdf

We evaluate the current commercial harvest of harp seal (Pagophilus groenlandicus) and proposed subsistence harvests of northern fur seal (*Callorhinus ursinus*) pups based on intraspecific comparisons. These comparisons utilize a pattern derived from 167 cases of estimated consumption rates by large mammals. In all cases, the predation rates involve large mammal prey less than 1 year of age. Recent harvests of harp seal pups are exceeded by 20 (about 12%) of the estimated consumption rates among the nonhuman species. Although this is not statistically significant, further analysis may find this harvest to be unsustainable when we account for other factors such as the number of other predators, the number of prey each predator consumes, trophic level, the biodiversity of the system, and differences involving terrestrial predators preying on marine prey. Initially, there is no scientific basis for rejecting a proposed subsistence harvest of 150 northern fur seal pups on St. George Island, Alaska, or a comparable harvest of 1,125 pups on St. Paul Island. The proposed harvests of fur seal pups are exceeded by 162 (97%) of the 167 cases of predation among nonhuman predatory species. In both cases, therefore, the harvests represent consumption rates in the lower extremes of predation rates observed for nonhuman species. Further explicit consideration of relevant factors could lead to a slight reduction in the assurance that the harvest of 150 pups is sustainable, but there is a low likelihood that such a harvest would prove to be unsustainable. This determination accounts for the complexity of the ecosystems involved owing to the integrative nature of the patterns used in the evaluation. The northern fur seal population is declining, raising concerns about the addition of a subsistence harvest to

the mortality this species experiences. In management, a declining population reflects all of the contributing factors to include all human influence. Management is necessary to relieve systems of the abnormal effects of our activities whenever human influence is found to be unusual, abnormal, or pathological. Such influence involves the full spectrum of human activities to include the effects of abnormal fisheries harvests, pollution, and CO2 production. As long as harvests of the declining species are not abnormally large, other abnormal human influences are the preferred focus of management. The comparisons used in our study make the conclusions regarding northern fur seals seem conservative, largely because most examples of predation among nonhuman predators exceed the harvest rates proposed for this species. Overtly accounting for other factors could lead to the conclusion that proposed harvests are less conservative than initially indicated. We show, for example, that directly accounting for the number of competing predators is likely to show the proposed harvest to be exceeded by a smaller portion of the sample among nonhuman predators than when this factor is not explicitly treated. Nevertheless, the mortality rates of the proposed harvest are small enough that it is likely that they fall in the lower end of the spectrum of most subsets of data for consumption rates among other large mammals – subsets that would emerge through explicit consideration of more specific management questions.

Frisman, E. Y., Zhdanova, O. L., & Kuzin, A. E. (2019). The Outcome of Northern Fur Seal Harvesting: The Results of Calibration of Mathematical Models Based on Observation Data (the Example of Tyulenii Island Population). *Russian Journal of Ecology, 50*(2), 161-171. https://doi.org/10.1134/s1067413619020048

Tendencies in the dynamics of harvested northern fur seal (*Callorhinus ursinus*) population on the Tyulenii Island have been analyzed in detail. The results show that retardation of reproduction (decrease in the numbers of pups) and decline in the survival of young females (up to 3 years of age) by the late 1980s resulted in a reduction of the total number of females and a significant increase in the proportion of older females. This tendency changed during the later observation period (after 1988-1989) due to increase in the survival of young females: the female population has gradually recovered, with the proportion of young females increasing at the expense of old females (aged over 10 years). The age composition of males has also changed: the proportion of young animals has decreased, while that of large mature males (bulls) has increased. Moreover, the number of bulls continues to increase and has already exceeded the level that formerly provided for the well-being of the population. This, a paradoxical situation has arisen: the numbers of females and bulls are increasing, whereas pup production remains at a low level.

Gelatt, T. S., & Gentry, R. (2018). Northern Fur Seal: *Callorhinus Ursinus*. In *Encyclopedia of Marine Mammals.* B. Würsig, J. G. M. Thewissen, & K. M. Kovacs (Eds.), (3rd ed., pp. 645-648). London; San Diego, CA: Academic Press. https://doi.org/10.1016/B978-0-12-804327-1.00184-9

The northern fur seal is the oldest living genus of the family Otariidae, with origins 2–5 million years ago. They inhabit the North Pacific Ocean and Bering Sea with breeding rookeries extending from Sakhalin Island in the Sea of Okhotsk east to the Kuril Islands, Commander Islands, Pribilof, and Aleutian Islands in the Bering Sea, and the Farallon and San Miguel Islands of California. Northern fur seals have been the target of intensive commercial harvest since at least the late 1700s with the primary focus on the Pribilof Islands of Alaska. The species is considered “depleted,” meaning that abundance is currently believed to be below the optimum sustainable population.

Gibbons, A. (2010). Going Back to the Future to Understand Climate Change. *Science, 330*(6004), 581-581. Retrieved from https://science.sciencemag.org/content/sci/330/6004/582.full.pdf

The article discusses research wherein paleontological data is used to predict how various organisms will fare as heightened greenhouse gases usher in climatic changes. Stanford University paleoecologist Rebecca Terry and colleagues studied 24 species of rodents by examining owl pellets in Nevada and Utah. Elizabeth Hadly and Malin Pinsky, also of Stanford University, conducted a genetic study of northern fur seals.

Gmuca, N. V., Kuhn, C. E., Dickerson, B., & Liwanag, H. E. M. (2015). *Effects of Electronic Instrumentation on Thermoregulation in Northern Fur Seals.* Paper presented at the Integrative and Comparative Biology. Retrieved from http://www.sicb.org/meetings/2015/schedule/abstractdetails.php?id=182

The tracking of marine mammals with electronic devices enables researchers to gain a better understanding of their movements and at-sea behavior, thereby facilitating conservation efforts. In pinnipeds (seals and sea lions), electronic instruments are typically glued to the animal's fur, either directly to the pelage or on a neoprene patch. When instruments are recovered for data collection, they are retrieved either by cutting the fur or by cutting through the neoprene patch and leaving the bottom layer of neoprene attached to the animal. It is thought that the cut fur will be restored or the neoprene patch shed during the molt, but this has never been explicitly investigated. This study examined the effects of instrument attachment and retrieval on thermoregulation in northern fur seals. Northern fur seals rely primarily on their fur for insulation in water, and are thus ideal for determining the long term impacts of instrumentation on pelage function and recovery. To assess the thermoregulatory consequences of instrumentation, we measured the thermal conductivity of northern fur seal pelts in water for (a) instruments glued directly to the fur (N=30) and (b) instruments glued to the fur with a neoprene base (N=30). For each attachment method, we measured the thermal conductivity of the pelt (a) unmodified, (b) with instrument attached, and (c) with instrument removed. Using a hyperbaric chamber, we also measured the extent to which water is able to penetrate the air layer during diving, for both unmodified and modified pelts. This is the first study to measure the thermoregulatory consequences of instrumentation in fur seals and will help determine which method of instrument attachment best minimizes those consequences.

Gomez, M. D., Rosen, D. A. S., & Trites, A. W. (2016). Net Energy Gained by Northern Fur Seals (*Callorhinus ursinus*) Is Impacted More by Diet Quality Than by Diet Diversity. *Canadian Journal of Zoology, 94*(2), 123-135. https://doi.org/10.1139/cjz-2015-0143

Understanding whether northern fur seals (*Callorhinus ursinus* (L., 1758)) are negatively affected by changes in prey quality or diversity could provide insights into their on-going population decline in the central Bering Sea. We investigated how six captive female fur seals assimilated energy from eight different diets consisting of four prey species (walleye pollock (Gadus chalcogrammus Pallas, 1814, formerly Theragra chalcogrammus (Pallas, 1814)), Pacific herring (Clupea pallasii Valenciennes in Cuvier and Valenciennes, 1847), capelin (Mallotus villosus (Muller, 1776)), and magister armhook squid (Berryteuthis magister (Berry, 1913))) fed alone or in combination. Net energy was quantified by

measuring fecal energy loss, urinary energy loss, and heat increment of feeding. Digestible energy (95.9%-96.7%) was high (reflecting low fecal energy loss) and was negatively affected by ingested mass and dietary protein content. Urinary energy loss (9.3%-26.7%) increased significantly for high-protein diets. Heat increment of feeding (4.3%-12.4%) was significantly lower for high-lipid diets. Overall, net energy gain (57.9%-83.0%) was affected by lipid content and varied significantly across diets. Mixed-species diets did not provide any energetic benefit over single-species diets. Our study demonstrates that diet quality was more important in terms of energy gain than diet diversity. These findings suggest that fur seals consuming low-quality prey in the Bering Sea would be more challenged to obtain sufficient energy to satisfy energetic and metabolic demands, independent of high prey abundance.

Gramling, C. (2018). Strong Gusts Send Seal Pups on Longer Migrations. *Science News, 193*(5), 9-9. Retrieved from http://commerce.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=128257306&site=ehost-live&scope=site

The article discusses the impact that wind speed has on the migration of northern fur seal pups, referencing a study coauthored by scientist Noel Pelland.

Gudmundson, C. J., Zeppelin, T. K., & Ream, R. R. (2006). Application of Two Methods for Determining Diet of Northern Fur Seals (*Callorhinus ursinus*). *Fishery Bulletin, 104*(3), 445-455. Retrieved from https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/2006/1043/gudmundson.pdf

Examination of hard parts recovered from scats (feces) is currently the most common method for determining the diet of pinnipeds. However, large or sharp prey remains may be spewed (regurgitated) biasing prey composition and size estimations in diet studies based on scats. Percent frequency of occurrence (FO%) and age or size of selected prey remains recovered from northern fur seal (*Callorhinus ursinus*) seat (n=3444) and spew samples (n=267) collected from rookeries on St. George Island and St. Paul Island, Alaska, between 1990 and 2000 were compared to determine if a bias in prey composition and age or size estimations existed between scats and spews. Overall prey composition was similar between sample type and location, but the relative FO% of primary prey (>= 5%) varied by sample type and location. Age or size estimates of walleye pollock (Theragra chalcogramma) and of two species of gonatid squids (Gonatopsis borealis and Berryteuthis magister) were significantly larger in spews than in scats. Observed differences in FO% and estimated age or size of prey species whose remains were found in scats and spews likely result from size-selective digestion of prey remains. Scats were biased toward smaller prey remains, whereas spews were biased toward larger prey remains and cephalopod beaks. The percent overlap between age classes of walleye pollock caught by the commercial trawl fishery and age classes of walleye pollock consumed by northern fur seals varied noticeably between sample types for both islands (scats: St. George=15. 5%; St. Paul=4.1%; spews: St. George=94.6%; St. Paul=89.6%). These results demonstrate that the inclusion of multiple sampling methods allows for a more accurate assessment of northern fur seal prey occurrence and prey age and size.

Guell, B. A., Kurle, C. M., Zeppelin, T. K., & Ream, R. R. (2017). *Determining Northern Fur Seal Pup Weaning with Stable Isotope and Stomach Content Analyses.* Paper presented at the Integrative and Comparative Biology. Retrieved from http://www.sicb.org/meetings/2017/schedule/abstractdetails.php?id=972

Mammals undergo major dietary changes upon weaning, however their life histories can make it difficult to observe foraging behaviors in nature. Northern fur seals (*Callorhinus ursinus*; NFS) are primarily in the Bering Sea and North Pacific Ocean, and roughly half the world's population breeds on the Pribilof Islands, Alaska. Pups are born in July, nurse intermittently for ~4 months, then wean and depart the island for an extended pelagic migration. The often cryptic, pelagic foraging of NFS makes them ideal candidates for stable isotope analysis (SIA) which has been used to describe the foraging behaviors and habitat use of adults and juveniles. Because pups rely on their mother's milk before weaning, we assumed their stable isotope values would reflect a higher trophic level than that of their mothers throughout their nursing period. When pups begin consuming a likely diet of small fish and crustaceans, we expected to see lower stable nitrogen isotope values (δ15N) in pup tissues. The degree to which pups forage for prey to supplement milk consumption, however, or whether they abruptly switch when the migration begins, is unknown. To estimate this shift, we collected milk and prey contents from stomachs, vibrissae, muscle, liver, and serum samples from pups taken during subsistence harvests on St. George Island, Alaska, throughout the nursing period (Sept, n=5; Oct, n=31; Nov, n=21). NFS vibrissae grow throughout their lifetimes, so they provide a continuous record of assimilated diet. SIA of vibrissae segments allowed for a chronological measure of pup diet from in-utero to weaning, whereas SI values from liver and serum provided assimilated diet data from the week previous to sample collection. We compared stable isotope values from pup tissues to those from NFS milk and other prey collected from their stomachs to determine how well SIA captures the weaning process.

Gurarie, E., Andrews, R. D., & Laidre, K. L. (2009). A Novel Method for Identifying Behavioural Changes in Animal Movement Data. *Ecology Letters, 12*(5), 395-408. https://doi.org/10.1111/j.1461-0248.2009.01293.x

*A goal of animal mo*vement analysis is to reveal behavioural mechanisms by which organisms utilize complex and variable environments. Statistical analysis of movement data is complicated by the fact that the data are multidimensional, autocorrelated and often marked by error and irregular measurement intervals or gappiness. Furthermore, movement data reflect behaviours that are themselves heterogeneous. Here, we model movement data as a subsampling of a continuous stochastic processes, and introduce the behavioural change point analysis (BCPA), a likelihood-based method that allows for the identification of significant structural changes. The BCPA is robust to gappiness and measurement error, computationally efficient, easy to implement and reveals structure that is otherwise difficult to discern. We apply the analysis to a GPS movement track of a northern fur seal (*Callorhinus ursinus*), revealing an unexpectedly complex diurnal behavioural profile, and demonstrate its robustness to the greater errors associated with the ARGOS tracking system. By informing empirical interpretation of movement data, we suggest that the BCPA can eventually motivate the development of mechanistic behavioural models.

Hanks, E. M., Hooten, M. B., Johnson, D. S., & Sterling, J. T. (2011). Velocity-Based Movement Modeling for Individual and Population Level Inference. *PLoS One, 6*(8) https://doi.org/10.1371/journal.pone.0022795

Understanding animal movement and resource selection provides important information about the ecology of the animal, but an animal's movement and behavior are not typically constant in time. We present a velocity-based approach for modeling animal movement in space and time that allows for

temporal heterogeneity in an animal's response to the environment, allows for temporal irregularity in telemetry data, and accounts for the uncertainty in the location information. Population-level inference on movement patterns and resource selection can then be made through cluster analysis of the parameters related to movement and behavior. We illustrate this approach through a study of northern fur seal (*Callorhinus ursinus*) movement in the Bering Sea, Alaska, USA. Results show sex differentiation, with female northern fur seals exhibiting stronger response to environmental variables.

Hanna, G. D., & Lindsay, J. A. (2008). *The Alaska Fur-Seal Islands*. National Ocean Service Office of Response and Restoration. NOS OR&R 16.

[NO ABSTRACT AVAILABLE]

Hansen, M. J., Bertelsen, M. F., Christensen, H., Bisgaard, M., & Bojesen, A. M. (2012). Occurrence of *Pasteurellaceae* Bacteria in the Oral Cavity of Selected Marine Mammal Species. *Journal of Zoo and Wildlife Medicine, 43*(4), 828-835. https://doi.org/10.1638/2011-0264r1.1

The occurrence of bacteria belonging to Pasteurellaceae in the oral cavity of captive marine mammals was investigated using culture and subsequent geno- and phenotypic characterization and phylogenetic analyses. A total of 89 bacterial isolates from pinnipeds tentatively classified with the family Pasteurellaceae were further characterized by phylogenetic analysis of rpoB gene sequences, which showed that the isolates investigated formed five distinct groups. Four strains from California sea lions (Zalophus californianus) made up group I, which was classified with Pasteurella canis. Group II comprised four strains from harbor seals (Phoca vitulina) and grey seals (Halichoerus grypus) classified with Pasteurella stomatis. Group III consisted of 28 strains, isolated from harbor and gray seals and represented Bisgaardia genomospecies 1. Two strains from a harbor and a grey seal, group IV, were classified with Bisgaardia hudsonensis. Fifty-two strains from northern fur seals (*Callorhinus ursinus*), walruses (Odobenus rosmarus), and California and Steller sea lions (Eumetopias jubatus) formed group V and represented Otariodibacter oris. No Pasteurellaceae isolates were obtained from cetaceans, but Pasteurellaceae were isolated from all sampled pinnipeds. On the basis of these results, it is very likely that Pasteurellaceae bacteria represent a part of the normal oral flora in pinnipeds.

Hayden, A. B. (2012). *Variability in Population Trends, Life History Characteristics,and Milk Composition of Northern Fur Seals in Alaska.* University of Alaska Fairbanks. Retrieved from http://hdl.handle.net/11122/8586

The northern fur seal population on the Pribilof Islands has been declining since the 1960s and is now less than 30% of its former size. Chapter 1 examines factors that might cause a population to decrease to such an extent and concludes that only nutritional limitation caused by climate change or commercial fisheries, predation by killer whales, or a combination of factors that includes conditions in the North Pacific during the winter were possible explanations. Chapter 2 reports the seasonal patterns in proximate composition of fur seal milk between St. Paul Island (one of the Pribilof Islands) and Bogoslof Island (an increasing population) to understand the energy requirements of lactation and the energetics of pup growth and body condition at weaning. Factors that caused variability in milk composition included days postpartum, time ashore, individual phenotype, island and preceding trip duration. Average milk lipid increased from 45.5 plus or minus 0.7% to 53.8 plus or minus 1.0% at St. Paul and from 45.8 plus or minus 0.7% to 57.3 plus or minus 0.8% at Bogoslof between July and October, while

average milk protein remained relatively stable ranging between 10.0% and 10.5%. The lipid content of northern fur seal milk near peak lactation is the highest reported among otariid seals and among the highest known for all mammals.

Hernandez-Orts, J. S., Scholz, T., Brabec, J., Kuzmina, T., & Kuchta, R. (2015). High Morphological Plasticity and Global Geographical Distribution of the Pacific Broad Tapeworm *Adenocephalus pacificus* (Syn. *Diphyllobothrium pacificum*): Molecular and Morphological Survey. *Acta Tropica, 149*, 168-178. https://doi.org/10.1016/j.actatropica.2015.05.017

The most important causative agent of human diphyllobothriosis in South America, *Diphyllobothrium pacificum*, is transferred to the original genus *Adenocephalus* Nybelin, 1931; revised and redescribed on the basis of the evaluation of an extensive material collected mainly from northern fur seal,*Callorhinus ursinus*, from St. Paul Island, Alaska. Detailed analysis of morphological and morphometrical data shows a high variability in most of the characteristics traditionally used in diagnosis of diphyllobothriid tapeworms. Phylogenetic analyses based on newly characterised sequences of mitochondrial cytochrome c oxidase subunit 1 and nuclear large subunit ribosomal RNA genes consistently reveal Adenocephalus pacificus as a sister lineage to the clade formed of the remaining Diphyllobothrium species and other genera (Digramma, Diplogonoporus, Ligula). Despite the generally similar morphology, A. pacificus can be differentiated from the closely related taxa in the presence of transverse papilla-like tegumental protuberances distributed anteriorly, separated by narrow semicircular grooves on the ventral surface of proglottids between their anterior margin and the anterior edge of the male gonopore, and relatively small eggs. A. pacificus displays a relatively low host specificity (found in 9 of 16 otariids, and in accidental hosts such as man, dog and jackal, the latter representing a new host) and a uniquely wide geographical distribution on both hemispheres. In addition, suitability of morphological criteria used in diagnostics of diphyllobothriid cestodes is discussed.

Hernandez-Orts, J. S., Scholz, T., Brabec, J., Kuzmina, T., & Kuchta, R. (2018). Does the Number of Genital Organs Matter? Case of the Seal Tapeworm *Diphyllobothrium* (Syn. *Diplogonoporus*) *tetrapterum* (Cestoda: *Diphyllobothriidea*). *Canadian Journal of Zoology, 96*(3), 193-204. https://doi.org/10.1139/cjz-2017-0013

The seal tapeworm Diphyllobothrium tetrapterum (von Siebold, 1848) Baer, 1932 (syn. Diplogonoporus tetrapterus) is exceptional among cestodes because it possesses two types of the strobila, one with a multiple set of genitalia per proglottid and another with a single set of reproductive organs per proglottid. In this study, Diph. tetrapterum is redescribed on the basis of extensive, well-fixed material from the northern fur seal (*Callorhinus ursinus* (Linnaeus, 1758)) from Alaska, USA. A critical morphological and molecular study of comprehensive material from several hosts throughout the Northern Hemisphere is provided. As a result, Diplogonoporus mutabilis Belopolskaia, 1960 and Diplogonoporus violettae Yurakhno, 1986 become junior synonyms of Diph. tetrapterum. Our study provides evidence of intraspecific and even individual variability of Diph. tetrapterum in the number of genital complexes, thus making this generic feature questionable for circumscription of the diphyllobothriid genera. The seal tapeworm has been found exclusively in the Northern Hemisphere and exhibits a wide (euryxenous) specificity at the level of the definitive host, having been found in a number of seals, the sea otter (Enhydra lutris (Linnaeus, 1758)), and exceptionally, in other terrestrial mammals. Plerocercoids of Diph. tetrapterum are reported from the second (fish) intermediate host for the first time, in this case the pink salmon (Oncorhynchus gorbuscha (Walbaum, 1792)) from Alaska.

Horimoto, T., Mitani, Y., Kobayashi, M., Hattori, K., & Sakurai, Y. (2017). Seasonal and Spatial Occurrence of Northern Fur Seals *Callorhinus ursinus* around Northern Japan. *Mammal Study, 42*(1), 51-56. https://doi.org/10.3106/041.042.0106

Northern fur seals (*Callorhinus ursinus*) disperse to broad areas and overwinter in the North Pacific Ocean during the non-breeding season. Fur seals breeding on islands off Russia mainly overwinter in the Sea of Japan and the off Pacific side of Japan in this season. Although the distribution of fur seals seems to vary with sexes and growth stages in this season, there is little information around Japan. We analysed data on stranding and collecting records of fur seals in the non-breeding season around northern Japan during 2005-2014 for investigating their intra-seasonal and spatial occurrence. The sex and growth stage composition differed between sampling areas. Adult males were dominant in the Sea of Japan, while juveniles and adult females were dominant in the Pacific coast of northern Japan. Compared with previous researches, our results can provide important information for elucidating migration pattern and habitat selection of each sex and growth stage around northern Japan.

Horimoto, T., Mitani, Y., Kobayashi, Y., Hattori, K., & Sakurai, Y. (2012). Distribution and Stranding Records of the Northern Fur Seal *Callorhinus ursinus* near Tsugaru Strait During Winter and Spring 2009. *Nippon Suisan Gakkaishi, 78*(2), 256-258. https://doi.org/10.2331/suisan.78.256

[NO ABSTRACT AVAILABLE]

Horimoto, T., Mitani, Y., & Sakurai, Y. (2016). Spatial Association between Northern Fur Seal (*Callorhinus ursinus*) and Potential Prey Distribution During the Wintering Period in the Northern Sea of Japan. *Fisheries Oceanography, 25*(1), 44-53. https://doi.org/10.1111/fog.12133

Elucidating the response of marine predators to oceanographic features helps in understanding their foraging strategies and the cause of their spatial overlap and interference with fishery activities. Northern fur seal is a highly pelagic species during the wintering period. In recent years, fur seals have consistently been found distributed near the coast of southwest Hokkaido, Japan. Because interference by fur seals with coastal fishery activities has become a serious concern, an understanding is sought as to why fur seals come ashore in this area. We conducted ship-based observations and estimated fur seal density. To elucidate the spatial and seasonal association of fur seal distribution and ocean environments, we constructed statistical models to describe how potential prey distribution and oceanographic features influenced the fur seal spatial distribution during the wintering period. Fur seal distribution corresponded markedly to potential prey distribution, and they tended to aggregate along the narrow continental shelf that is the main geographic feature of this area, which is 2000m deep and approximately 10km from the coast. Walleye pollock [Gadus chlcogrmm (Theragra chlcogrmm)] and arabesque greenling (Pleurogrammus azonus), which are one of the main prey for fur seals, move to the shallow area to spawn on the continental shelf seasonally, so potential prey abundance could be higher in coastal areas than offshore. Moreover, the absence of a mesopelagic biotic community may be one of the main factors in the coastal distribution of the fur seal.

Hunt, G. L., Napp, J. M., & Stabeno, P. J. (2006). *Ecosystem Responses to Recent Warming in the Southeastern Bering Sea.* Paper presented at the Ocean Sciences Meeting. Retrieved from https://search.proquest.com/docview/20321698?accountid=28258

During the past decade, the southeastern Bering Sea has experienced an overall trend of diminishing seasonal sea ice cover, increasing water temperatures and increased stratification. Ecosystem responses have included changes in the timing of the spring bloom, summer blooms of species heretofore rare in the southeastern Bering, decreases in summer zooplankton biomass, including that of jellyfish, and shifts in species composition, northward shifts in the distribution of some fish species, and continuing declines in northern fur seal populations at the Pribilof Islands. Population declines of seabirds at the Pribilofs may have stabilized or reversed for some species. Ecosystem responses reflect changes in the pathways of energy through the ecosystem. Although the interannual signal is strongest for the physical parameters, many of the responses of upper trophic level species occur over longer time-scales. The strong interannual variations in the physics provide the opportunity to identify mechanisms that will be important in determining how future climate change may affect the marine ecosystem of the eastern Bering Sea.

Huntington, H. P., Braem, N. M., Brown, C. L., Hunn, E., Krieg, T. M., Lestenkof, P., . . . Zavadil, P. (2013). Local and Traditional Knowledge Regarding the Bering Sea Ecosystem: Selected Results from Five Indigenous Communities. *Deep Sea Research Part II: Topical Studies in Oceanography, 94*, 323-332. https://doi.org/10.1016/j.dsr2.2013.04.025

We documented local and traditional knowledge (LTK) about the Bering Sea ecosystem through interviews with Alaska Native elders, hunters, and fishers in the coastal communities of Akutan, St. Paul, Togiak, Emmonak, and Savoonga. Their observations describe a complex and changing ecosystem, with indications of divergent impacts of change in the south (many species in decline) and the north (a productive ecosystem). Observed changes in species abundance suggest that the marginal zone of maximum (March) sea-ice extent is experiencing the most rapid directional changes, including shifts in distribution of ice-associated species such as bearded seal (Erignathus barbatus). Causes of declines in other species such as northern fur seals (*Callorhinus ursinus*) and murres (Uria spp.) are harder to identify, and seabird abundance trends appear to vary greatly with location. Connections between the LTK findings and other research under the North Pacific Research Board and National Science Foundation's Bering Sea Project were modest due to mismatches in temporal and spatial scales of reference and the fact that LTK observations were not initially made with scientific relevance in mind. We found, however, the overall observations to be consistent with the emerging picture of high spatial variability in the Bering Sea ecosystem.

Insley, S. J., Robson, B. W., Yack, T., Ream, R. R., & Burgess, W. C. (2008). Acoustic Determination of Activity and Flipper Stroke Rate in Foraging Northern Fur Seal Females. *Endangered Species Research, 4*(1-2), 147-155. https://doi.org/10.3354/esr00050

Foraging effort for lactating female otariid pinnipeds is largely a function of the energy expended swimming to a site and diving in search of prey. This is especially true for northern fur seal *Callorhinus ursinus* females, which predictably punctuate their suckling with 7 to 12 d foraging trips at sea, with swimming distances often exceeding 400 km. In the present study we tested a unique approach (flow noise from onboard acoustic dataloggers) to empirically measure swim effort in free ranging female

northern fur seals, the first such field measurements on an otariid pinniped. We first measured behavioural activity budgets of seals from a combination of satellite telemetry, pressure (depth), and onboard acoustic data. From these data we were able to quantify the time spent in each of 4 mutually exclusive forms of behaviour: locomoting, diving, resting, and surface activity. Second, flipper stroke rates and stroke rate patterns were measured from the acoustic data for each seal during 3 dive types (i.e. locomoting, shallow and mid/deep dives) and during 3 dive parts (descent, bottom time and ascent). Although stroke rates during each of the 3 dive types were similar (ca. 0.5 Hz), they were distinct during the different parts of a dive. In each case, variation among individuals was significant. Stroke rate patterns were distinct for the different dive types and dive parts. Overall, in addition to applying a unique technique to measure foraging effort in a declining population, the results emphasize the importance of accounting for individual variation to obtain accurate estimates of foraging cost.

Ionita, M., Varela, M. G., Lyons, E. T., Spraker, T. R., & Tolliver, S. C. (2008). Hookworms (*Uncinaria lucasi*) and *Acanthocephalans* (*Corynosoma* Spp. and *Bolbosoma* Spp.) Found in Dead Northern Fur Seals (*Callorhinus ursinus*) on St. Paul Island, Alaska in 2007. *Parasitology Research, 103*(5), 1025-1029. https://doi.org/10.1007/s00436-008-1087-0

Intestines of dead northern fur seals (*Callorhinus ursinus*) on St. Paul Island (SPI), Alaska were inspected for specific internal parasites (hookworms and acanthocephalans) in July and August, 2007. Pups (n = 64) were examined for adult hookworms (Uncinaria lucasi) and four (6.25%) were infected. The number of specimens per infected pup was 1, 2, 2, or 408. Low prevalence was similar to that determined in the last investigation (2001) in dead fur seal pups on SPI by two of the present authors (Lyons and Spraker). Subadult males (SAMS-3-4 years old, n = 115) were examined for acanthocephalans and 25 (21.7.0%) were infected. Adult Corynosoma (C. obtuscens, C. strumosum, and C. validum) (n = 56) and immature Bolbosoma spp. (n = 4) were found. Apparently, this is a new host record for C. obtuscens and C. validum. Notes were made on finding tapeworms. in 114 of the 115 SAMs. Examination of some specimens revealed scolices characteristic of Diphyllobothrium spp.

Ishii, C., Ikenaka, Y., Nakayama, S. M. M., Mizukawa, H., Yohannes, Y. B., Watanuki, Y., . . . Ishizuka, M. (2017). Contamination Status and Accumulation Characteristics of Heavy Metals and Arsenic in Five Seabird Species from the Central Bering Sea. *Journal of Veterinary Medical Science, 79*(4), 807-814. https://doi.org/10.1292/jvms.16-0441

Seabirds are marine top predators and accumulate high levels of metals and metalloids in their tissues. Contamination by metals in the highly productive offshore region has become a matter of public concern. It is home to 80% of the seabird population in the U.S.A., 95% of northern fur seals (*Callorhinus ursinus*), and major populations of Steller sea lions (Eumetopias jubatus), walruses (Odobenus rosmarus) and whales. Here, the concentrations of eight heavy metals (Hg, Cd, Cr, Co, Ni, Cu, Zn and Pb) and a metalloid (As) in the liver and kidneys of the northern fulmar (Fulmarus glacialis), thick-billed murre (Uria lomvia), short-tailed shearwater (Puffinus tenuirostris), tufted puffin (Fratercula cirrhata) and horned puffin (Fratercula corniculata) collected in the Bering Sea were measured. As proxies of trophic level and habitat, nitrogen (delta N-15) and carbon (delta C-13) stable isotope ratios of breast muscles were also measured. Hepatic Hg concentration was high in northern fulmar, whereas Cd level was high in tufted puffin and northern fulmar. The Hg concentration and d15N value were positively correlated across individual birds, suggesting that Hg uptake was linked to the trophic status of consumed prey.

Furthermore, Hg concentration in our study was higher than those of the same species of seabirds collected in 1990.

Iwata, T., Mitani, Y., Yonezaki, S., Kohyama, K., & Takahashi, A. (2009). Validation of Acceleration Records to Monitor Swimming and Prey-Capture Behavior in the Captive Northern Fur Seal. *Nippon Suisan Gakkaishi, 75*(6), 989-994. https://doi.org/10.2331/suisan.75.989

This study aimed to evaluate the utility of acceleration data for monitoring the swimming and foraging behavior of a marine mammal. We examined the matches between the acceleration records obtained by animal-borne data loggers and the video observation of flipper movement and prey capture for a captive northern fur seal. The results showed that 93% of forelimb strokes were successfully detected. Furthermore, elevated swim speed, large changes in body angle and elevated stroke frequency were detected during prey pursuit or capture events. These results suggest that the swimming costs and the number of prey pursuits or captures can be estimated in free-ranging otariids using acceleration data.

Iwata, T., Yonezaki, S., Kohyama, K., & Mitani, Y. (2013). Detection of Grooming Behaviours with an Acceleration Data Logger in a Captive Northern Fur Seal (*Callorhinus ursinus*). *Aquatic Mammals, 39*(4), 378. https://doi.org/10.1578/am.39.4.2013.378

Northern fur seals (*Callorhinus ursinus*) continue to dive and forage during foraging trips in cold water. Although their dense fur may prevent a decrease in body temperature, they must spend considerable time grooming to maintain a layer of trapped air in their fur. This study examined grooming and shaking behaviours, which are high-energy cost movements, using an acceleration data logger to accurately estimate the energy budget of these aquatic mammals. The authors examined the consistency between the behav- ioural records obtained using an animal-borne acceleration data logger and video observations of a captive northern fur seal. Grooming behav- iour was defined as rubbing the body with its flippers with rolling that was occasionally associated with shaking. Grooming behaviour was detected by low-frequency components of lateral and dorsoventral acceleration resulting from rolling and high-frequency components of lateral acceleration resulting from rubbing and shaking. These observations show that the grooming and shaking behaviours of northern fur seals can be accurately detected using an acceleration data logger. We suggest that the energy budgets of free-ranging northern fur seals can be more accurately estimated using an index of energy costs and benefits captured using an acceleration data logger.

Jeanniard-du-Dot, T. (2015). *Foraging Strategies and Efficiencies of Lactating Northern and Antarctic Fur Seals: Implications for Reproductive Success.* (Ph.D.), University of British Columbia, Vancouver, BC, Canada. https://doi.org/10.14288/1.0166743

Efficient extraction of energy from the environment is key to the survival and reproductive success of wild animals. Understanding the ratio of energy gained to energy spent of different foraging strategies (i.e., foraging efficiency) can shed light on how animals cope with environmental changes and how it affects population trajectories. I investigated how female foraging strategies during the breeding season impact the foraging efficiencies and reproductive successes of two fur seal species—one declining (NFS–northern fur seals, St. Paul Island, Alaska) and one increasing (AFS–Antarctic fur seals, Kerguelen Island, Southern Ocean). I also sought to develop new accelerometry-based methods to easily determine fine-

scale energy expenditure at sea (VeDBA and flipper stroke metrics). Twenty lactating females of each species were captured and equipped with biologging tags to record GPS locations, depth and tri-axial acceleration. Energy expenditure for each foraging trip was measured using the doubly-labeled water method, and energy gained while foraging was determined from 1) diet composition (scat hard-parts and DNA) and blood stable isotope ratios; and 2) numbers of prey capture attempts (from head acceleration). Maternal investment in pups was determined from pup growth rates or from energy content of milk samples. Results showed acceleration metrics were only accurate at predicting energy expended by fur seals when time-activity budgets were taken into account (i.e., time spent performing different types of activity). Foraging strategies of AFS females resulted in efficiencies of ~3.4, with more efficient females producing bigger pups at weaning that had greater chances of survival. NFS females employed two foraging strategies with very different efficiencies (~1.4 vs ~3.0) that were associated with different foraging habitats and diet qualities. However, NFS with the more efficient strategy (3.0) undertook longer foraging trips than the other NFS (1.4) or AFS (3.4), and thus fed their pups ~20% less frequently. As a consequence, the declining NFS (unlike the increasing AFS) had to compromise between the rate of energy acquisition and the pup feeding frequency. Such reductions in energy intake and time allocated to nursing pups can ultimately lower juvenile survival, and may explain the population decline of NFS in Alaska.

Jeanniard-du-Dot, T., Guinet, C., Arnould, J. P. Y., Speakman, J. R., & Trites, A. W. (2017). Accelerometers Can Measure Total and Activity-Specific Energy Expenditures in Free-Ranging Marine Mammals Only If Linked to Time-Activity Budgets. *Functional Ecology, 31*(2), 377-386. https://doi.org/10.1111/1365-2435.12729

1. Energy expenditure is an important component of foraging ecology, but is extremely difficult to estimate in free-ranging animals and depends on how animals partition their time between different activities during foraging. Acceleration data have emerged as a new way to determine energy expenditure at a fine scale but this needs to be tested and validated in wild animals. 2. This study investigated whether vectorial dynamic body acceleration (VeDBA) could accurately predict the energy expended by marine predators during a full foraging trip. We also aimed to determine whether the accuracy of predictions of energy expenditure derived from acceleration increased when partitioned by different types of at-sea activities (i.e. diving, transiting, resting and surface activities). 3. To do so, we equipped 20 lactating northern (*Callorhinus ursinus*) and 20 lactating Antarctic fur seals (Arctocephalus gazella) with GPS, time-depth recorders and tri-axial accelerometers and obtained estimates of field metabolic rates using the doubly labelled water (DLW) method. VeDBA was derived from tri-axial acceleration, and at-sea activities (diving, transiting, resting and surface activities) were determined using dive depth, tri-axial acceleration and travelling speed. 4. We found that VeDBA did not accurately predict the total energy expended by fur seals during their full foraging trips (R-2 = 0.36). However, the accuracy of VeDBA as a predictor of total energy expenditure increased significantly when foraging trips were partitioned by activity and when activity-specific VeDBA was paired with time-activity budgets (R-2 = 0.70). Activity-specific VeDBA also accurately predicted the energy expenditures of each activity independent of each other (R-2 > 0.85). 5. Our study confirms that acceleration is a promising way to estimate energy expenditures of free-ranging marine mammals at a fine scale never attained before. However, it shows that it needs to be based on the time-activity budgets that make up foraging trips rather than being derived as a single measure of VeDBA applied to entire foraging trips. Our activity-based method provides a cost-effective means to accurately calculate energy expenditures of fur seals using acceleration and time-activity budgets, that can be transfered to studies on other species.

Jeanniard-du-Dot, T., Thomas, A. C., Cherel, Y., Trites, A. W., & Guinet, C. (2017). Combining Hard-Part and DNA Analyses of Scats with Biologging and Stable Isotopes Can Reveal Different Diet Compositions and Feeding Strategies within a Fur Seal Population. *Marine Ecology Progress Series, 584*, 1-16. https://doi.org/10.3354/meps12381

Accurately estimating predators' diets at relevant spatial and temporal scales is key to understanding animals' energetics and fitness, particularly in populations whose decline might be related to their diet such as northern fur seals *Callorhinus ursinus*. Our goals were to improve the accuracy of diet estimates and extend understanding of feeding ecology by combining 2 scat-based methods of diet determination (hard-part identification and DNA-metabarcoding) with stable isotope measurements and individual behavioural data. We collected 98 scats on a northern fur seal breeding colony. We also tracked 20 females with biologgers, and took blood samples to determine delta C-13 and delta N-15 values as proxies for seal foraging habitat and diet. Results show that diet composition from hard-parts analysis corresponded well with DNA results, with DNA yielding a greater diversity of prey species at a finer taxonomic level. Overall, scat-based methods showed that seals mostly fed on neritic shelf-associated prey. Cluster analyses of combined hard-parts and DNA results however identified 2 diet groups, one mostly neritic and the other mostly pelagic. Stable isotopes and behavioural data revealed that 40% of seals fed in oceanic waters on pelagic prey. This is more than indicated by scat-based analyses, which are likely biased towards animals foraging closest to the colony and underestimate some dietary specializations within the population. Consequently, the combination of multiple methods for diet identification with at-sea tracking of individuals can help identify and quantify specialist groups within a population and provide a wider spatial and temporal ecological context for dietary analysis.

Jeanniard-du-Dot, T., Trites, A. W., Arnould, J. P. Y., Speakman, J. R., & Guinet, C. (2017). Activity-Specific Metabolic Rates for Diving, Transiting, and Resting at Sea Can Be Estimated from Time-Activity Budgets in Free-Ranging Marine Mammals. *Ecology and Evolution, 7*(9), 2969-2976. https://doi.org/10.1002/ece3.2546

Time and energy are the two most important currencies in animal bioenergetics. How much time animals spend engaged in different activities with specific energetic costs ultimately defines their likelihood of surviving and successfully reproducing. However, it is extremely difficult to determine the energetic costs of independent activities for free-ranging animals. In this study, we developed a new method to calculate activity-specific metabolic rates, and applied it to female fur seals. We attached biologgers (that recorded GPS locations, depth profiles, and triaxial acceleration) to 12 northern (*Callorhinus ursinus*) and 13 Antarctic fur seals (Arctocephalus gazella), and used a hierarchical decision tree algorithm to determine time allocation between diving, transiting, resting, and performing slow movements at the surface (grooming, etc.). We concomitantly measured the total energy expenditure using the doubly-labelled water method. We used a general least-square model to establish the relationship between time-activity budgets and the total energy spent by each individual during their foraging trip to predict activity-specific metabolic rates. Results show that both species allocated similar time to diving (similar to 29%), transiting to and from their foraging grounds (similar to 26-30%), and resting (similar to 8-11%). However, Antarctic fur seals spent significantly more time grooming and moving slowly at the surface than northern fur seals (36% vs. 29%). Diving was the most expensive activity (similar to 30 MJ/day if done non-stop for 24 hr), followed by transiting at the surface (similar to 21 MJ/day). Interestingly, metabolic rates were similar between species while on land or while slowly moving at the surface (similar to 13 MJ/day). Overall, the average field metabolic rate was similar to 20

MJ/day (for all activities combined). The method we developed to calculate activity-specific metabolic rates can be applied to terrestrial and marine species to determine the energetic costs of daily activities, as well as to predict the energetic consequences for animals forced to change their time allocations in response to environmental shifts.

Jeanniard du Dot, T., Trites, A. W., Arnould, J. P. Y., Speakman, J. R., & Guinet, C. (2018). Trade-Offs between Foraging Efficiency and Pup Feeding Rate of Lactating Northern Fur Seals in a Declining Population. *Marine Ecology Progress Series, 600*, 207-222. https://doi.org/10.3354/meps12638

Foraging strategies and their resulting efficiency (energy gain to cost ratio) affect animals' survival and reproductive success and can be linked to population dynamics. However, they have rarely been studied quantitatively in free-ranging animals. We investigated foraging strategies and efficiencies of wild northern fur seals *Callorhinus ursinus* during their breeding season to understand potential links to the observed population decline in the Bering Sea. We equipped 20 lactating females with biologgers to determine at-sea foraging behaviours. We measured energy expenditure while foraging using the doubly-labelled water method, and energy gained using (1) the types and energy densities of prey consumed, and (2) the number of prey capture attempts (from acceleration data). Our results show that seals employed 2 foraging strategies: one group (40%) fed mostly in oceanic waters on small, high energy-density prey, while the other (60%) stayed over the shallow continental shelf feeding mostly on larger, lower quality fish. Females foraging in oceanic waters captured 3 times more prey, and had double the foraging efficiencies of females that foraged on-shelf in neritic waters. However, neritic seals made comparatively shorter trips, and likely fed their pups ~20 to 25% more frequently. The presence of these strategies which either favor foraging efficiency (energy) or frequency of nursing (time) might be maintained in the population because they have similar net fitness outcomes. However, neither strategy appears to simultaneously maximize time and energy allocated to nursing, with potential impacts on the survival of pups during their first year at sea.

Johnson, D. S., Hooten, M. B., & Kuhn, C. E. (2013). Estimating Animal Resource Selection from Telemetry Data Using Point Process Models. *Journal of Animal Ecology, 82*(6), 1155-1164. https://doi.org/10.1111/1365-2656.12087

Analyses of animal resource selection functions (RSF) using data collected from relocations of individuals via remote telemetry devices have become commonplace. Increasing technological advances, however, have produced statistical challenges in analysing such highly autocorrelated data. Weighted distribution methods have been proposed for analysing RSFs with telemetry data. However, they can be computationally challenging due to an intractable normalizing constant and cannot be aggregated (i.e. collapsed) over time to make space-only inference. In this study, we take a conceptually different approach to modelling animal telemetry data for making RSF inference. We consider the telemetry data to be a realization of a space-time point process. Under the point process paradigm, the times of the relocations are also considered to be random rather than fixed. We show the point process models we propose are a generalization of the weighted distribution telemetry models. By generalizing the weighted model, we can access several numerical techniques for evaluating point process likelihoods that make use of common statistical software. Thus, the analysis methods can be readily implemented by animal ecologists. In addition to ease of computation, the point process models can be aggregated over time by marginalizing over the temporal component of the model. This allows a full range of models to be constructed for RSF analysis at the individual movement level up to the study area level. To

demonstrate the analysis of telemetry data with the point process approach, we analysed a data set of telemetry locations from northern fur seals (*Callorhinus ursinus*) in the Pribilof Islands, Alaska. Both a space-time and an aggregated space-only model were fitted. At the individual level, the space-time analysis showed little selection relative to the habitat covariates. However, at the study area level, the space-only model showed strong selection relative to the covariates.

Johnson, D. S., London, J. M., & Kuhn, C. E. (2011). Bayesian Inference for Animal Space Use and Other Movement Metrics. *Journal of Agricultural Biological and Environmental Statistics, 16*(3), 357-370. https://doi.org/10.1007/s13253-011-0056-8

The analysis of animal movement and resource use has become a standard tool in the study of animal ecology. Telemetry devices have become quite sophisticated in terms of overall size and data collecting capacity. Statistical methods to analyze movement have responded, becoming ever more complex, often relying on state-space modeling. Estimation of movement metrics such as utilization distributions have not followed suit, relying primarily on kernel density estimation. Here we consider a method for making inference about space use that is free of all of the major problems associated with kernel density estimation of utilization distributions such as autocorrelation, irregular time gaps, and error in observed locations. Our proposed method is based on a data augmentation approach that defines use as a summary of the complete path of the animal which is only partially observed. We use a sample from the posterior distribution of the complete path to construct a posterior sample for the metric of interest. Three basic importance sampling based methods for sampling from the posterior distribution of the path are proposed and compared. We demonstrate the augmentation approach by estimating a spatial map of diving intensity for female northern fur seals in the Pribilof Islands, Alaska.

Johnson, D. S., London, J. M., Lea, M. A., & Durban, J. W. (2008). Continuous-Time Correlated Random Walk Model for Animal Telemetry Data. *Ecology, 89*(5), 1208-1215. https://doi.org/10.1890/07-1032.1

We propose a continuous-time version of the correlated random walk model for animal telemetry data. The continuous-time formulation allows data that have been nonuniformly collected over time to be modeled without subsampling, interpolation, or aggregation to obtain a set of locations uniformly spaced in time. The model is derived from a continuous-time Ornstein-Uhlenbeck velocity process that is integrated to form a location process. The continuous-time model was placed into a state-space framework to allow parameter estimation and location predictions from observed animal locations. Two previously unpublished marine mammal telemetry data sets were analyzed to illustrate use of the model, by-products available from the analysis, and different modifications which are possible. A harbor seal data set was analyzed with a model that incorporates the proportion of each hour spent on land. Also, a northern fur seal pup data set was analyzed with a random drift component to account for directed travel and ocean currents.

Johnson, D. S., Pelland, N. A., & Sterling, J. T. (2018 - IN REVIEW). A Continuous-Time Semi-Markov Model for Animal Movement in a Dynamic Environment. Unpublished manuscript. https://doi.org/10.1101/353516

We consider an extension to discrete-space continuous-time models animal movement that have previously be presented in the literature. The extension from a continuous-time Markov formulation to a continuous-time semi-Markov formulation allows for the inclusion of temporally dynamic habitat conditions as well as temporally changing movement responses by animals to that environment. We show that with only a little additional consideration, the Poisson likelihood approximation for the Markov version can still be used within the multiple imputation framework commonly employed for analysis of telemetry data. In addition, we consider a Bayesian model selection methodology with the imputation framework. The model selection method uses a Laplace approximation to the posterior model probability to provide a computationally feasible approach. The full methodology is then used to analyze movements of 15 northern fur seal (*Callorhinus ursinus*) pups with respect to surface winds, geostrophic currents, and sea surface temperature. The highest posterior model probabilities belonged to those models containing only winds and current, SST did not seem to be a significant factor for modeling their movement.

Johnson, D. S., Ream, R. R., Towell, R. G., Williams, M. T., & Guerrero, J. D. L. (2013). Bayesian Clustering of Animal Abundance Trends for Inference and Dimension Reduction. *Journal of Agricultural Biological and Environmental Statistics, 18*(3), 299-313. https://doi.org/10.1007/s13253-013-0143-0

We consider a model-based clustering approach to examining abundance trends in a metapopulation. When examining trends for an animal population with management goals in mind one is often interested in those segments of the population that behave similarly to one another with respect to abundance. Our proposed trend analysis incorporates a clustering method that is an extension of the classic Chinese Restaurant Process, and the associated Dirichlet process prior, which allows for inclusion of distance covariates between sites. This approach has two main benefits: (1) nonparametric spatial association of trends and (2) reduced dimension of the spatio-temporal trend process. We present a transdimensional Gibbs sampler for making Bayesian inference that is efficient in the sense that all of the full conditionals can be directly sampled from save one. To demonstrate the proposed method we examine long term trends in northern fur seal pup production at 19 rookeries in the Pribilof Islands, Alaska. There was strong evidence that clustering of similar year-to-year deviation from linear trends was associated with whether rookeries were located on the same island. Clustering of local linear trends did not seem to be strongly associated with any of the distance covariates. In the fur seal trends analysis an overwhelming proportion of the MCMC iterations produced a 73-79 % reduction in the dimension of the spatio-temporal trend process, depending on the number of cluster groups.

Joy, R., Dowd, M. G., Battaile, B. C., Lestenkof, P. M., Sterling, J. T., Trites, A. W., & Routledge, R. D. (2015). Linking Northern Fur Seal Dive Behavior to Environmental Variables in the Eastern Bering Sea. *Ecosphere, 6*(5). https://doi.org/10.1890/es14-00314.1

Northern fur seals (*Callorhinus ursinus*) breeding on the Pribilof Islands, Alaska have declined dramatically over the past 40 years. Effective conservation of northern fur seals depends on understanding the foraging behavior of adult females whose foraging success is linked to pup survival. We determined the foraging behavior for 11 tagged lactating female northern fur seals from the Pribilof Islands using a state-space modeling approach with an autoregressive movement model. To interpret at-sea behavior in the context of oceanic habitat, we spatially and temporally matched high-resolution reconstructed tracks to a set of environmental covariates that included: commercial groundfish catch,

sea surface temperature, primary productivity, wind speed, depth and time of day. We used a Bayesian hierarchical framework to implement a multinomial regression model to link behavior to environmental covariates and account for the mismatch of scale between fur seal behavior and the environmental variables by incorporating an error-in- covariates approach into the hierarchical model. The Bayesian framework allowed us to build a single model to synthesize the information from all the northern fur seal foraging tracks and the available information about the underlying environmental conditions. Application of the approach indicated that the behavioral states for the northern fur seal were significantly related to the Alaska commercial groundfish catch, particularly walleye pollock (Gadus chalogramma).

Kakehi, M., Ikenaka, Y., Nakayama, S. M. M., Kawai, Y. K., Watanabe, K. P., Mizukawa, H., . . . Ishizuka, M. (2015). Uridine Diphosphate-Glucuronosyltransferase (UGT) Xenobiotic Metabolizing Activity and Genetic Evolution in Pinniped Species. *Toxicological Sciences, 147*(2), 360-369. https://doi.org/10.1093/toxsci/kfv144

There are various interspecies differences in xenobiotic-metabolizing enzymes. It is known that cats show slow glucuronidation of drugs such as acetaminophen and strong side effects due to the UGT1A6 pseudogene. Recently, the UGT1A6 pseudogene was found in the Northern elephant seal and Otariidae was suggested to be UGT1A6-deficient. From the results of measurements of uridine diphosphate-glucuronosyltransferase (UGT) activity using liver microsomes, the Steller sea lion, Northern fur seal, and Caspian seal showed UGT activity toward 1-hydroxypyrene and acetaminophen as low as in cats, which was significantly lower than in rat and dog. Furthermore, UGT1A6 pseudogenes were found in Steller sea lion and Northern fur seal, and all Otariidae species were suggested to have the UGT1A6 pseudogene. The UGT1 family genes appear to have undergone birth-and-death evolution based on a phylogenetic and synteny analysis of the UGT1 family in mammals including Carnivora. UGT1A2-1A5 and UGT1A7-1A10 are paralogous genes to UGT1A1 and UGTA6, respectively, and their numbers were lower in cat, ferret and Pacific walrus than in human, rat, and dog. Felidae and Pinnipedia, which are less exposed to natural xenobiotics such as plant-derived toxins due to their carnivorous diet, have experienced fewer gene duplications of xenobiotic-metabolizing UGT genes, and even possess UGT1A6 pseudogenes. Artificial environmental pollutants and drugs conjugated by UGT are increasing dramatically, and their elimination to the environment can be of great consequence to cat and Pinnipedia species, whose low xenobiotic glucuronidation capacity makes them highly sensitive to these compounds.

Karamanlidis, A. A., Lyamin, O., Adamantopoulou, S., & Dendrinos, P. (2017). First Observations of Aquatic Sleep in the Mediterranean Monk Seal (*Monachus monachus*). *Aquatic Mammals, 43*(1), 82-86. https://doi.org/10.1578/AM.43.1.2017.82

The article reports on Mediterranean monk seal also called Monachus monachus. Topics discussed include Halichoerus grypus, Pagophilus groenlandicus, and Mirounga angustirostris. Also being discussed are the observation of aquatic sleep in Mediterranean monk seal, and the species *Callorhinus ursinus* and Pusa caspica.

Kaschner, K., Watson, R., Trites, A. W., & Pauly, D. (2006). Mapping World-Wide Distributions of Marine Mammal Species Using a Relative Environmental Suitability (Res) Model. *Marine Ecology Progress Series, 316*, 285-310. https://doi.org/10.3354/meps316285

The lack of comprehensive sighting data sets precludes the application of standard habitat suitability modeling approaches to predict distributions of the majority of marine mammal species on very large scales. As an alternative, we developed an ecological niche model to map global distributions of 115 cetacean and pinniped species living in the marine environment using more readily available expert knowledge about habitat usage. We started by assigning each species to broad-scale niche categories with respect to depth, sea-surface temperature, and ice edge association based on synopses of published information. Within a global information system framework and a global grid of 0.5' latitude/longitude cell dimensions, we then generated an index of the relative environmental suitability (RES) of each cell for a given species by relating known habitat usage to local environmental conditions. RES predictions closely matched published maximum ranges for most species, thus representing useful, more objective alternatives to existing sketched distributional outlines. In addition, raster-based predictions provided detailed information about heterogeneous patterns of potentially suitable habitat for species throughout their range. We tested RES model outputs for 11 species (northern fur seal, harbor porpoise, sperm whale, killer whale, hourglass dolphin, fin whale, humpback whale, blue whale, Antarctic minke, and dwarf minke whales) from a broad taxonomic and geographic range, using data from dedicated surveys. Observed encounter rates and species-specific predicted environmental suitability were significantly and positively correlated for all but 1 species. In comparison, encounter rates were correlated with < 1 % of 1000 simulated random data sets for all but 2 species. Mapping of large-scale marine mammal distributions using this environmental envelope model is helpful for evaluating current assumptions and knowledge about species' occurrences, especially for data-poor species. Moreover, RES modeling can help to focus research efforts on smaller geographic scales and usefully supplement other, statistical, habitat suitability models.

Kendall-Bar, J. M., Vyssotski, A. L., Mukhametov, L. M., Siegel, J. M., & Lyamin, O. I. (2019). Eye State Asymmetry During Aquatic Unihemispheric Slow Wave Sleep in Northern Fur Seals (*Callorhinus ursinus*). *PLoS One, 14*(5). https://doi.org/10.1371/journal.pone.0217025

Unihemispheric slow wave sleep (USWS) is a unique form of sleep in which one brain hemisphere maintains low voltage electrical activity indicative of waking while the opposite exhibits slow wave electrical activity indicative of sleep. USWS is present in several marine mammals and in some species of birds. One proposed biological function of USWS is to enable the animal to monitor the environment to detect predators or conspecifics. While asymmetrical eye state was often observed during behavioral sleep in birds and marine mammals, electrophysiological (electroencephalogram, EEG) correlates between the asymmetry of eye state and EEG of two cortical hemispheres have not been reliably established. This study examined the association between eye state and EEG activity during aquatic sleep in two subadult northern fur seals (*Callorhinus ursinus*), taking advantage of the simultaneous visibility of both eyes when the seals were in the prone position. We found that during USWS the eye contralateral to the sleeping hemisphere was closed on average 99.4 +/- 0.1% of the recording time. The eye contralateral to the waking hemisphere opened briefly for on average 1.9 +/- 0.1 sec with a rate of 8.2 +/- 1.0 per min. This eye was open on average 24.8 +/- 2.5% of the USWS time and it was closed no longer than 3 sec, on average 39.4 +/- 5.6% of the time. These data indicate that fur seals sleep in seawater by having intermittent visual monitoring. Our findings document the extent of visual monitoring of both eyes during USWS and support the idea that USWS allows intermittent visual vigilance. Thus, USWS serves two functions in the fur seal, facilitating movement and visual vigilance, which may also be the case in cetaceans.

Kiyota, M., Insley, S. J., & Lance, S. L. (2008). Effectiveness of Territorial Polygyny and Alternative Mating Strategies in Northern Fur Seals, *Callorhinus ursinus*. *Behavioral Ecology and Sociobiology, 62*, 739. https://doi.org/10.1007/s00265-007-0499-7

We conducted a 6-year longitudinal behavioral and genetic investigation of a highly polygynous pinniped, the northern fur seal (*Callorhinus ursinus*), to determine the contribution of terrestrial polygyny to male fertilization success and to assess the occurrence of alternative mating strategies. Genetic samples from 37 adult males, 50 adult females, and 85 pups were collected and genotyped using five polymorphic microsatellite loci. Pup paternity was assigned using Cervus 2.0 at 99% confidence level. Paternity of 83 pups (98%) was assigned to terrestrial males who held territories or stayed temporarily in the study area during the breeding season when fertilization occurred. For 56 pups of which attendance records of their mothers were available, paternity of 45 pups (80%) was assigned to the associate males in whose territory their mothers stayed during the perioestrus period. In addition to defending breeding territories, territorial males have often been observed attempting to forcibly abduct adult females from adjacent territories (female stealing): We observed a total of 95 such cases, in which the stealers had significantly fewer females than the territorial males from whose territories they stole females. Our results indicate that terrestrial resource-defense polygyny is the major mating system in this species and that nonassociated paternity occurs mostly as a result of alternative mating strategies of less successful males. Male northern fur seals thus appear to adopt conditional alternative strategies that depend on their current social status to maximize their lifetime reproductive success.

Kiyota, M., Okamura, H., Itou, H., Suzuki, N., & Kohyama, K. (2013). Measurement of Diet Preference and Its Variability in Captive Northern Fur Seals (*Callorhinus ursinus*). *Mammal Study, 38*(3), 199-210. https://doi.org/10.3106/041.038.0308

Diet preferences of three captive northern fur seals for seven prey items (Okhotsk atka mackerel, rainbow trout, common mackerel, walleye pollock, Pacific sand lance, horse mackerel, and Japanese common squid) were measured through repeated two-choice tests. Preference indices estimated from the paired consumption data using the normal Bradley-Terry model revealed the existence of diet preferences and their individual variation. The three seals generally preferred Okhotsk atka mackerel, rainbow trout, and common mackerel, but showed individual differences for less preferred food items. The preferred items had moderate food size and high energy content per one item. Once diet preferences were determined, animals were given rainbow trout laced with lithium chloride (LiCl) to induce conditioned taste aversion (CTA). Four to five LiCl treatments were required for CTA, but could only induce temporary aversion of rainbow trout in favor of horse mackerel. Choice tests after CTA demonstrated a decrease in preference indices for rainbow trout in the three animals, but the ranking and preference indices of rainbow trout did not fall below those for horse mackerel. These results suggest that preference and aversion are relative phenomena, and the success of CTA is dependent on the reduction of preference relative to other food items.

Kiyota, M., Tomita, N., & Baba, N. (2009). Latitudinal Variation in Birth Dates of Northern Fur Seals (*Callorhinus ursinus*) in Captivity. *Mammal Study, 34*(4), 231-235. https://doi.org/10.3106/041.034.0409

Seasonality of mammalian reproduction is ultimately related to dietary and climatic factors, and the timing of birth is scheduled to optimize offspring survival (Bronson 1985). Reproductive synchrony also represents a strategy that individuals adopt to maximize reproductive success in the course of sociobiological and ecological processes such as sexual selection and predation (Ims 1990). Pinnipeds (seals, walruses and sea lions; Carnivora, Pinnipedia) are distinct from other mammals in having two different phases in their life cycles: reproduction on land (or on ice) and foraging in water. Reproduction in most pinniped species is characterized by tight synchrony of births which ensures that pups are born at the optimal time of year (Atkinson 1997). Seasonality and synchrony of births in pinnipeds then lead to temporal aggregation of postpartum estrus and copulation (Stirling 1975; Boness 1991). Reproductive cycles of female pinnipeds are characterized by embryonic diapause and delayed implantation, a preadaptive feature shared with ursid and mustelid carnivores (Mead 1989; Boyd 1991). Lengths of postimplantation gestation (active gestation) are relatively constant in most pinnipeds (ca. 8 months), and the period of delay in embryo implantation adjusts the length of the whole gestation period and determines the timing of births (Boyd 1991).

Kiyota, M., & Yonezaki, S. (2017). Reconstruction of Historical Changes in Northern Fur Seal Prey Availability and Diversity in the Western North Pacific through Individual-Based Analysis of Dietary Records. *Deep-Sea Research Part II-Topical Studies in Oceanography, 140*, 25-35. https://doi.org/10.1016/j.dsr2.2017.02.005

We analyzed long-term dietary records of northern fur seals (*Callorhinus ursinus*) to reconstruct historical changes in prey availability and diversity in the western North Pacific off northeastern Japan. The nominal relationships between the occurrence frequencies of fishes or squids in fur seal stomachs and the sampling locations reflected the spatial heterogeneity of fish and squid distributions along the shelf slope offshore continuum off northeastern Japan, whereas changes in the temporal occurrence frequencies reflected mainly the migration and foraging patterns of the fur seals. The occurrence probabilities of fishes and squids in fur seal stomachs were standardized by using generalized linear models to compensate for sampling biases in space and time. The reconstructed historical trends revealed decadal shifts in relatively high prey abundance from mackerels in the 1970s to Japanese sardine in the 1980s and myctophids/sparkling enope squids in the 1990s that were related to decadal shifts in the oceanographic regime. The sequential increase in mackerel and Japanese sardine abundances coincided with the annual catch trends of commercial fisheries. The index of overall prey availability calculated from the standardized occurrence probabilities of fishes and squids in fur seal stomachs was fairly stable over the decades.

Kiyota, M., Yonezaki, S., Kohyama, K., & Baba, N. (2011). Methods for Capturing and Handling Northern Fur Seals (*Callorhinus ursinus*). *Honyurui Kagaku/Mammalian Science, 51*(1), 71-78. https://doi.org/10.11238/mammalianscience.51.71

This paper describes capture and handling methods of northern fur seals (*Callorhinus ursinus*) on land and at sea for scientific research and for proper treatment of individuals stranded or caught incidentally in fisheries. Females and smaller males (c.a. 70 kg in body weight) can be caught on land by using a noose pole or a hoop net, and physically immobilized with a restraint board. Handling of large males requires chemical immobilization. Careful attention should be paid to the respiratory condition of animals during capture and immobilization. On breeding lands where northern fur seals form dense social aggregation, proper methods of approach, capture and restraint should be chosen to minimize

disturbance to the breeding aggregation and to ensure the safety of animals and field workers. Captured animals should be returned safely to the original location so that they can retain social relationships with other individuals. Live capture of northern fur seals at sea is possible using gillnets in foraging areas. Since capture and possession of northern fur seals are restricted by Japanese domestic law, government permission is required to capture northern fur seals for scientific research.

Klein, D. R., & Shulski, M. (2011). The Role of Lichens, Reindeer, and Climate in Ecosystem Change on a Bering Sea Island. *Arctic, 64*(3), 353-361. https://doi.org/10.14430/arctic4124

Archived reports. from an international controversy in the early 1890s over management of the harvest of fur seals,*Callorhinus ursinus*, on the Pribilof Islands in the southeastern Bering Sea provided an unanticipated record of observations on the growth of lichens in association with the prevailing climatic conditions. The abundance of lichens observed in plant communities on the Pribilof Islands prompted the introduction of reindeer, Rangifer tarandus, in 1911. Grazing pressure by the introduced reindeer brought changes to lichen presence in the plant communities of St. Paul Island of the Pribilof's: lichens were depleted, and vascular plants expanded to replace the depleted lichens in a climate that became markedly warmer and drier in comparison to that of the late 19th century. These changes are described primarily through the use of historical documentation. Dominance of lichens in the plant communities on the Pribilof Islands at the time of their discovery and settlement appears to have been a relict of their development in the cooler and moister climate that characterized the southern Bering Sea in the mid-Holocene.

Kobayashi, Y., Jono, M., Goto, Y., Hattori, K., & Sakurai, Y. (2011). The Occurrence of Pinnipeds and Fishery Conflict Records in the Oshima Peninsula, Hokkaido, Sea of Japan. *Bulletin of fisheries sciences, Hokkaido University, 61*(2-3), 75-82. Retrieved from http://hdl.handle.net/2115/48641

To examine the distribution of Steller sea lions Eumetopias jubatus and other marine mammals and their impact on coastal fisheries (destruction of fishing gear and decreased fish catches) in the western Oshima Peninsula, Hokkaido, Japan, a questionnaire survey was carried out, and a collection of photographic records and analyses of by-catch and stranding samples obtained February-May, 2008 was generated. There are eleven small haul-out sites for Steller sea lions observed along the coast of the Sea of Japan. Seven by-catch and stranding records of Steller sea lions and Northern fur seals Callorhinus *ursinus* were obtained, and two samples were collected. It has been suggested that marine mammal-fishery conflict involving Steller sea lions and Northern fur seals results in damage to fishing gear or decreased fish catches in this area.

Kohyama, K., & Inoshima, Y. (2017). Normal Hematology and Serum Chemistry of Northern Fur Seals (*Callorhinus ursinus*) in Captivity. *Zoo Biology, 36*(5), 345-350. https://doi.org/10.1002/zoo.21376

Northern fur seals (Callorhinus ursinus) are endemic to the North Pacific Ocean. They were hunted for their fur and became endangered in the late 1800s, but their populations recovered following the introduction of protection laws. Recently, populations have been decreasing again, although the reasons are unclear. For individuals that are bred and reared in captivity as part of ex situ conservation projects, details of blood characteristics are essential to ensure good health. However, the normal ranges of

hematology and serum chemistry of captive northern fur seals have not been defined. This study determined the normal ranges of hematology and serum chemistry of captive fur seals. Blood samples were collected every month for 2 years from four captive northern fur seals in Japan (three born in an aquarium and one kept in the same aquarium following rescue). Fifteen blood characteristics and 29 serum chemistry properties were compared with those previously reported for wild northern fur seals in the USA. Several parameters were not within the normal ranges reported previously in wild northern fur seals. In particular, levels of alkaline phosphatase was outside of the normal ranges previously reported. The hematological and serum chemistry ranges in this study can help provide a guideline for understanding the health of northern fur seals in captivity.

Kohyama, K., Yanai, T., Noda, A., & Hashimoto, A. (2015). Alimentary Lymphoma in a Northern Fur Seal *Callorhinus ursinus*. *Honyurui Kagaku/Mammalian Science, 54*(2), 251-256. https://doi.org/10.11238/mammalianscience.54.251

We report a case of alimentary lymphoma in a northern fur seal kept in Izu Mito Sea Paradise. At necropsy, a perforatedulcer approximately 7cm in diameter and 3cm deep was observed on the mucous of bottom of the stomach. The thick end of the stomach wall around the ulcer was diagnosed histopathologically as lymphoma. This case is the first supposed case of alimentary lymphoma in the northern fur seal.

Kondo, T., Ikenaka, Y., Nakayama, S. M. M., Kawai, Y. K., Mizukawa, H., Mitani, Y., . . . Ishizuka, M. (2017). Uridine Diphosphate-Glucuronosyltransferase (UGT) 2B Subfamily Interspecies Differences in Carnivores. *Toxicological Sciences, 158*(1), 90-100. https://doi.org/10.1093/toxsci/kfx072

UDP-glucuronosyltransferases (UGTs) are among the most important xenobiotic metabolizing enzymes that conjugate a wide range of chemicals. Previous studies showed that Felidae and Pinnipedia species have very low UGT activities toward some phenolic compounds because of the UGT1A6 pseudogene and small numbers of UGT1A isozymes. In addition to the UGT1As, UGT2Bs isozymes also conjugate various endogenous (eg, estrogens, androgens, and bile acids) and exogenous compounds (opioids, non-steroidal anti-inflammatory drugs, and environmental pollutants). However UGT2B activity and genetic background are unknown in carnivore species. Therefore, this study was performed to elucidate the species differences of UGT2Bs. Using typical substrates for UGT2Bs, UGT activity was measured in vitro. In addition, UGT2B genetic features are analyzed in silico. Results of UGT activity measurement indicate marked species differences between dogs and other carnivores (cats, Northern fur seals, Steller sea lions, Harbor seals, and Caspian seals). Dogs have very high V-max/K-m toward estradiol (17-glucuronide), estrone, lorazepam, oxazepam, and temazepam. Conversely, cats and pinniped species (especially Caspian seals and Harbor seals) have very low activities toward these substrates. The results of genetic synteny analysis indicate that Felidae and pinniped species have very small numbers of UGT2B isozymes (one or none) compared with dogs, rodents, and humans. Furthermore, Felidae species have the same nonsense mutation in UGT2B, which suggests that Felidae UGT2B31-like is also a pseudogene in addition to UGT1A6. These findings of lower activity of UGT2B suggest that Felidae and some pinniped species have very low UGT activity toward a wide range of chemicals. These results are important for Felidae and Pinnipedia species that are frequently exposed to drugs and environmental pollutants.

Kosenko, P., Lyamin, O., Belyaev, E., Kibalnikov, A., Lapierre, J., Mukhametov, L., & Siegel, J. (2009). Selective REM Sleep Deprivation of the Northern Fur Seal on Land. *Sleep, 32*, A2. Retrieved from https://academic.oup.com/sleep/pages/abstract_supplements

[NO ABSTRACT AVAILABLE]

Kot, B. W., Morisaka, T., Sears, R., Samuelson, D., & Marshall, C. D. (2012). Low Prevalence of Visual Impairment in a Coastal Population of Gray Seals (*Halichoerus grypus*) in the Gulf of St. Lawrence, Canada. *Aquatic Mammals, 38*(4), 423-427. https://doi.org/10.1578/am.38.4.2012.423

Visual impairment is common in captive pinnipeds (Sweeney, 1974; Ridgway et al., 1975; Stoskopf et al., 1983; Greenwood, 1985; Colitz et al., 2010a, 2010b), but its prevalence in the wild is currently unclear due to the limited number of published studies and inconsistent information in the relevant literature (e.g., Griner, 1983; Filer et al., 2003). Visual impairment is a broad category that includes pathological, parasitological, traumatic, or congenital conditions (e.g., Aguirre, 2004; Dailey et al., 2005). Although the prevalence of specific conditions affecting pinniped vision (e.g., Leptospira pomona infection) may be under-reported, partly due to the difficulties of field diagnosis methods, general conditions (e.g., opacities, lesions, etc.) are reported most often (Stoskopf et al., 1985; Gerber et al., 1993; Aguirre, 2004). What is clear is that visual impairment reported in wild pinnipeds is usually associated with the cornea, anterior chamber, iris, and lens (e.g., Smith et al., 1977; Stoskopf et al., 1985; Schoon & Schoon, 1992; Baker et al., 1998). However, this prevalence is likely because these are the most conspicuous structures to observers.

Koutsos, E. A., Schmitt, T., Colitz, C. M. H., & Mazzaro, L. (2013). Absorption and Ocular Deposition of Dietary Lutein in Marine Mammals. *Zoo Biology, 32*(3), 316-323. https://doi.org/10.1002/zoo.21033

Cataracts and ocular disease are common lesions of marine mammals in zoological collections. Lutein, an oxygenated carotenoid, may have therapeutic or prophylactic effects on ocular disorder. Therefore, this study examined the ability of marine mammals to absorb dietary lutein. Two preliminary trials examined lutein in two forms (beadlet or ester) in a small sample size of marine mammals representing pinnipeds and cetaceans. Lutein was fed daily in tablets providing 0.89-3.6 mg lutein/kg body weight0.75 per day for 15 days to 2 years. A third study was conducted using lutein beadlet fed at 3.6 mg lutein/kg body weight0.75 per day for 15-21 days. Blood was analyzed for lutein pre- and postsupplementation. In the preliminary trials, lutein beadlet was observed to result in greater blood lutein levels than lutein esters, and cetaceans had more noticeable responses than pinnipeds. In Study 3, serum lutein and zeaxanthin increased postsupplementation in beluga whales ($P < 0.05$), and serum lutein tended to increase postsupplementation in dolphins ($P < 0.10$), but little change was seen in serum lutein in pinnipeds or manatee. Opportunistic retinal samples demonstrated some detectable lutein in the retina of a dolphin and several harp seals. The lutein levels in dolphins after supplementation are similar to those reported in free-ranging animals. Ocular lutein in harp seals demonstrates that ocular deposition occurs despite low circulating lutein levels.

Kromann, S. (2011). *Providing Access to a Hidden Resource: The National Marine Mammal Laboratory Fur Seal Archive*. Retrieved from https://darchive.mblwhoilibrary.org/bitstream/handle/1912/4593/Kromann_iamslic2010.pdf?sequence=1&isAllowed=y

NOAA's National Marine Mammal Laboratory (NMML) Library houses an archive documenting the northern fur seal research program that has been ongoing for over a century on the Pribilof Islands in the Bering Sea, as well as including information on commercial and subsistence harvests, and utilization by the Pribilof Island people. The archive includes research materials, photos, correspondence, and documents relating to the research and commercial harvest of northern fur seals on the Pribilof Islands. Archive materials and documents were generated by the various U.S. government agencies responsible for managing northern fur seal populations. Since 1970 this responsibility has been held by the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service. Also included are materials from related organizations such as the International North Pacific Fur Seal Commission (INPFSC). The archive is a repository for current research output and is used locally for historic research, but online access to the public was previously limited to a brief paragraph describing the collection on the NMML Library home page. A web page to provide access to the NMML Fur Seal Archive was developed in 2010. The NMML Fur Seal Archive page now provides access to an extensive finding aid with links to the full-text of some of the majordocument series and other archive documents, as well as related publications. Moving forward, additional archive materials will be digitized and links to relevant materials and resources on the northern fur seal will be added.

Kuhn, C. E. (2011). The Influence of Subsurface Thermal Structure on the Diving Behavior of Northern Fur Seals (*Callorhinus ursinus*) During the Breeding Season. *Marine Biology, 158*(3), 649-663. https://doi.org/10.1007/s00227-010-1589-z

In the heterogeneous marine environment, predators can increase foraging success by targeting physical oceanographic features, which often aggregate prey. For northern fur seals (*Callorhinus ursinus*), two prevalent oceanographic features characterize foraging areas during summer in the Bering Sea: a stable thermocline and a subsurface "cold pool". The objective of this study was to examine the influence of these features on foraging behavior by equipping fur seals from St. Paul Island (Alaska, USA) with time-depth recorders that also measured water temperature. Foraging bout variables (e.g., mean dive depth and percent time diving in a bout) were compared with respect to subsurface thermal characteristics (thermocline presence and strength and cold pool presence). Over 74% of bouts occurred in association with strong thermoclines (temperature change > 5A degrees C). Few differences were found for dive behavior in relation to the presence of a thermocline and the cold pool, but for epipelagic bouts, a strong thermocline resulted in increased bottom times, number of dive wiggles, and percent time diving when compared to moderate thermoclines. There was also a positive relationship between mean dive depth and thermocline depth. The combination of increasing foraging effort in areas with strong thermoclines and diving to depths closely related to the thermocline indicates this feature is important foraging habitat for northern fur seals and may act to concentrate prey and increase foraging success. By recognizing the environmental features northern fur seals use to find prey, managers will be better equipped to identify and protect foraging habitat that is important to northern fur seals, and possibly other marine predators in the Bering Sea.

Kuhn, C. E., Baker, J. D., Towell, R. G., & Ream, R. R. (2014). Evidence of Localized Resource Depletion Following a Natural Colonization Event by a Large Marine Predator. *Journal of Animal Ecology, 83*(5), 1169-1177. https://doi.org/10.1111/1365-2656.12202

For central place foragers, forming colonies can lead to extensive competition for prey around breeding areas and a zone of local prey depletion. As populations grow, this area of reduced prey can expand impacting foraging success and forcing animals to alter foraging behaviour. 2. Here, we examine a population of marine predators, the northern fur seal (*Callorhinus ursinus*), which colonized a recently formed volcanic island, and assess changes in foraging behaviour associated with increasing population density. Specifically, we measured pup production and adult foraging behaviour over a 15-year period, during which the population increased 4-fold. 3. Using measures of at-sea movements and dive behaviour, we found clear evidence that as the population expanded, animals were required to allot increasing effort to obtain resources. These changes in behaviour included longer duration foraging trips, farther distances travelled, a larger foraging range surrounding the island and deeper maximum dives. 4. Our results suggest that as the northern fur seal population increased, local prey resources were depleted as a result of increased intraspecific competition. In addition, the recent slowing of population growth indicates that this population may be approaching carrying capacity just 31 years after a natural colonization event. 5. Our study offers insight into the dynamics of population growth and impacts of increasing population density on a large marine predator. Such data could be vital for understanding future population fluctuations that occur in response to the dynamic environment, as natural and anthropogenic factors continue to modify marine habitats.

Kuhn, C. E., Johnson, D. S., Ream, R. R., & Gelatt, T. S. (2009). Advances in the Tracking of Marine Species: Using GPS Locations to Evaluate Satellite Track Data and a Continuous-Time Movement Model. *Marine Ecology Progress Series, 393*, 97-109. https://doi.org/10.3354/meps08229

Argos satellite tracking provides information about the large-scale movements of marine species, but the limitations in position accuracy and frequency make it difficult to interpret fine-scale behaviour. With Fastloc global positioning system (GPS) technology, it is now possible to overcome these limitations when tracking diving marine species. We compared differences among archived GPS (GPS), transmitted GPS (GPS-t) and Argos satellite (PTT) tracks acquired simultaneously on 30 northern fur seals *Callorhinus ursinus*. We examined times and distances between locations, as well as overall trip characteristics (e.g. distance traveled and transit rate). The GPS data were also used to test the accuracy of a continuous-time correlated random walk model created to cope with the spatial error and gap times associated with PTT locations. Significantly more GPS locations per day were acquired than PTT locations (31.6 +/- 1.9 vs. 12.0 +/- 0.3, respectively), and the GPS locations were more evenly distributed along the track. The influence of data type (GPS, GPS-t, PTT) varied based on the parameter measured, ranging from different among all (e.g. average transit rate) to no significant difference (e.g. maximum distance traveled). Modeling of both PTT and GPS-t data resulted in tracks with over 79% of predicted locations less than 5 km from the GPS location (average location error: 3.2 +/- 0.1 and 1.7 +/- 0.1 km, respectively). This study demonstrates the added benefit of using GPS to track marine species, as well as how and when modeled PTT data may be sufficient to address study questions.

Kuhn, C. E., Sterling, J. T., & Zeppelin, T. K. (2015). Linking Northern Fur Seal Behavior with Prey Distributions: The Impact of Temporal Mismatch between Predator Studies and Prey Surveys. *Animal Biotelemetry, 3*(1), 1-12. https://doi.org/10.1186/s40317-015-0064-5

An essential part of foraging ecology research is identifying how the distribution and abundance of prey influence predator behavior. However, in marine systems, temporal or spatial mismatches often exist between prey surveys and predator tracking periods, especially for species with large foraging ranges. Using northern fur seals (*Callorhinus ursinus*) as a model, we investigated how conclusions about predator-prey relationships change with increasing temporal disparity between predator tracking periods and prey surveys. To measure foraging behavior, northern fur seals (n = 20) from St. Paul Island (Alaska, USA) were equipped with satellite tracking transmitters and time-depth recorders from July to October 2006. Fur seal dive and movement metrics were examined in relation to the relative abundance of the fur seals' primary prey, walleye pollock (Gadus chalcogrammus), reported from the annual eastern Bering Sea groundish survey. Relationships between foraging behavior metrics and prey abundance were examined within the Bering shelf survey grid cells at three timescales: within 2 weeks of the prey survey, within 1 month, and over the northern fur seal reproductive season (>4 months). Results: We found significant relationships between northern fur seal behavior and prey abundance, even with the limited sample size at the shortest temporal resolution (2 weeks). Changes in dive behavior that were associated with areas of abundant pollock (for example, increased vertical distance traveled and longer periods of diving) were consistent with previously reported metrics of pinniped foraging success. When behavioral metrics, such as vertical distance traveled and time spent diving, remained significantly related to prey abundance at multiple temporal scales, the relationship strength was reduced as temporal mismatch increased. Conclusion: Our results suggest that relationships between behavioral metrics and prey abundance vary as temporal mismatch increases between prey surveys and predator tracking periods. For northern fur seals, pollock surveys conducted early in the reproductive season may still provide information useful to examine predator-prey relationships as the reproductive season progresses, albeit with diminished predictive power. Understanding predator-prey relationships, including the impact of varying temporal scales, is particularly valuable for guiding research and conservation strategies for northern fur seals as the population continues to decline.

Kuhn, C. E., Tremblay, Y., Ream, R. R., & Gelatt, T. S. (2010). Coupling GPS Tracking with Dive Behavior to Examine the Relationship between Foraging Strategy and Fine-Scale Movements of Northern Fur Seals. *Endangered Species Research, 12*, 125-139. https://doi.org/10.3354/esr00297

The foraging strategies of diving marine species are often categorized into 3 fundamental groups (epipelagic, mesopelagic, and benthic foraging) based on diving, habitat use, and diet studies. Because these foraging strategies are influenced by the distribution and behavior of the prey being targeted, we would expect search behavior and space use to differ depending on the strategy employed. Since northern fur seals *Callorhinus ursinus* display both epipelagic and benthic foraging strategies, they were an ideal model to test the hypothesis that fine-scale movement and space-use patterns will vary when animals use markedly different foraging strategies. Dive bouts were characterized into foraging strategies based on numerous dive parameters (depth, duration, etc.). For each strategy, we compared movement patterns (e.g. transit rate and path straightness) and space use (area-restricted search [ARS] zones) around St. Paul Island, Alaska, USA. Nearly all dive parameters were significantly different between foraging strategies (epipelagic vs. benthic). In addition, epipelagic bouts were more sinuous and covered a greater total distance than benthic bouts. However, the greater distances traveled in epipelagic bouts were due to longer bout durations, as transit rates were not different between the 2 strategies. On average, <2 ARS zones were identified per trip, and the characteristics of epipelagic and benthic ARS zones were not different. By combining dive behavior with precise at-sea locations, this study has provided a greater understanding of the finescale foraging behavior of northern fur seals.

Monitoring changes in foraging behavior over time and comparing behavior among populations with differing population trajectories may provide more clues as to why northern fur seal numbers on St. Paul Island continue to decline.

Kunisue, T., & Tanabe, S. (2009). Hydroxylated Poloychlorinated Biphenyls (OH-PCBs) in the Blood of Mammals and Birds from Japan: Lower Chlorinated OH-PCBs and Profiles. *Chemosphere, 74*(7), 950-961. https://doi.org/10.1016/j.chemosphere.2008.10.038

An analytical method was developed to measure tri- to octa-chlorinated OH-PCBs and pentachlorophenol (PCP) in the whole blood. Further, baseline data on the levels and profiles of these phenolic compounds in Japanese mammals (human, cat, dog, raccoon dog, and northern fur seal) and birds (black-tailed gull, common cormorant, and jungle crow) were obtained. Eighteen identifiable and fifty unknown peaks of OH-PCBs were detected and the major congeners identified were 4'OH-CB101/120, 4OH-CB107/4'OH-CB108, 4OH-CB146, 4OH-CB178, 4OH-CB187, 4'OH-CB172, 4OH-CB202, and 4'OH-CB199. Relatively higher concentrations of OH-PCBs were found in animal species than humans; OH-PCB levels in dog, raccoon dog, black-tailed gull, and common cormorant blood were one order of magnitude higher than in humans. Penta- to hepta-chlorinated OH-PCB congeners were predominant in human blood, but profiles of OH-PCBs in other animals widely varied by species. Elevated composition of tri- and tetra-chlorinated OH-PCBs in cat blood and octa-chlorinated OH-PCBs in dog and raccoon dog blood were observed. In cat blood, elevated PCP concentration was also found. When concentration ratios of OH-PCBs to PCBs were calculated in all the animal blood, the ratios in dog, raccoon dog, and cat were notably higher than in other species. These results indicate that animals other than humans, especially cat and canine species such as dog and raccoon dog, might be at risk from OH-PCBs.

Kuzin, A. E. (2008). *The Morphological Aspects of Intrauterine Growth of the Northern Fur Seal*: TINRO-Center, Vladivostok.

Peculiarities of forming and weight ratios of the Northern Fur Seals, which make up so called 'uterine complex' during a female's pregnancy, are viewed. Both weight and linear foetus growths, as well as the process of forming of constitution are evaluated. Structure of skin-and-hair coverlet is described. Ossification, linear and weight characteristics at various stages of the intrauterine growth are studies. Term of initiation, calcification, alveolar and gingival eruption of permanent and deciduous teeth is established. Topography and dynamics of the internals weight, forming of outer architectonics and brain dimensions in embryogenesis are considered. Basis conception of development of respiratory organs and their blood supply, as well as morphological composition of red and white blood are submitted. Estimate of evolutional transformations in the Northern Fur Seals' ontogenesis by means of embryological modification of morphogenesis is made.

Kuzin, A. E. (2010). The Intrapopulation Structure of the Northern Fur Seal (*Callorhinus ursinus* L.) on Tyuleniy Island During the Post-Depression Years (1993-2009). *Russian Journal of Marine Biology, 36*(7), 507-517. https://doi.org/10.1134/s1063074010070047

The dynamics of the intrapopulation parameters of the northern fur seal on Tyuleniy Island are considered for the period when their population was recovering after a depression. Almost all its

characteristics, except for those dependent on density, showed a positive tendency. Dynamic processes in the northern fur seal populations in the post-depression years are found to be based on the demographic transformation of the community, which closely correlates with its qualitative changes, predetermined by the dynamics of its age structure. The process of complete reversal in the state of the fur seal population, which is distinguished by peak values at the depression and in the years of prosperity, is approximately equal to the life span of one generation of these animals.

Kuzin, A. E. (2011). The Contemporary Condition and Some Demographic Characteristics of the Steller Sea Lion (*Eumetopias jubatus*) Reproductive Group on Tyuleniy Island, Sea of Okhotsk. *Russian Journal of Marine Biology, 37*(7), 549-557. https://doi.org/10.1134/s1063074011070054

In 2010, the largest part of the Steller sea lion breeding community on Tyuleniy Island was located on the harem rookery of northern fur seals, which occupied the eastern beach, as well as on the western side of the island, which was free of fur seals. At the culmination of harem activity on June 29, 26.5% of the animals at the age of 1+ concentrated on the eastern beach and 41.1%, on the western beach in the daytime. However, 52.3% of the pups were born on the eastern beach and only 30.4% were born on the western beach. Pups were also present on the capes: 9.1% of the pups were observed on the northern cape and 8.2% on the southern cape, while the main population on these sites consisted of non-harem bulls, bachelors, and young animals. At the peak of harem activity, the number of females per one harem bull was 13.1 at sites 1 to 3 of the eastern beach and each of them, on average, had 1.05 pups; on sites 7-12 there were, respectively, 9.1 females and 1.42 pups per female, and on the western beach, 21.7 females and 0.64 pups. The resulting abundance of sea lions on Tyuleniy Island in 2010 exceeded 1500, which was almost ten times as many as their number in 1989. A total of about 100 bulls, 60 harem bulls, 1000 females, and 700 pups were recorded there. Half-bulls and young animals amounted to one-third of the entire population. Meanwhile the overall sex ratio at the culmination of harem activity was 11.5 females per one bull and 18.8 per one harem bull. About 75% of the females belonged to the parous group. The mortality rate among newborns reached 5.4%. No mortality was observed in adults. As many as 133 previously branded Steller sea lions were found and 109 of them (81.9%) were immigrants. Among immigrants, 29% were branded individuals of reproductive groups from the Kuril Islands, 54% were from the Iony Islands, 16% were from the Yamsky Islands, and about 1% were from Kamchatka. Four-year-old individuals predominated among the branded immigrants (23.8%). The oldest Steller sea lion (21 years of age) was one that was branded on the Srednego Islands in 1989. The rate of marked animal return from 175 pups that were branded on Tyuleniy Island the year before was 13.8%.

Kuzin, A. E. (2013). Linear Characteristic of Skeleton for Some Eared and True Seals. *Transactions of the Pacific Research Fisheries Centre, 173*, 119-129. Retrieved from https://elibrary.ru/item.asp?id=20781667

Absolute and relative measurements of axial skeleton and extremities are presented for 130 seals of different species and ages (northern fur seal *Callorhinus ursinus*, steller sea lion Eumetopias jubatus, spotted seal Phoca largha, and harbor seal Phoca vitulina stejnegeri). Parameters of the axial skeleton depend on the way of locomotion and physical load to certain parts of the vertebral column under interaction with propulsive organs. Proportions of proximal and distal parts of extremities are determined by location of propulsive organs and locomotor muscles development. The eared seals use their back fins for thermoregulation, that also influences on measurements of these organs.

Kuzin, A. E. (2014). New Data on the Abundance of the Northern Fur Seal (*Callorhinus ursinus*), Steller Sea Lion (*Eumetopias jubatus*), and Spotted Seal (*Phoca largha*) on Tyuleniy Island, Sea of Okhotsk. *Russian Journal of Marine Biology, 40*(7), 532-538. https://doi.org/10.1134/s1063074014070037

The latest data on the abundance and distribution of the northern fur seal (*Callorhinus ursinus*), steller sea lion (Eumetopias jubatus), and spotted seal (Phoca largha) on Tyuleniy Island (Sea of Okhotsk) are presented. Based on the surveys in June and July of 2013, the total estimated number of northern fur seals is 115000. The direct counts showed 5000 bulls, 30300 females, and 34700 pups (31500 live and 3200 dead). The total decrease in the number of females and pups for the recent 4 years is 18.0% (or 4.5% per year). The counted number of Steller sea lions is 1879 adults, viz., 119 bulls, 1390 females (of which 68.5% were parous), and 370 animals of other categories. A total of 890 pups were recorded. The reproductive group of sea lions is increasing due to immigrants. The largest number of spotted seals is 162 individuals. Its seasonal and daily variations are dynamic.

Kuzin, A. E. (2015). Analysis of Commercial Hunting on Northern Fur Seal (*Callorhinus ursinus*) at Tyuleny Island. *Transactions of the Pacific Research Institute of Fisheries and Oceanography, 183*, 71-80. Retrieved from https://elibrary.ru/item.asp?id=24859318

Structure of commercial hunting on northern fur seal at Tyuleny Island is considered including effectiveness of podding, age-sex composition of the podded and captured animals, age structure of culled males, and reasons of culling. In total, the number from 2650 to 5099 of fur seals were podded during the harvest seasons of 1990-2008, 45.80 not equal to 2.17 % of them were killed and 54.20 not equal to 2.16 % were released. The bachelors prevailed among the podded animals, as well as in the bachelor rookeries (51.70 not equal to 2.56 %). The bulls were more numerous in the pod (35.80 not equal to 2.12 %) in compare with the half-bulls (10.20 not equal to 0.99 %) and the females (2.00 not equal to 0.85 %). Among the harvested animals, the bachelors prevailed, as well (93.50 not equal to 1.06 %), whereas the bulls, females, and half-bulls weren't numerous (3.83 not equal to 0.87 %, 2.51 not equal to 0.67 %, 1.49 not equal to 0.29 %, respectively); frequency of the bulls and females captures changed from year to year. The most numerous age group of captured seals was the 3-year old animals (52.80 not equal to 1.60 %). All groups were presented among the culling animals, but the bachelors prevailed. The most common reason for culling was injuring of seals by commercial fishery wastes (scraps of fishing nets, ropes, packaging tapes, etc.): 64.20 not equal to 6.86 % of the culled animals were injured by the wastes.

Kuzin, A. E., & Trukhin, A. M. (2019). Entanglement of Northern Fur Seals (*Callorhinus ursinus*) in Marine Debris on Tyuleniy Island (Sea of Okhotsk) in 1998–2013. *Marine Pollution Bulletin, 143*, 187. https://doi.org/10.1016/j.marpolbul.2019.04.051

The systematic annual observations of the northern fur seal rookery on Tyuleniy (= Robben) Island, Sea of Okhotsk, were started in 1958. Since 1975, all seals entangled in marine debris have been registered. Some of the data on this issue, collected on the island in the late 20th century, were published earlier. This report provides data for the period of completion of the commercial sealing (from 1998 to 2013). During this period, a total of 867 fur seals were observed entangled in marine debris, including 212 bulls, 97 half-bulls, 223 bachelors, and 335 females. The estimated mean annual number of entangled fur

seals in 1998–2013 is 1113 individuals. Marine debris was found mainly on the neck and, less frequently, on the head and front flippers of the animals. This included pieces of fishing nets, packaging bands, ropes, fishing lines, and other items of anthropogenic origin.

Kuzin, A. E., & Zasypkin, M. Y. (2010). Frequency Variability of Some Phenetic Features in the Northern Fur Seal *Callorhinus ursinus* from Tyuleniy Island and Adjacent Waters. *Russian Journal of Marine Biology, 36*(5), 346-353. https://doi.org/10.1134/s1063074010050044

This study examines discrete features in the northern fur seal *Callorhinus ursinus* related to the shape of the posterior edge of the front flipper, which is characterized by a varying degree of manifestation of quantitative (number of festoons) and qualitative (shape, size, and arrangement of lobes) features of each dactyl. Analysis of frequencies of the investigated morphological features in 12 samples of northern fur seal showed their high chronological variability and the significance of intersample differences both within the Tyuleniy Island population and between different reproductive groups. Thus, the reliability of the above features as criteria for separating populations of northern fur seal appears to be doubtful.

Kuzmina, T. A., Hernandez-Orts, J. S., Lyons, E. T., Spraker, T. R., Kornyushyn, V. V., & Kuchta, R. (2015). The Cestode Community in Northern Fur Seals (*Callorhinus ursinus*) on St. Paul Island, Alaska. *International Journal for Parasitology-Parasites and Wildlife, 4*(2), 256-263. https://doi.org/10.1016/j.ijppaw.2015.04.007

The diversity and ecology of cestodes from the northern fur seals, *Callorhinus ursinus* (NFS), were examined using newly collected material from 756 humanely harvested subadult males between 2011 and 2014. NFSs were collected from five different haul-outs on St. Paul Island, Alaska. A total of 14,660 tapeworms were collected with a prevalence of 98.5% and intensity up to 107 cestodes per host (mean intensity 19.7 +/- 16.5 SD). Three species of tapeworms were found: Adenocephalus pacificus (Diphyllobothriidea) was the most prevalent (prevalence 97.4%), followed by Diplogonoporus tetrapterus (49.7%), and 5 immature specimens of Anophryocephalus cf. ochotensis (Tetrabothriidea) (0.5%). Most of the cestodes found in the NFS were immature (69.7%). However, only 0.9% of cestodes were in larval (plerocercoid) stages. The species composition, prevalence and intensity of cestodes from these NFSs were not statistically different between the five separate haul-outs. Significant increases in the intensity of NFS infections were observed during the study period.

Kuzmina, T. A., Kuzmin, Y. I., Tkach, V. V., Spraker, T. R., & Lyons, E. T. (2013). Ecological, Morphological, and Molecular Studies of *Acanthocheilonema odendhali* (Nematoda: Filarioidea) in Northern Fur Seals (*Callorhinus ursinus*) on St. Paul Island, Alaska. *Parasitology Research, 112*(9), 3091-3100. https://doi.org/10.1007/s00436-013-3483-3

Studies of northern fur seal (*Callorhinus ursinus* Linnaeus, 1758) infection by the filariid nematode Acanthocheilonema odendhali were carried out in 2011-2012 on St. Paul Island, Pribilof Archipelago, Alaska. Skins of 502 humanely harvested northern fur seals from haul-out areas of five rookeries, Polovina (n = 122), Morjovi (n = 54), Zapadni (n = 72), Lukanin (n = 109), and Gorbatch (n = 145), were examined. A. odendhali was found in 18 % of northern fur seals. The prevalence of infection ranged from 12.5 % up to 22.9 % on different haul-out areas on the island. The mean intensity of infection was

1.3 (range 1-7). Detailed morphological examination of collected specimens was performed using light microscopy. Several characters were added to the morphological description of the species, among them lateral thickening of the body cuticle, especially prominent in males, variations in number and position of genital papillae in males, transverse striation of the cuticle, and terminal dilation on tail end in microfilariae. The adult specimens studied had a shorter esophagus than type specimens from the California sea lion described by Perry (1967). Comparison of partial sequences of the mitochondrial cox1 gene from specimens collected from five sampling sites on St. Paul Island and a specimen from the type host and territory in California showed no significant differences and strongly supported conspecificity of the material from Alaska with A. odendhali.

Kuzmina, T. A., Lisitsyna, O. I., Lyons, E. T., Spraker, T. R., & Tolliver, S. C. (2012). Acanthocephalans in Northern Fur Seals (*Callorhinus ursinus*) and a Harbor Seal (*Phoca vitulina*) on St. Paul Island, Alaska: Species, Prevalence, and Biodiversity in Four Fur Seal Subpopulations. *Parasitology Research, 111*(3), 1049-1058. https://doi.org/10.1007/s00436-012-2930-x

Monitoring studies of acanthocephalans in northern fur seals (*Callorhinus ursinus* Linnaeus, 1758) (NFSs) and a harbor seal (Phoca vitulina Linnaeus, 1758) were performed on St. Paul Island, Alaska, in July-August 2011. Gastrointestinal tracts of 105 humanely harvested NFS subadult males (SAMs) (3-4 years old) were collected during the annual Aleut subsistence harvest at four haul-out areas (HOAS): Lukanin (n = 26 NFSs), Polovina (n = 28), Gorbatch (n = 30), and Morzhovyi (n = 21). One gastrointestinal tract collected from a harbor seal (about 3-4 years old) found dead at Morzhovyi HOAS was also examined. The total prevalence of infection in NFSs with acanthocephalans was 29.52 % with variations from 7.69 % to 47.62 % between the four different HOAS. Eight acanthocephalan species of two genera-Corynosoma Luhe, 1904 (Corynosoma strumosum, Corynosoma alaskensis, Corynosoma cameroni, Corynosoma semerme, Corynosoma similis, Corynosoma validum, and Corynosoma villosum), and Bolbosoma Porta, 1908 (Bolbosoma nipponicum)-were found in the NFSs and a harbor seal. This is a new record of C. alaskensis for the NFSs. Short biological notes of the species found are presented. Differences in species composition as well as in prevalence of acanthocephalans parasitizing NFSs were observed in subpopulations from four different HOAS on St. Paul Island. The highest biodiversity of acanthocephalans and infection were found in subpopulations on Polovina and Morzhovyj HOAS, the lowest was on Lukanin HOAS. From 3.2 % (for C. validum) to 19.4 % (for C. villosum) of NFSs were infected by one acanthocephalan species; two species were found in 22.6 %; three in 9.7 %; and four in 3.2 %. Further studies of NFS parasites are necessary to follow the trends in parasitic infection rates and diversity in NFS population on the Pribilov Islands and for monitoring the influence of various ecological factors on NFS populations in Alaska.

Kuzmina, T. A., Lyons, E. T., & Spraker, T. R. (2014). Anisakids (Nematoda: Anisakidae) from Stomachs of Northern Fur Seals (*Callorhinus ursinus*) on St. Paul Island, Alaska: Parasitological and Pathological Analysis. *Parasitology Research, 113*(12), 4463-4470. https://doi.org/10.1007/s00436-014-4131-2

Anisakid nematodes parasitize the alimentary tracts of aquatic vertebrates, including northern fur seals (*Callorhinus ursinus*) (NFS). The main purpose of this study was to estimate the prevalence, intensity, and species composition of anisakids in NFSs on St. Paul Island, Alaska, and to analyze changes in NFS infection with these nematodes during the last decades. The study was carried out on St. Paul Island, Alaska, in July-August 2011-2013. Stomachs of 443 humanely harvested NFS males were collected from

five separate haul-out areas. A total of 4,460 anisakid specimens were collected and identified by morphological criteria. Gross and histological examinations of stomachs were also performed. The overall prevalence of NFS infection was 91.2 %; overallmean intensity 10.9, and overall median intensity 6. Five species, Anisakis simplex s. l., Contracaecum osculatum s. l., Pseudoterranova decipiens s. l., P. azarazi and Phocascaris cystophorae, were found. The prevalence of Anisakis was 46.5%, its intensity 7.5. The prevalence and intensity of Contracaecum, Pseudoterranova, and Phocascaris were 33.6 % and 3.5, 81.9 % and 6.5, and 5.2 % and 1.7, respectively. Significant differences in the prevalence of NFS infection were observed between separate haul-outs. Comparison of the present data with the results of studies performed in the North Pacific in the 1960s, showed a significant decrease in the intensity of NFS infection with anisakids during the last decades. The prevalence of mucosal lesions in NFS stomachs caused by anisakids also decreased from 92 to 20.9 %. Possible reasons for the changes in NFS infection with anisakids are discussed.

Kuzmina, T. A., Tkach, V. V., Spraker, T. R., Lyons, E. T., & Kudlai, O. (2018). Digeneans of Northern Fur Seals *Callorhinus ursinus* (Pinnipedia: Otariidae) from Five Subpopulations on St. Paul Island, Alaska. *Parasitology Research, 117*(4), 1079-1086. https://doi.org/10.1007/s00436-018-5784-z

A parasitological survey of 651 northern fur seals *Callorhinus ursinus* L. from five subpopulations was conducted on St. Paul Island, Alaska, during July-August 2012-2014. Digenean trematodes were found in 210 of 651 fur seals with a total prevalence of 32.3%. Intensity of infection varied from 1 to 1540 parasites with mean intensity 18.4 +/- 111.1 SD and median intensity of 2 specimens per host. Significant differences in prevalence and intensity of infection in northern fur seals between separate rookeries was not observed (Mann-Whitney test; $p > 0.05$). Four species of digeneans belonging to the families Heterophyidae (Apophallus zalophi Price, 1932, Phocitrema fusiforme Goto and Ozaki, 1930, and Galactosomum ubelakeri (Dailey, 1969)) and Troglotrematidae (Nanophyetus salmincola (Chapin, 1926)) were found. Nanophyetus salmincola is reported from C. ursinus for the first time. We obtained partial 28S rDNA sequences for all digenean species and conducted molecular phylogenetic analysis to demonstrate their phylogenetic relationships.

Lander, M. E., Lindstrom, T., Rutishause, M., Franzheim, A., & Holland, M. (2015). Development and Field Testing a Satellite-Linked Fluorometer for Marine Vertebrates. *Animal Biotelemetry, 3*, 1-11. https://doi.org/10.1186/s40317-015-0070-7

Understanding the responses of marine vertebrates to spatial and temporal variability of primary productivity is fundamental for their conservation and for predicting how they will be affected by climate change. Despite recent advances in biotelemetry, fluorometers have only recently been incorporated into larger transmitting systems. The purpose of this project was to incorporate a miniature fluorometer into a satellite-linked transmitter to provide measures of in situ phytoplankton fluorescence, which were used to calculate chlorophyll-a (chl-a), a proxy for primary productivity. After evaluating the suitability of commercially available fluorometers, the ECO PuckTM (WET Labs, Philomath, OR), which measures chl-a (0 to 75 µg Chl/L), was first interfaced with an archival instrument (TDR10) manufactured by Wildlife Computers (Redmond, WA, USA) to (1) determine if the interfaced prototype functioned properly, (2) examine data relative to the orientation of the optics, (3) monitor the behavior of tagged animals, and (4) collect a complete dive/sensor record to validate a data reduction routine established for Service Argos and verify performance of the Argos message generation.

Lapierre, J. L., Kosenko, P. O., Kodama, T., Peever, J. H., Mukhametov, L. M., Lyamin, O. I., & Siegel, J. M. (2013). Symmetrical Serotonin Release During Asymmetrical Slow-Wave Sleep: Implications for the Neurochemistry of Sleep-Waking States. *Journal of Neuroscience, 33*(6), 2555-2561. https://doi.org/10.1523/jneurosci.2603-12.2013

On land, fur seals predominately display bilaterally synchronized electroencephalogram (EEG) activity during slow-wave sleep (SWS), similar to that observed in all terrestrial mammals. In water, however, fur seals exhibit asymmetric slow-wave sleep (ASWS), resembling the unihemispheric slow-wave sleep of odontocetes (toothed whales). The unique sleeping pattern of fur seals allows us to distinguish neuronal mechanisms mediating EEG changes from those mediating behavioral quiescence. In a prior study we found that cortical acetylcholine release is lateralized during ASWS in the northern fur seal, with greater release in the hemisphere displaying low-voltage (waking) EEG activity, linking acetylcholine release to hemispheric EEG activation (Lapierre et al. 2007). In contrast to acetylcholine, we now report that cortical serotonin release is not lateralized during ASWS. Our data demonstrate that bilaterally symmetric levels of serotonin are compatible with interhemispheric EEG asymmetry in the fur seal. We also find greatly elevated levels during eating and hosing the animals with water, suggesting that serotonin is more closely linked to bilateral variables, such as axial motor and autonomic control, than to the lateralized cortical activation manifested in asymmetrical sleep.

Lapierre, J. L., Kosenko, P. O., Lyamin, O. I., Kodama, T., Mukhametov, L. M., & Siegel, J. M. (2007). Cortical Acetylcholine Release Is Lateralized During Asymmetrical Slow-Wave Sleep in Northern Fur Seals. *Journal of Neuroscience, 27*(44), 11999-12006. https://doi.org/10.1523/jneurosci.2968-07.2007

Fur seals are unique in that they display both bilateral slow-wave sleep (BSWS), as seen in all terrestrial mammals, and slow-wave sleep with interhemispheric electroencephalogram (EEG) asymmetry, resembling the unihemispheric slow waves of cetaceans. Little is known about the underlying mechanisms of this phenomenon, which is also termed asymmetrical slow wave sleep (ASWS). However, we may begin to understand the expression of ASWS by studying the neurotransmitter systems thought to be involved in the generation and maintenance of sleep-wake states in terrestrial mammals. We examined bilaterally the release of cortical acetylcholine (ACh), a neurotransmitter implicated in the regulation of cortical EEG and behavioral arousal, across the sleep-wake cycle in four juvenile northern fur seals (*Callorhinus ursinus*). In vivo microdialysis and high-performance liquid chromatography coupled with electrochemical detection were used to measure cortical ACh levels during polygraphically defined behavioral states. Cortical ACh release was state-dependent, showing maximal release during active waking (AW), similar levels during quiet waking (QW), and rapid eye movement (REM) sleep, and minimal release during BSWS. When compared with BSWS, cortical ACh levels increased similar to 300% during AW, and similar to 200% during QW and REM sleep. During these bilaterally symmetrical EEG states, ACh was synchronously released from both hemispheres. However, during ASWS, ACh release was lateralized with greater release in the hemisphere displaying lower voltage activity, at levels approximating those seen in QW. These findings demonstrate that cortical ACh release is tightly linked to hemispheric EEG activation.

Larson, S., & Casson, C. J. (2007). Reproductive Hormone Levels within Captive Female Northern Fur Seals (*Callorhinus ursinus*) with and without Chemical Contraceptives. *Aquatic Mammals, 33*(2), 195. https://doi.org/10.1578/AM.33.2.2007.195

Physiologically, there is little difference between pseudopregnancy and delayed implantation in Northern fur seals, and there is little difference in serum progesterone (P) levels between the delayed and implanted phase of pregnancy or active gestation and subsequent growth of the fertilized egg or embryo (Boyd et al., 1999).

Lea, M. A., Johnson, D., Melin, S., Ream, R., & Gelatt, T. (2010). Diving Ontogeny and Lunar Responses in a Highly Migratory Mammal, the Northern Fur Seal *Callorhinus ursinus*. *Marine Ecology Progress Series, 419*, 233-247. https://doi.org/10.3354/meps08758

Diving ontogeny studies enable the examination of both the evolution of diving strategies and the physiological constraints and environmental factors determining foraging behaviour. Northern fur seal (NFS) *Callorhinus ursinus* pups that undertake far-ranging migrations in their first year are an ideal species for examining such factors. The diving behaviour of 64 NFS pups from 4 North American breeding sites was studied using satellite-dive recorders deployed on pups prior to weaning. Summarised diving activity (6 h histograms of dive depth and duration) was recorded during the pups' first 8 mo at sea and transmitted via satellite. During the first month at sea, pups adopted the nocturnal diving patterns characteristic of adults, with average maximum nightly and crepuscular dive depths and durations exceeding daytime values by a factor of from 4 to 4.5. Diving capacity in terms of maximum depths (112 m) and durations (285 s) attained also increased linearly with age until similar to 8 to 10 mo of age. Overlaid on diving capability development was the significant influence of environmental cues, such as lunar phase, on migratory diving behaviour. During full moons, pups dived deeper and for longer periods than during other lunar phases, as pups likely mimicked the behaviour of their vertically migrating prey. These findings indicate that prey accessibility, particularly for younger pups with reduced diving capacity, may prove more challenging during higher lunar illumination periods.

Lea, M. A., Johnson, D., Ream, R., Sterling, J., Melin, S., & Gelatt, T. (2009). Extreme Weather Events Influence Dispersal of Naive Northern Fur Seals. *Biology Letters, 5*(2), 252-257. https://doi.org/10.1098/rsbl.2008.0643

Since 1975, northern fur seal (*Callorhinus ursinus*) numbers at the Pribilof Islands (PI) in the Bering Sea have declined rapidly for unknown reasons. Migratory dispersal and habitat choice may affect first-year survivorship, thereby contributing to this decline. We compared migratory behaviour of 166 naive pups during 2 years from islands with disparate population trends (increasing: Bogoslof and San Miguel Islands; declining: PI), hypothesizing that climatic conditions at weaning may differentially affect dispersal and survival. Atmospheric conditions (Bering Sea) in autumn 2005-2006 were anomalously cold, while 2006-2007 was considerably warmer and less stormy. In 2005, pups departed earlier at all sites, and the majority of PI pups (68-85%) departed within 1 day of Arctic storms and dispersed quickly, travelling southwards through the Aleutian Islands. Tailwinds enabled faster rates of travel than headwinds, a trend not previously shown for marine mammals. Weather effects were less pronounced at Bogoslof Island (approx. 400 km further south), and, at San Miguel Island, (California) departures were more gradual, and only influenced by wind and air pressure in 2005. We suggest that increasingly

variable climatic conditions at weaning, particularly timing, frequency and intensity of autumnal storms in the Bering Sea, may alter timing, direction of dispersal and potentially survival of pups.

Lecky, J. H. (2010). *Environmental Assessment for Issuance of an Incidental Harassment Authorization for Replacement and Repair of Northern Fur Seal Observation Towers and Walkways on St. Paul Island, Alaska*. National Marine Fisheries Service Office of Protected Resources. Retrieved from https://repository.library.noaa.gov/view/noaa/3818

The National Marine Fisheries Service (NMFS) proposes to issue an Incidental Harassment Authorization (IHA) to the NMFS Alaska Regional Office (NMFS AKR) for the take, by Level B harassment only, ofmarine mammals during construction (i.e., replacement and repair) operations of northern fur seal observation towers and walkways on St. Paul Island, Alaska, April to June and December, 2010. NMFS has detennined that the impact ofconducting the replacement and repair operations on St. Paul Island may result, at worst, in a temporary modification in behavior of small numbers ofnorthern fur seals. No injury, serious injury, or mortality is anticipated to result from this activity, nor is it authorized. NMFS has further detennined that this activity will result in a negligible impact on the affected species or stocks.

Lee, D. E., Berger, R. W., Tietz, J. R., Warzybok, P., Bradley, R. W., Orr, A. J., . . . Jahncke, J. (2018). Initial Growth of Northern Fur Seal (*Callorhinus ursinus*) Colonies at the South Farallon, San Miguel, and Bogoslof Islands. *Journal of Mammalogy, 99*(6), 1529-1538. https://doi.org/10.1093/jmammal/gyy131

Understanding the colonization or recolonization of breeding sites used by colonial animals is fundamental to metapopulation theory and has practical applications in conservation biology. Historically, pinniped species were heavily exploited worldwide, resulting in some breeding colonies becoming extirpated. As populations recover, some abandoned sites may be recolonized or new sites can be colonized. We analyzed aerial and ground survey data on pup counts from 3 islands (South Farallon, San Miguel, and Bogoslof) (re)colonized by northern fur seals (*Callorhinus ursinus*), using classical and Bayesian state-space modeling approaches to describe population growth rates during their initial 21 years, with particular focus on the South Farallon Islands. We used information from tagged animals that immigrated to the South Farallon Islands from San Miguel Island to describe the age and sex structure of the founding recolonizers of the South Farallon Islands. We also examined the evidence for the generality of Roux's (1987) description of fur seal population recovery using a literature review of published fur seal population growth rates. We found the 3 colonies had different annual population growth rates (South Farallon = 34%, San Miguel = 45%, Bogoslof = 59%), but all were growing at rates among the fastest observed for fur seals worldwide. Immigrants from San Miguel to the South Farallon Islands were younger and female-biased relative to the tagged population at San Miguel Island. The general framework described by Roux (1987) was an effective description of observed fur seal population recovery. Our results inform our understanding of the initiation and growth of pinniped breeding colonies.

Lee, O., Andrews, R. D., Burkanov, V. N., & Davis, R. W. (2014). Ontogeny of Early Diving and Foraging Behavior of Northern Fur Seal (*Callorhinus ursinus*) Pups from Bering Island, Russia. *Marine Biology, 161*(5), 1165-1178. https://doi.org/10.1007/s00227-014-2408-8

The ontogeny of diving and foraging behavior of northern fur seal pups from a stable population on Bering Island, Russia, was recorded with animal-borne instruments during their first few months at sea, a critical period during their first year at sea. Thirty-five pups were instrumented with satellite-linked time-depth recorders and stomach temperature pills. Diving occurred predominantly at night with deeper and longer dives as the pups matured. Mean dive depths were correlated with lunar illumination, whereas mean dive durations were also correlated with time of day and sex. Foraging success did not differ between sexes, and there was no relationship between meal size (as indicated by feeding event duration and minimum stomach temperature) and lunar illumination fraction or maximum foraging depth. Although most pups were able to successfully forage within 3 days of starting their migration, the number of feeding events recorded each day remained low (mean 1.6 events day(-1)). There was no indication of an appreciable increase in meal size after the first 2 weeks of the migration despite an increase in dive frequency and depth. The results are consistent with observations that pups do not gain mass during their first year and emphasize the risk of starvation from infrequent foraging in cold water.

Lee, O. A. (2011). *Early Migratory Behavior of Northern Fur Seal (Callorhinus ursinus) Pups from Bering Island, Russia.* Texas A&M University. Retrieved from http://hdl.handle.net/1969.1/ETD-TAMU-2011-05-9144

I examined the population trends of northern fur seals (*Callorhinus ursinus*) using an age-specific metapopulation model that allowed migration between rookeries. Mortality and birth rates were modified to simulate future population trends. I also examined the early migratory behavior and habitat associations of pups from Bering Island (BI), Russia. I instrumented 35 pups with Mk10-AL satellite tags and stomach temperature telemeters which provided diving, foraging and location data. I hypothesized that some aspects of pup behavior from the stable BI population differed from the behavior of pups from the unstable Pribilof Islands (PI). The population model revealed that emigration did not contribute significantly to the current PI population decline. However, large source populations contributed significantly to population growth in newly colonized rookeries. A stabilization of the PI population was predicted with a 10 to 20 % reduction in both juvenile and adult female mortality rates. The diving behavior of pups showed a general progression towards longer and deeper dives as pups aged, particularly between 1600 - 0400 (local time), that was similar to PI pup behavior. However, unlike pups from the PI, I found three main diving strategies among BI pups: 1) shallow daytime divers (mean depth = 3.56 m), 2) deep daytime divers (mean depth = 6.36 m) and 3) mixed divers (mean depth = 4.81 m). The foraging behavior of pups showed that most successful ingestion events occurred between 1600 - 0400, with successful ingestion events lasting 25.36 plus or minus 27.37 min. There was no significant difference among the three strategies in the depth of successful foraging dives. I also examined the foraging search strategies in adult females and pups. Both pups and adults conducted Levy walks, although pups foraged in smaller patches (1 km scales). Using a logistic model to determine habitat associations, I found that pup locations were positively correlated with increasing chlorophyll a concentrations, distances from shore, and sea surface temperatures, and were negatively correlated with depth. There was no significant relationship between all pup locations and the regions (peripheries or centers) or types (cyclonic or anti-cyclonic) of eddies, but ingestion event locations were related to mesoscale eddy peripheries.

Lee, O. A., Burkanov, V., & Neill, W. H. (2014). Population Trends of Northern Fur Seals (*Callorhinus ursinus*) from a Metapopulation Perspective. *Journal of Experimental Marine Biology and Ecology, 451*, 25-34. https://doi.org/10.1016/j.jembe.2013.10.029

A metapopulation model was created to explore source-sink population dynamics in northern fur seals (*Callorhinus ursinus*), for which the largest source population is declining, but smaller, newly established populations are either stable or growing. A declining source population could therefore slow down the growth of newly established populations. We also investigated changes in mortality and birth rates that could stabilize the declining population trend on the Pribilof Islands. The six main breeding populations-in the Pribilof Islands, Commander Islands, Kuril Islands, Robben Island, San Miguel Island, and Bogoslof Island-were modeled as individual age-structured populations, that were linked together using a migration model. The migration model component allowed movement of subadults among the six populations, with rules based on distances between populations, average travel speeds, habitat preferences, and El Nino events. The metapopulation model revealed the importance of immigration to newly established populations during the first 8 years of population growth. After the initial growth period, additional immigration had no noticeable effect on population growth in sink populations. The population trend on the Pribilof Islands was difficult to stabilize, and immigration from smaller populations could not slow the population decline. Consequently, conservation of the Pribilof Islands population likely requires a long recovery period following reductions in population-specific mortality rates for adult females, juveniles and pups.

Lee, S. M., Lee, M. Y., Jeon, H. S., Kim, J. A., Lee, S. H., & An, J. (2018). Complete Mitochondrial Genome and Phylogenetic Analysis of *Callorhinus ursinus*: An Endangered Species from South Korea. *Mitochondrial DNA Part B-Resources, 3*(2), 496-497. https://doi.org/10.1080/23802359.2018.1457992

We present the complete mitochondrial genome and a phylogenetic analysis o*Callorhinus ursinus*, the northern fur seal, determined using Illumina next-generation sequencing (NGS) technology. The total length of the mitogenome was 17,154 bp, which consisted of 13 protein-coding genes, two ribosomal RNA genes, 22 tRNA genes, and one control region. The base composition of the entire mitogenome was 33.5% (A), 26.3% (C), 13.9% (G), and 26.3% (T) with an A+T bias of 59.8%. The control region contained two types of tandem repeats. A neighbour-joining (NJ) tree was constructed and comprised two clades with C. ursinus forming a monophyletic group. Data produced in this study will aid exploration of the genetic diversity of endangered C. ursinus and contribute to molecular identification of this species.

Lefebvre, K. A., Quakenbush, L., Frame, E., Huntington, K. B., Sheffield, G., Stimmelmayr, R., . . . Gill, V. (2016). Prevalence of Algal Toxins in Alaskan Marine Mammals Foraging in a Changing Arctic and Subarctic Environment. *Harmful Algae, 55*, 13-24. https://doi.org/10.1016/j.hal.2016.01.007

Current climate trends resulting in rapid declines in sea ice and increasing water temperatures are likely to expand the northern geographic range and duration of favorable conditions for harmful algal blooms (HABs), making algal toxins a growing concern in Alaskan marine food webs. Two of the most common HAB toxins along the west coast of North America are the neurotoxins domoic acid (DA) and saxitoxin (STX). Over the last 20 years, DA toxicosis has caused significant illness and mortality in marine mammals along the west coast of the USA, but has not been reported to impact marine mammals foraging in Alaskan waters. Saxitoxin, the most potent of the paralytic shellfish poisoning toxins, has

been well-documented in shellfish in the Aleutians and Gulf of Alaska for decades and associated with human illnesses and deaths due to consumption of toxic clams. There is little information regarding exposure of Alaskan marine mammals. Here, the spatial patterns and prevalence of DA and STX exposure in Alaskan marine mammals are documented in order to assess health risks to northern populations including those species that are important to the nutritional, cultural, and economic well-being of Alaskan coastal communities. In this study, 905 marine mammals from 13 species were sampled including; humpback whales, bowhead whales, beluga whales, harbor porpoises, northern fur seals, Steller sea lions, harbor seals, ringed seals, bearded seals, spotted seals, ribbon seals, Pacific walruses, and northern sea otters. Domoic acid was detected in all 13 species examined and had the greatest prevalence in bowhead whales (68%) and harbor seals (67%). Saxitoxin was detected in 10 of the 13 species, with the highest prevalence in humpback whales (50%) and bowhead whales (32%). Pacific walruses contained the highest concentrations of both STX and DA, with DA concentrations similar to those detected in California sea lions exhibiting clinical signs of DA toxicosis (seizures) off the coast of Central California, USA. Forty-six individual marine mammals contained detectable concentrations of both toxins emphasizing the potential for combined exposure risks. Additionally, fetuses from a beluga whale, a harbor porpoise and a Steller sea lion contained detectable concentrations of DA documenting maternal toxin transfer in these species. These results provide evidence that HAB toxins are present throughout Alaska waters at levels high enough to be detected in marine mammals and have the potential to impact marine mammal health in the Arctic marine environment.

Lefebvre, K. A., Robertson, A., Frame, E. R., Colegrove, K. M., Nance, S., Baugh, K. A., . . . Gulland, F. M. D. (2010). Clinical Signs and Histopathology Associated with Domoic Acid Poisoning in Northern Fur Seals (*Callorhinus ursinus*) and Comparison of Toxin Detection Methods. *Harmful Algae, 9*(4), 374-383. https://doi.org/10.1016/j.hal.2010.01.007

Between July 2005 and March 2009, 33 northern fur seals *(Callorhinus ursinus*) were collected after stranding along the central California coast between Sonoma and San Luis Obispo counties. Of these, 26 were collected live and could be observed for signs of neuroexcitotoxicity. Approximately half exhibited the classic clinical signs of domoic acid (DA) toxicosis including muscle twitches and ataxia, to seizures and coma, and had lesions in the central nervous system and heart. Several biological fluids were collected for DA analysis including aqueous humor, serum, stomach contents, feces, urine, abdominal fluid, amniotic fluid and milk. Four analytical methods were employed including receptor binding assay (RBA), enzyme-linked immunosorbent assay (ELISA), high performance liquid chromatography (HPLC-UV) and ultra performance liquid chromatography-tandem mass spectrometry (UPLC-MS/MS). The DA concentrations determined by each method were positively correlated. Domoic acid was detected in 83% of fecal samples collected from northern fur seals in the present study and in one animal was calculated to contain up to 18.6 mu g DA/g. Interestingly, DA was detected and confirmed in the aqueous humor of the only animal this sample-type was collected from, suggesting that this may prove to be a useful diagnostic body fluid for algal toxin detection in marine mammal mortality events. These data document for the first time that northern fur seals are impacted by DA-producing harmful algal blooms along the California coast.

Lim, S. Y., Jin, S. J., & Yoo, S. H. (2017). The Economic Benefits of the Dokdo Seals Restoration Project in Korea: A Contingent Valuation Study. *Sustainability, 9*(6) https://doi.org/10.3390/su9060968

Northern fur seals (*Callorhinus ursinus*), especially those that live in Dokdo, Korea, represent an endangered species in Korea. Thus, the government is considering the implementation of the Dokdo Seals (DS) restoration project. This article looks at the economic benefits for implementing the project, which includes making habitats for the DS, such as an artificial sea ranch, and training DS rescued from fishing nets and wounded in the wild to adapt to the wild so that they can be released into the Dokdo Sea. To this end, we looked at the willingness to pay (WTP) for the implementation of the project by conducting a contingent valuation (CV) survey of 1000 Korean households. We employed a one-and-one-half-bounded dichotomous choice question format. Furthermore, we used a spike model to model the WTP responses with zero observations. The mean yearly WTP for the project implementation was computed to be KRW 4923 (USD 4.86) for next ten years per household, which is statistically significant at the 1% level. The national annual value amounts to KRW 90.9 billion (USD 89.8 million). This value can be taken as an indication of the economic benefits of restoring the endangered species.

Lindsay, B. A., & Lindsay, J. A. (2009). *Pribilof Islands, Alaska: Genealogy and Census: A Historical Account Told through Illustrated Genealogy and Census Records*. Seattle, WA: U.S. Department of Commerce.

[NO ABSTRACT AVAILABLE]

Lindsay, B. A., & Lindsay, J. A. (Eds.). (2010). *Pribilof Islands, Alaska: The People: A Historical Account Told through Illustrated Biographies*. Seattle, WA: U.S. Department of Commerce.

[NO ABSTRACT AVAILABLE]

Lindsay, J. A. (Ed.) (2008). *Pribilof Islands, Alaska: Preserving the Legacy*. Seattle, WA: U.S. Department of Commerce, NOAA, NOS, Office of Response and Restoration.

[NO ABSTRACT AVAILABLE]

Lindsay, J. A., Sclater, K., Maberry, R., Winandy, D. B., & Lindsay, B. A. (2012). *St. Paul Island Guide to Historical Resources, 1867-1984 : Seal Island National Historic Landmark District, Pribilof Islands, Alaska*. National Marine Fisheries Service. NMFS-F/SPO-122. Retrieved from https://repository.library.noaa.gov/view/noaa/12860

This book examines the Seal Islands' history by tracing the historical resources on St. Paul Island, particularly those identified within the NHLD. Historical emphasis is on the time period between the Pribilof Islands accession into the United States (1867) and the end of commercial fur-sealing on the islands (1984). This time period highlights some of the ways Aleuts, Russians, the U.S. government, and U.S. businesses influenced the socio-economic development of the islands. While this book focuses on St. Paul Island, it includes an overview of historical resources on St. George Island; a similar book spotlighting St. George Island will be completed if time and funding allow. This book contains some of the materials submitted to and accepted by the SHPO and NPS, including as the Alaska Historic Resources Survey (AHRS) and Historic American Buildings Survey (HABS) forms, respectively. The AHRS and HABS forms in this book are presented in book format, rather than the original submission format,

and have been updated to reflect new information and corrections. NOAA did not submit photographs with the AHRS forms sent to the SHPO, nor the HABS forms sent to NPS; however, photographs complement AHRS and HABS forms here. Photos include those taken during an AHRS site visit in 2007, as well as images taken at earlier times found in various collections. In 2004, NOAA contracted with NPS to produce large format (5 x 7 inches) photographs and measured drawings (House #59, Teacher's House 103 [aka "Teacher's House D"], and Government House) of contributing resources and some noncontributing resources, according to HABS standards, such as Webster House, remaining on St. Paul Island. Many of the approximately 120 5 x 7 photographs and four measured drawings, now in the Library of Congress (http://memory.loc.gov/cgi-bin/query/D?hh:16:./temp/~ammem_nI49), are reproduced in this book and accompany the relevant resource. Since 2004, additional images of some of the subjects studied by NPS offered perspectives similar to those in the Library of Congress HABS photograph collection, although on a smaller scale (35 mm, 6 cm x 7 cm, and in digital formats). Some of these are included herein.

Liu, Y., Zidek, J. V., Trites, A. W., & Battaile, B. C. (2016). Bayesian Data Fusion Approaches to Predicting Spatial Tracks: Application to Marine Mammals. *Annals of Applied Statistics, 10*(3), 1517-1546. https://doi.org/10.1214/16-aoas945

Bayesian Melding (BM) and downscaling are two Bayesian approaches commonly used to combine data from different sources for statistical inference. We extend these two approaches to combine accurate but sparse direct observations with another set of high-resolution but biased calculated observations. We use our methods to estimate the path of a moving or evolving object and apply them in a case study of tracking northern fur seals. To make the BM approach computationally feasible for high-dimensional (big) data, we exploit the properties of the processes along with approximations to the likelihood to break the high-dimensional problem into a series of lower dimensional problems. To implement the alternative, downscaling approach, we use R-INLA to connect the two sources of observations via a linear mixed effect model. We compare the predictions of the two approaches by cross-validation as well as simulations. Our results show that both approaches yield similar results-both provide accurate, high resolution estimates of the at-sea locations of the northern fur seals, as well as Bayesian credible intervals to characterize the uncertainty about the estimated movement paths.

Liwanag, H. E. M. (2010). Energetic Costs and Thermoregulation in Northern Fur Seal (*Callorhinus ursinus*) Pups: The Importance of Behavioral Strategies for Thermal Balance in Furred Marine Mammals. *Physiological and Biochemical Zoology, 83*(6), 898-910. https://doi.org/10.1086/656426

Behavioral thermoregulation represents an important strategy for reducing energetic costs in thermally challenging environments, particularly among terrestrial vertebrates. Because of the cryptic lifestyle of aquatic species, the energetic benefits of such behaviors in marine endotherms have been much more difficult to demonstrate. In this study, I examined the importance of behavioral thermoregulation in the northern fur seal (*Callorhinus ursinus*) pup, a small-bodied endotherm that spends prolonged periods at sea. The thermal neutral zones of three weaned male northern fur seal pups (body mass range = 11.8-12.8 kg) were determined by measuring resting metabolic rate using open-flow respirometry at water temperatures ranging from 2.5 degrees to 25.0 degrees C. Metabolic rate averaged 10.03 +/- 2.26 mL O(2) kg(-1) min(-1) for pups resting within their thermal neutral zone; lower critical temperature was 8.3 degrees +/- 2.5 degrees C, approximately 8 degrees C higher than the coldest sea surface temperatures

encountered in northern Pacific waters. To determine whether behavioral strategies could mitigate this potential thermal limitation, I measured metabolic rate during grooming activities and the unique jughandling behavior of fur seals. Both sedentary grooming and active grooming resulted in significant increases in metabolic rate relative to rest (P = 0.001), and percent time spent grooming increased significantly at colder water temperatures (P < 0.001). Jughandling metabolic rate (12.71 +/- 2.73 mL O(2) kg(-1) min(-1)) was significantly greater than resting rates at water temperatures within the thermal neutral zone (P < 0.05) but less than resting metabolism at colder water temperatures. These data indicate that behavioral strategies may help to mitigate thermal challenges faced by northern fur seal pups while resting at sea.

Liwanag, M., & Elizabeth, H. (2008). *Fur Versus Blubber: A Comparative Look at Marine Mammal Insulation and Its Metabolic and Behavioral Consequences.* (Ph.D.), University of California, Santa Cruz, Ann Arbor. Retrieved from https://static1.squarespace.com/static/5b2b3ff925bf021e06c941f5/t/5babb5dee4966b82cad3f754/1537979877044/Mostman+Liwanag+Thesis.pdf

This research compares the use of fur and blubber as insulation in mammals, with a focus on the otariids (fur seals and sea lions) and the transition of mammals to aquatic living. The otariids represent the only mammalian family to include both types of insulation: fur seals have dense, waterproof fur and a moderate blubber layer, while sea lions rely solely on blubber for insulation in water. To compare the effectiveness of these different mechanisms of insulation, I examined the thermal properties of the fur and blubber of various otariid species, and evaluated their role in the physiological and behavioral responses of the California sea lion (Zalophus californianus) and northern fur seal (*Callorhinus ursinus*) exposed to different water temperatures. Chapter 1 presents the morphological and thermal characteristics of fur and blubber as measured on sculps (fur, skin, and blubber) from a wide variety of pinniped species. Values were then compared to those of pelts (fur and skin) from terrestrial and semi-aquatic carnivores. Morphological measurements included hair cuticle shape, hair circularity, hair length, fur density, and blubber thickness. In addition, the composition of blubber fat was determined from lipid and water content, and fatty acid profiles. The effects of hydrostatic pressure on the insulating layer were determined empirically. Measurement of the thermal conductivity of the samples allowed assessment of the overall effectiveness of each insulation type. I found consistent trends in hair morphology associated with aquatic living, which included (1) flattening and shortening of the hairs, (2) elongation of hair cuticle scales, and (3) increases in fur density for species utilizing fur for insulation in water. Such characteristics are considered critical for maintaining an insulating air layer within the fur during submersion. I also observed a secondary loss of these features in species with more developed blubber layers. Comparisons of blubber composition indicated stratification of this layer in species relying on the blubber for insulation. Lipid stratification was consistent with the use of the outer layer for thermoregulation and the inner layer for energy storage. Among otariids, blubber quality (lipid content and thermal conductivity) did not differ between fur seals and sea lions. Rather, blubber quantity (thickness) differentiated each otariid group. Overall, differences in total insulation among carnivore species, both terrestrial and aquatic, were influenced substantially by body size and habitat, and to a lesser extent by latitudinal climate. Chapters 2 and 3 subsequently address the influence of body size, insulation type, and maturity on whole-animal metabolic responses to water temperature. Once again, California sea lions and northern fur seals were compared as representatives of two different thermal mechanisms. Lower critical temperatures (TLC) and the metabolic consequences of at-sea behaviors were determined for both species. By comparing the TLC determined in the laboratory with routine temperatures encountered in the wild, I was able to assess a relative thermal liability for

each species. With a TLC of 5°C, adult female California sea lions demonstrated thermal competence across the natural range of water temperatures encountered by this species in the wild. In contrast, juvenile California sea lions had a TLC greater than 12°C, revealing a potential thermal limitation that was mitigated by swimming activity. Northern fur seal pups, small-bodied marine mammals using only fur for insulation, had a TLC of 8°C, and thus also exhibited thermal limitations within their natural water temperature range. Based on this and the pelagic lifestyle of young fur seals, other mechanisms of thermoregulation would be required for the animals to remain in thermal balance when resting at sea. I propose that young fur seals utilize both the heat increment of feeding as well as a variety of at-sea behaviors, including grooming and a unique jughandle position, to mitigate the observed ther al limitation. In summary, the results of these studies indicate that fur underwent considerable evolutionary modification for aquatic living. Ultimately, based on an examination of extant species, fur acts as an effective insulator in water for small-bodied endotherms. Fur is the superior insulator in terms of thermal resistance per unit thickness, as long as the air layer can be maintained among the hairs. This requires a metabolic investment by the animal through grooming. With larger body size, marine mammals can develop extraordinarily thick blubber layers, which facilitate thermal balance during swimming and diving. This form of insulation can serve additional roles such as buoyancy control, energy storage, and streamlining. Overall, I find that the most effective form of insulation for aquatic mammals depends on body size as well as habitat. Heat generated by the processing of food and through skeletal muscle thermogenesis during activity helps to mitigate thermal shortfalls in insulation, and this mechanism of thermal substitution appears to be especially important for maintaining thermal balance in the smaller aquatic species and during immature life stages.

Lyamin, O., Kibalnikov, A., Kosenko, P., Mukhametov, L., & Siegel, J. (2010). Cardio-Respiratory Pattern of Northern Fur Seals During Sleep and Waking. *Sleep, 33*, A23.

[NO ABSTRACT AVAILABLE]

Lyamin, O., Pryaslova, J., Mukhametov, L., & Siegel, J. (2010). Circadian Activity of Northern Fur Seals under the Controlled Light-Dark Cycle. *Sleep, 33*, A73.

[NO ABSTRACT AVAILABLE]

Lyamin, O. I., Kosenko, P. O., Korneva, S. M., Vyssotski, A. L., Mukhametov, L. M., & Siegel, J. M. (2018). Fur Seals Suppress REM Sleep for Very Long Periods without Subsequent Rebound. *Current Biology, 28*(12). https://doi.org/10.1016/j.cub.2018.05.022

Virtually all land mammals and birds have two sleep states: slow-wave sleep (SWS) and rapid eye movement (REM) sleep [1, 2]. After deprivation of REM sleep by repeated awakenings, mammals increase REM sleep time [3], supporting the idea that REM sleep is homeostatically regulated. Some evidence suggests that periods of REM sleep deprivation for a week or more cause physiological dysfunction and eventual death [4, 5]. However, separating the effects of REM sleep loss from the stress of repeated awakening is difficult [2, 6]. The northern fur seal (*Callorhinus ursinus*) is a semiaquatic mammal [7]. It can sleep on land and in seawater. The fur seal is unique in showing both the bilateral SWS seen in most mammals and the asymmetric sleep previously reported in cetaceans [8]. Here we show that when the fur seal stays in seawater, where it spends most of its life [7], it goes without or

greatly reduces REM sleep for days or weeks. After this nearly complete elimination of REM, it displays minimal or no REM rebound upon returning to baseline conditions. Our data are consistent with the hypothesis that REM sleep may serve to reverse the reduced brain temperature and metabolism effects of bilateral nonREM sleep, a state that is greatly reduced when the fur seal is in the seawater, rather than REM sleep being directly homeostatically regulated. This can explain the absence of REM sleep in the dolphin and other cetaceans and its increasing proportion as the end of the sleep period approaches in humans and other mammals.

Lyamin, O. I., Kosenko, P. O., Lapierre, J. L., Mukhametov, L. M., & Siegel, J. M. (2008). Fur Seals Display a Strong Drive for Bilateral Slow-Wave Sleep While on Land. *Journal of Neuroscience, 28*(48), 12614-12621. https://doi.org/10.1523/jneurosci.2306-08.2008

Fur seals (pinnipeds of the family Otariidae) display two fundamentally different patterns of sleep: bilaterally symmetrical slow-wave sleep (BSWS) as seen in terrestrial mammals and slow-wave sleep (SWS) with a striking interhemispheric EEG asymmetry (asymmetrical SWS or ASWS) as observed in cetaceans. We examined the effect of preventing fur seals from sleeping in BSWS on their pattern of sleep. Four northern fur seals (*Callorhinus* ursinus) kept on land were sleep deprived (SD) of BSWS for 3 consecutive days, followed by 1 recovery day. EEG asymmetry was evaluated both visually and by EEG spectral analysis. SD significantly reduced the percentage of high-voltage BSWS (on average to 14% of baseline) and REM sleep (to 60% of baseline) whereas the percentage of low-voltage BSWS was not affected. During the SD period, all seals repeatedly tried to enter BSWS (109-411 attempts per day). SD significantly increased the amount of ASWS in each seal when scored visually (to 116-235% of baseline) and the difference in the EEG slow-wave activity (spectral power in the range of 1.2-4.0 Hz) between the two hemispheres (117-197%) as measured by the asymmetry index. High-voltage BSWS and the amount of SWS in each hemisphere were significantly elevated during the first 4 h of recovery. These data indicate that fur seals display a homeostatic response to the loss of SWS and that alternating SWS in the two hemispheres does not adequately compensate for the absence of BSWS.

Lyamin, O. I., Lapierre, J. L., Kosenko, P. O., Kodama, T., Bhagwandin, A., Korneva, S. M., . . . Siegel, J. M. (2016). Monoamine Release During Unihemispheric Sleep and Unihemispheric Waking in the Fur Seal. *Sleep, 39*(3), 625-636. https://doi.org/10.5665/sleep.5540

Study Objectives: Our understanding of the role of neurotransmitters in the control of the electroencephalogram (EEG) has been entirely based on studies of animals with bilateral sleep. The study of animals with unihemispheric sleep presents the opportunity of separating the neurochemical substrates of waking and sleep EEG from the systemic, bilateral correlates of sleep and waking states. Methods: The release of histamine (HI), norepinephrine (NE), and serotonin (5HT) in cortical and subcortical areas (hypothalamus, thalamus and caudate nucleus) was measured in unrestrained northern fur seals (*Callorhinus ursinus*) using in vivo microdialysis, in combination with, polygraphic recording of EEG, electrooculogram, and neck electromyogram. Results: The pattern of cortical and subcortical HI, NE, and 5HT release in fur seals is similar during bilaterally symmetrical states: highest in active waking, reduced in quiet waking and bilateral slow wave sleep, and lowest in rapid eye movement (REM) sleep. Cortical and subcortical HI, NE, and 5HT release in seals is highly elevated during certain waking stimuli and behaviors, such as being sprayed with water and feeding. However, in contrast to acetylcholine (ACh), which we have previously studied, the release of HI, NE, and 5HT during unihemispheric sleep is not lateralized in the fur seal. Conclusions: Among the studied

neurotransmitters most strongly implicated in waking control, only ACh release is asymmetric in unihemispheric sleep and waking, being greatly increased on the activated side of the brain.

Lyamin, O. I., Lapierre, J. L., Kosenko, P. O., Mukhametov, L. M., & Siegel, J. M. (2008). Electroencephalogram Asymmetry and Spectral Power During Sleep in the Northern Fur Seal. *Journal of Sleep Research, 17*(2), 154-165. https://doi.org/10.1111/j.1365-2869.2008.00639.x

The fur seal (*Callorhinus ursinus*), a member of the Pinniped family, displays a highly expressed electroencephalogram (EEG) asymmetry during slow wave sleep (SWS), which is comparable with the unihemispheric sleep in cetaceans. In this study, we investigated the EEG asymmetry in the fur seal using spectral analysis. Four young (2-3 years old) seals were implanted with EEG electrodes for polygraphic sleep recording. In each animal, EEG spectral power in the frequency range of 1.2-16 Hz was computed in symmetrical cortical recordings over two consecutive nights. The degree of EEG asymmetry was measured by using the asymmetry index [AI = (L - R)/(L + R), where L and R are the spectral powers in the left and right hemispheres, respectively]. In fur seals, EEG asymmetry, as measured by the percent of 20-s epochs with absolute AI > 0.3 and > 0.6, was expressed in the entire frequency range (1.2-16 Hz). The asymmetry was significantly greater during SWS (25.6-44.2% of all SWS epochs had an absolute AI > 0.3 and 2.1-12.2% of all epochs had AI > 0.6) than during quiet waking (11.0-20.3% and 0-1.9% of all waking epochs, respectively) and REM sleep (4.2-8.9% of all REM sleep epochs and no epochs, respectively). EEG asymmetry was recorded during both low- and high-voltage SWS, and was maximal in the range of 1.2-4 and 12-16 Hz. As shown in this study, the degree of EEG asymmetry and the frequency range in which it is expressed during SWS in fur seals are profoundly different from those of terrestrial mammals and birds.

Lyamin, O. I., Mukhametov, L. M., & Siegel, J. M. (2017). Sleep in the Northern Fur Seal. *Current Opinion in Neurobiology, 44*, 144-151. https://doi.org/10.1016/j.conb.2017.04.009

The pattern of sleep in the fur seal, a semiaquatic pinniped, has several striking behavioral and physiological adaptations that allow this species to inhabit both the land and water environment. These features include unihemispheric slow wave sleep (USWS, also being unihemispheric waking), the ability to maintain movement for stabilization of the sleep posture and to briefly open one eye while having a sleep electroencephalogram (EEG) in one hemisphere. In vivo microdialysis studies suggest that acetylcholine release is required for cortical activation during USWS, and that monoamines are not required for USWS. The need to breathe, to maintain efficient thermoregulation, and to avoid predation have shaped the sleep patterns in semiaquatic fur seals as in fully aquatic cetaceans.

Lyamin, O. I., Pavlova, I. F., Kosenko, P. O., Mukhametov, L. M., & Siegel, J. M. (2012). Regional Differences in Cortical Electroencephalogram (EEG) Slow Wave Activity and Interhemispheric EEG Asymmetry in the Fur Seal. *Journal of Sleep Research, 21*(6), 603-611. https://doi.org/10.1111/j.1365-2869.2012.01023.x

Slow wave sleep (SWS) in the northern fur seal (*Callorhinus ursinus*) is characterized by a highly expressed interhemispheric electroencephalogram (EEG) asymmetry, called unihemispheric or asymmetrical SWS. The aim of this study was to examine the regional differences in slow wave activity (SWA; power in the range of 1.24.0 Hz) within one hemisphere and differences in the degree of

interhemispheric EEG asymmetry within this species. Three seals were implanted with 10 EEG electrodes, positioned bilaterally (five in each hemisphere) over the frontal, occipital and parietal cortex. The expression of interhemispheric SWA asymmetry between symmetrical monopolar recordings was estimated based on the asymmetry index [AI = (L-R)/(L+R), where L and R are the power in the left and right hemispheres, respectively]. Our findings indicate an anteriorposterior gradient in SWA during asymmetrical SWS in fur seals, which is opposite to that described for other mammals, including humans, with a larger SWA recorded in the parietal and occipital cortex. Interhemispheric EEG asymmetry in fur seals was recorded across the entire dorsal cerebral cortex, including sensory (visual and somatosensory), motor and associative (parietal or suprasylvian) cortical areas. The expression of asymmetry was greatest in occipitallateral and parietal derivations and smallest in frontalmedial derivations. Regardless of regional differences in SWA, the majority (90%) of SWS episodes with interhemispheric EEG asymmetry meet the criteria for unihemispheric SWS (one hemisphere is asleep while the other is awake). The remaining episodes can be described as episodes of bilateral SWS with a local activation in one cerebral hemisphere.

Lyons, E. T., DeLong, R. L., Nadler, S. A., Laake, J. L., Orr, A. J., DeLong, B. L., & Pagan, C. (2011). Investigations of Peritoneal and Intestinal Infections of Adult Hookworms (*Uncinaria* spp.) in Northern Fur Seal (*Callorhinus ursinus*) and California Sea Lion (*Zalophus californianus*) Pups on San Miguel Island, California (2003). *Parasitology Research, 109*(3), 581-589. https://doi.org/10.1007/s00436-011-2289-4

The peritoneal cavity (PNC) and intestine of northern fur seal (*Callorhinus ursinus*) pups and California sea lion (*Zalophus californianus*) pups that died in late July and early August, 2003, on San Miguel Island, California, were examined for hookworms. Prevalence and morphometric studies were done with the hookworms in addition to molecular characterization. Based on this and previous molecular studies, hookworms from fur seals are designated as Uncinaria lucasi and the species from sea lions as Uncinaria species A. Adult hookworms were found in the PNC of 35 of 57 (61.4%) fur seal pups and of 13 of 104 (12.5%) sea lion pups. The number of hookworms located in the PNC ranged from 1 to 33 (median = 3) for the infected fur seal pups and 1 to 16 (median = 2) for the infected sea lion pups. In addition to the PNC, intestines of 43 fur seal and 32 sea lion pups were examined. All of these pups were positive for adult hookworms. The worms were counted from all but one of the sea lion pups. Numbers of these parasites in the intestine varied from 3 to 2,344 (median = 931) for the fur seal pups and 39 to 2,766 (median = 643) for the sea lion pups. Sea lion pups with peritoneal infections had higher intensity infections in the intestines than did pups without peritoneal infections, lending some support for the hypothesis that peritoneal infections result from high-intensity infections of adult worms. There was no difference in intestinal infection intensities between fur seal pups with and without peritoneal infections. Female adult hookworms in the intestines of both host species were significantly larger than males, and sea lion hookworms were larger than those in fur seals. Worms in the intestine also were larger than worms found in the PNC. Gene sequencing and (RFLP) analysis of (PCR) amplified (ITS) ribosomal DNA were used to diagnose the species of 172 hookworms recovered from the PNC and intestine of 18 C. ursinus and seven *Z. californianus* hosts. These molecular data revealed that U. lucasi (hookworm of *C. ursinus*) and Uncinaria species A (of *Z. californianus*) infrequently mature in the intestine of the opposite host species in California rookeries. However, there is no support from molecular data for the hypothesis that cross-infection with "the wrong" Uncinaria species is a contributing factor in these cases of host peritonitis. The major significance of this research is the unusual finding of adult hookworms in the PNC of so many dead pups. No obvious explanation for this occurrence could be determined. Further research, like in the present study, should help understand

and monitor the apparent ever changing role of hookworm disease in the health of northern fur seal and California sea lion pups on SMI.

Lyons, E. T., Kuzmina, T. A., Carie, J. L., Tolliver, S. C., & Spraker, T. R. (2014). Prevalence of Hookworms, *Uncinaria lucasi* (Ancylostomatidae), in Northern Fur Seals (*Callorhinus ursinus*) on St. Paul Island, Alaska. *Vestnik Zoologii, 48*(3), 221-230. https://doi.org/10.2478/vzoo-2014-0025

Prevalence of Hookworms, Uncinaria lucasi (Ancylostomatidae), in Northern Fur Seals (*Callorhinus ursinus*) on St. Paul Island, Alaska. Lyons, E. T., Kuzmina, T. A., Carie, J. L., Tolliver, S. C., Spraker, T. R. - Review of main studies on biology and ecology of the hookworm Uncinaria lucasi Stiles, 1901 performed on St. Paul Island, Alaska, is presented. Current data on prevalence of adult hookworms parasitizing northern fur seals (NFS),*Callorhinus ursinus* Linnaeus, 1758, were obtained based on the examination of the intestines of dead NFS pups and subadult 3-4 year-old males in July and August of 2011-2013. In addition, blubber samples collected from subadult NFS males were examined for parasitic third stage hookworm larvae (L3). All current data were compared with previously published studies performed in 1950s-1960s. Current prevalence of U. lucasi in dead pups collected from Reef Rookery was 4.9 % in 2011, 0 % in 2012 and 10.5 % in 2013. This rookery has a rocky substrate. On sandy rookeries prevalence was up to 75 % on Morjovi Rookery and 50 % on Vostochni Rookery. Parasitic L3 were recovered in 2.5 % of subadult males examined in 2013. Decreasing prevalence of hookworm infection of dead pups and subadult males during the last several years follows the tremendous decline in the number of fur seals in the herd on St. Paul Island during last several decades.

Lyons, E. T., kuzmina, T. A., Spraker, T. R., & DeLong, R. L. (2016). Parasitological Examination of Northern Elephant Seal (*Mirounga angustirostris*) Pups for Presence of Hookworms (*Uncinaria* Spp.) on San Miguel Island, California. *Helminthologia, 53*(2), 191-194. https://doi.org/10.1515/helmin-2016-0009

Necropsy and extensive parasitological examination of dead northern elephant seal (NES) pups was done on San Miguel Island, California, in February, 2015. The main interest in the current study was to determine if hookworms were present in NESs on San Miguel Island where two hookworm species of the genus Uncinaria are known to be present – Uncinaria lyonsi in California sea lions and Uncinaria lucasi in northern fur seals. Hookworms were not detected in any of the NESs examined: stomachs or intestines of 16 pups, blubber of 13 pups and blubber of one bull. The results obtained in the present study of NESs on San Miguel Island plus similar fi nding on Año Nuevo State Reserve and The Marine Mammal Center provide strong indication that NES are not appropriate hosts for Uncinaria spp. Hookworm free-living third stage larvae, developed from eggs of California sea lions and northern fur seals, were recovered from sand. It seems that at this time, further search for hookworms in NESs would be nonproductive.

Lyons, E. T., Kuzmina, T. A., Spraker, T. R., Melin, S. R., & DeLong, R. L. (2016). Hookworms (*Uncinaria lyonsi*) in Dead California Sea Lion (*Zalophus californianus*) Pups and Sand in Winter (2014-2015) on San Miguel Island, California. *Comparative Parasitology, 83*(2), 283-286. https://doi.org/10.1654/4824i.1

Necropsy of dead California sea lion (CSL) (Zalophus californianus) pups (n = 20) born in 2014 was done on San Miguel Island, California, in December 2014 and February 2015. The main objective was to obtain data on prevalence/intensity of hookworms (Uncinaria lyonsi) in pups at that time of the year and to compare the results with data from previous studies conducted in December, January, and February. Fourteen dead pups were examined for adult hookworms in December 2014; all pups were infected (prevalence = 100%) with intensity from 6 to 140 (average 58.9 +/- 38.9 SD) nematodes per host. Six dead pups were examined in February 2015. Hookworms were present in the intestines of 2 pups (prevalence=33%); two adult female worms were found in each infected pup. From 1 to 23 (average 7.5) parasitic larvae (L-3) were found in the blubber of 4 pups. The findings in this study (2014-2015) verify, from earlier observation, that adult U. lyonsi are shed by pups by late February. The prevalence of parasitic L3 in blubber of pups in February has not been previously reported. Sand samples collected in February 2015 from 4 rookery sites were positive for free-living third-stage hookworm larvae, resulting from eggs passed in feces of CSL or northern fur seal pups inhabiting the same rookeries.

Lyons, E. T., Kuzmina, T. A., Tolliver, S. C., & Spraker, T. R. (2012). Update on the Prevalence of the Hookworm, *Uncinaria lucasi*, in Northern Fur Seals (*Callorhinus ursinus*) on St. Paul Island, Alaska, 2011. *Parasitology Research, 111*(3), 1397-1400. https://doi.org/10.1007/s00436-012-2881-2

Prevalence of hookworms (*Uncinaria lucasi* Stiles, 1901) was determined in the northern fur seal (*Callorhinus ursinus* Linnaeus, 1758) on St. Paul Island (SPI), Alaska in July and August, 2011. Three of 61 (4.9%) dead pups harbored 1 to 13 adult hookworms each in their intestines. Parasitic larvae (L-3) of hookworms were recovered from the blubber of 4 of 133 (3%) of subadult males (SAMs) examined. One parasitic L-3 was detected from each infected SAM. Adult *U. lucasi* (n = 3) were found in the intestine of 1 of 105 SAMs examined (0.95%). This is the first documented finding of adult *U. lucasi* in SAMs of the northern fur seals. Continued low prevalence of hookworms the last several years parallels the tremendous decline in the number of fur seals on SPI over a similar time period.

Lyons, E. T., Spraker, T. R., De Long, R. L., Ionita, M., Melin, S. R., Nadler, S. A., & Tolliver, S. C. (2011). Review of Research on Hookworms (*Uncinaria lucasi* Stiles, 1901) in Northern Fur Seals (*Callorhinus ursinus* Linnaeus, 1758). *Parasitology Research, 109*(2), 257-265. https://doi.org/10.1007/s00436-011-2420-6

The objective of this article is to review knowledge on the hookworm Uncinaria lucasi Stiles, 1901 in northern fur seals, *Callorhinus ursinus* Linnaeus, 1758. Emphasis is placed on research on this host-parasite system in the Pribilof Islands, AK, USA where the bulk of the studies has been performed.

Macklin, S. A., Schumacher, Schumacher, J., Moore, S. E., & Smith, S. (2008). Sustaining the Marine Ecosystem of the Pribilof Domain. *Deep-Sea Research Part II-Topical Studies in Oceanography, 55*(16-17), 1698-1700. https://doi.org/10.1016/j.dsr2.2008.04.023

“Keep them going through time for the coming generations…” requires sustaining regional ecosystem services (food, fuel and fibers, as well as spiritual, recreational, educational and other nonmaterial benefits to society) of the Pribilof Domain, those waters between and surrounding the Pribilof Islands. This necessitates changing perspectives and adopting management strategies supported by a greater

knowledge base. Scientists have begun to realize the need to shift attitude from one of taking available natural resources (e.g., ecosystem services) to one of receiving Earth's services in a respectful way (Schumacher and Kendall, 1995; Hoopes, 2004). More recently, a synthesis of research from the Aleutian Islands suggests that science alone is not sufficient; management needs to expand to include input from a broad stakeholder community involving sectors of commercial and recreational fishing, subsistence, conservation, oil and gas development, tourism and others (Schumacher and Kruse, 2005). While local traditional knowledge has been accumulated over many generations, western scientific research is more limited, particularly with respect to regional ecosystem dynamics. To address such pressing issues as responses to climate change and increased human impacts, the research presented herein was undertaken to provide insight to key biophysical processes. The integration of all forms of knowledge (e.g., local traditional, western science, economics, legal, policy making) can provide the greatest potential of sustaining regional ecosystem services through effective management of direct and indirect human impacts and responses to ongoing climate change caused by anthropogenic and natural forcing.

Mahood, S. P., & Duckworth, J. W. (2016). Status of Pinnipeds in Southeast Asia. *Mammalia, 80*(2), 227-230. https://doi.org/10.1515/mammalia-2014-0144

There are no published records of pinnipeds in Southeast Asia. Photographs in the national media between January 2010 and December 2013 documented seven pinniped records. All were individuals caught by fishermen in the central part of Vietnam (17 degrees 56' N south to 15 degrees 23' N). All except one pinniped record can be assigned to Largha (= Spotted) Seal Phoca largha, the most southerly breeding true seal in the north Pacific. The only other pinniped species recorded in Vietnam during the period was one Northern Fur Seal *Callorhinus ursinus*. The minimum distance between the southernmost area where these species occur regularly and central Vietnam is 3500 km; this is comparable to distances travelled by other vagrant pinnipeds in other parts of the world. Based on such evidence, Largha Seal and Northern Fur Seal should be added to the list of naturally occurring mammals in Vietnamese and Southeast Asian waters.

Marcus, A. D., Higgins, D. P., Slapeta, J., & Gray, R. (2014). *Uncinaria sanguinis* Sp N. (Nematoda: Ancylostomatidae) from the Endangered Australian Sea Lion, *Neophoca cinerea* (Carnivora: Otariidae). *Folia Parasitologica, 61*(3), 255-265. https://doi.org/10.14411/fp.2014.037

This study investigates the identity of hookworms parasitising the Australian sea lion, Neophoca cinerea (Peron), from three colonies in South Australia, Australia. The Australian sea lion is at risk of extinction because its population is small and genetically fragmented. Using morphological and molecular techniques, we describe a single novel species, Uncinaria sanguinis sp. n. (Nematoda: Ancylostomatidae). The new species is most similar to hookworms also parasitic in otariid hosts, Uncinaria lucasi Stiles, 1901 and Uncinaria hamiltoni Baylis, 1933. Comparative morphometrics offered limited utility for distinguishing between species within this genus whilst morphological features and differences in nuclear ribosomal DNA sequences delineated U. sanguinis sp. n. from named congeners. Male specimens of U sanguinis sp. n. differ from U. lucasi and U. hamiltoni by relatively shorter anterolateral and externodorsal rays, respectively, and from other congeners by the relative lengths and angulations of bursal rays, and in the shape of the spicules. Female specimens of U. sanguinis sp. n. are differentiated from Uncinaria spp. parasitic in terrestrial mammals by differences in vulval anatomy and the larger size of their eggs, although are morphologically indistinguishable from U. lucasi and U.

hamiltoni. Molecular techniques clearly delimited U. sanguinis sp. n. as a distinct novel species. Obtaining baseline data on the parasites of wildlife hosts is important for the investigation of disease and the effective implementation and monitoring of conservation management.

Marshall, C. D., Rosen, D., & Trites, A. W. (2016). Feeding Kinematics and Performance of Basal Otariid Pinnipeds, Steller Sea Lions, and Northern Fur Seals: Implications for the Evolution of Mammalian Feeding. *Integrative and Comparative Biology, 56*, E138-E138. https://doi.org/10.1242/jeb.126573

Feeding performance studies can address questions relevant to feeding ecology and evolution. Our current understanding of feeding mechanisms for aquatic mammals is poor. Therefore, we characterized the feeding kinematics and performance of five Steller sea lions (Eumetopias jubatus) and six northern fur seals (*Callorhinus ursinus*). We tested the hypotheses that both species use suction as their primary feeding mode, and that rapid jaw opening was related to suction generation. Steller sea lions used suction as their primary feeding mode, but also used a biting feeding mode. In contrast, northern fur seals only used a biting feeding mode. Kinematic profiles of Steller sea lions were all indicative of suction feeding (i.e. a small gape, small gape angle, large depression of the hyolingual apparatus and lip pursing). However, jaw opening as measured by gape angle opening velocity (GAOV) was relatively slow in Steller sea lions. In contrast to Steller sea lions, the GAOV of northern fur seals was extremely fast, but their kinematic profiles indicated a biting feeding mode (i.e. northern fur seals exhibited a greater gape, a greater gape angle and minimal depression of the hyolingual apparatus compared with Steller sea lions). Steller sea lions produced both subambient and suprambient pressures at 45 kPa. In contrast, northern fur seals produced no detectable pressure measurements. Steller sea lions have a broader feeding repertoire than northern fur seals, which likely enables them to feed on a greater variety of prey, in more diverse habitats. Based on the basal phylogenetic position of northern fur seals, craniodental morphological data of the Callorhinus lineage, and the performance data provided in this study, we suggest that northern fur seals may be exhibiting their ancestral feeding mode.

Matkin, C. O., Barrett-Lennard, L. G., Yurk, H., Ellifrit, D., & Trites, A. W. (2007). Ecotypic Variation and Predatory Behavior among Killer Whales (*Orcinus orca*) Off the Eastern Aleutian Islands, Alaska. *Fishery Bulletin, 105*(1), 74-87. Retrieved from https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/2007/1051/matkin.pdf

From 2001 to 2004 in the eastern Aleutian Islands, Alaska, killer whales (Orcinus orca) were encountered 250 times during 421 days of surveys that covered a total of 22,491 miles. Three killer whale groups (resident, transient, and offshore) were identified acoustically and genetically. Resident killer whales were found 12 times more frequently than transient killer whales, and offshore killer whales were encountered only once. A minimum of 901 photographically identified resident whales used the region during our study. A total of 165 mammal-eating transient killer whales were identified, and the majority (70%) were encountered during spring (May and June). The diet of transient killer whales in spring was primarily gray whales (Eschrichtius robustus), and in summer primarily northern fur seals (*Callorhinus ursinus*). Steller sea lions (Eumetopias jubatus) did not appear to be a preferred prey or major prey item during spring and summer. The majority of killer whales in the eastern Aleutian Islands are the resident ecotype, which does not consume marine mammals.

Maxwell, S. M., Frank, J. J., Breed, G. A., Robinson, P. W., Simmons, S. E., Crocker, D. E., . . . Costa, D. P. (2012). Benthic Foraging on Seamounts: A Specialized Foraging Behavior in a Deep-Diving Pinniped. *Marine Mammal Science, 28*(3), E333-E344. https://doi.org/10.1111/j.1748-7692.2011.00527.x

The article presents a study which investigates the foraging behaviors of benthic animals such as pinniped. The study used Bayesian Markov Chain Monte Carlo (MCMC) simulation, ArcMap, and algorithms. Results show that crabeater seals or the Lobodon carcinophagus and fur seals or the *Callorhinus ursinus* have favored seamounts for pelagic foraging in Antarctic.

McClintock, B. T., & Michelot, T. (2018). Momentuhmm: R Package for Generalized Hidden Markov Models of Animal Movement. *Methods in Ecology and Evolution, 9*(6), 1518-1530. https://doi.org/10.1111/2041-210x.12995

1. Discrete-time hidden Markov models (HMMs) have become an immensely popular tool for inferring latent animal behaviours from telemetry data. While movement HMMs typically rely solely on location data (e.g. step length and turning angle), auxiliary biotelemetry and environmental data are powerful and readily-available resources for incorporating much more ecological and behavioural realism. However, complex movement or observation process models often necessitate custom and computationally demanding HMM model-fitting techniques that are impractical for most practitioners, and there is a paucity of generalized user-friendly software available for implementing multivariate HMMs of animal movement. 2. Here, we introduce an open-source R package, momentuHMM, that addresses many of the deficiencies in existing HMM software. Features include: (1) data pre-processing and visualization; (2) user-specified probability distributions for an unlimited number of data streams and latent behaviour states; (3) biased and correlated random walk movement models, including dynamic "activity centres" associated with attractive or repulsive forces; (4) user-specified design matrices and constraints for covariate modelling of parameters using formulas familiar to most R users; (5) multiple imputation methods that account for measurement error and temporally irregular or missing data; (6) seamless integration of spatio-temporal covariate raster data; (7) cosinor and spline models for cyclical and other complicated patterns; (8) model checking and selection; and (9) simulation. 3. After providing an overview of the main features of the package, we demonstrate some of the capabilities of momentuHMM using real-world examples. These include models for cyclical movement patterns of African elephants, foraging trips of northern fur seals, loggerhead turtle movements relative to ocean surface currents, and grey seal movements among three activity centres. 4. momentuHMM considerably extends the capabilities of existing HMM software while accounting for common challenges associated with telemetry data. It therefore facilitates more realistic hypothesis-driven animal movement analyses that have hitherto been largely inaccessible to non-statisticians. While motivated by telemetry data, the package can be used for analysing any type of data that is amenable to HMMs. Practitioners interested in additional features are encouraged to contact the authors.

McLaren, D., Rahemtulla, F., White, G., & Fedje, D. (2015). Prerogatives, Sea Level, and the Strength of Persistent Places: Archaeological Evidence for Long-Term Occupation of the Central Coast of British Columbia. *BC Studies*(187), 155-306. Retrieved from http://ojs.library.ubc.ca/index.php/bcstudies/article/download/186161/185693

Mammals: deer, harbour seal, dolphins, porpoises, sea lion, northern fur seal, sea otter, mink, marten, river otter, porcupine, beaver, black bear, mountain goat, and whale; Birds: loon, goose, duck, merganser, cormorant, grebe, auk, murrelet, murre, bald eagle, gulls, raven, shearwater, great blue heron, and owl; Fish: salmon, herring, flatfish, rockfish, cod, greenling, sculpin, sablefish, dogfish, ratfish, skate, and bluefin tuna. STABLE SHORELINES AND THE LONG-TERM ACCUMULATION OF ARCHAEOLOGICAL MATERIALS A primary environmental factor that has contributed to the prevalence of long-term occupation sites on the central coast is relative sea level change or lack thereof (McLaren et al. 2014).\n An early maritime economy is hypothesized based on the results of several decades of intensive investigation across Norway (outer coast, fjordlands, and inland regions).

Mecum, R. D., & Mabry, K. R. (2009). *Scoping Report for Northern Fur Seal Harvest Regulations Environmental Assessment April 2012.* URS Corporation National Marine Fisheries Service Retrieved from https://repository.library.noaa.gov/view/noaa/19190

This report reviews the comments received during the scoping period regarding proposed changes to the northern fur seal Harvest Regulations for St. George Island by the St. George Traditional Council (Traditional Council). The National Marine Fisheries Service (NMFS) received a petition from the Traditional Council in September 2006, proposing changes in harvest regulations to better provide for cultural and traditional practices. NMFS invited public comments on the petition through a Federal Register Notice on April 23, 2010 (75 FR 21233). NMFS is currently proceeding with preparation of an Environmental Assessment (EA), and sought public comments to help identify issues to be analyzed.

Melin, S. R., Ream, R. R., & Zeppelin, T. K. (2006). *Report of the Alaska Region and Alaska Fisheries Science Center Northern Fur Seal Tagging and Census Workshop 6-9 September 2005, Seattle, Washington*. National Marine Fisheries Service Alaska Fisheries Science Center. AFSC Processed Rep. 2006-15. Retrieved from http://www.afsc.noaa.gov/Publications/ProcRpt/PR%202006-15.pdf

The northern fur seal is listed as 'depleted' in U.S. waters under The Marine Mammal Protection Act of 1972. Under the Marine Mammal Protection Act, a conservation plan is required for all depleted species to assist management and research agencies in recovering the population. In 1993, the Northern Fur Seal Conservation Plan was adopted and has guided northern fur seal research over the past decade. In 2005, the conservation plan was reviewed and updated to reflect the current trends in the population and new biological information. One recommendation of the revised conservation plan was to gather current demographic information on northern fur seal populations. This workshop was convened to outline an approach for a robust marking program that can provide the demographic data necessary to build population models that are needed to assist management in the recovery process for the northern fur seal population. The working group evaluated permanent marking methods including various tagging options, tattoos, hot branding, freeze branding, radio frequency identification tags (RFIDs), natural markings, and new technologies to uniquely identify northern fur seals. The workshop participants also discussed study designs and statistical methods to obtain and analyze demographic data. In addition, the working group examined the current methods of estimating abundance based on direct counts and shear-sampling mark-recapture of pups and discussed alternative methods of population assessment. The working group agreed that a combination of longitudinal and cross-sectional permanent marking of live animals would provide a complete dataset of population parameters for demographic models. The working group determined that in the near-term, external flipper tags are the most feasible method for

marking large numbers of northern fur seals. However, tag loss remains a significant problem with the current tags available and a new tag needs to be developed. The working group acknowledged that the future of unique identification of fur seals lies in the development of electronic tags and remote data recorders. This technology is not yet applicable to the unique habitat, life history, distribution, and environmental conditions of pinniped species. The working group discussed the need to encourage manufacturers to develop an electronic tagging system that would be applicable to the needs of the fur seal and sea lion research community. The working group concluded that the current census methods of shear-sampling and direct counts of pups were sufficient but alternative methods for estimating abundance (e.g., medium format photography or infra-red imaging) may be useful in combination with the current methods to refine estimates.

Meyer, W., Kloepper, J. E., & Fleischer, L.-G. (2008). Demonstration of Square -Glucan Receptors in the Skin of Aquatic Mammals-a Preliminary Report. *European Journal of Wildlife Research, 54*(3), 479-486. http://dx.doi.org/10.1007/s10344-008-0173-z

Using immunohistochemistry, the study clearly demonstrates three important beta -glucan receptors (Ficolin/P35, MBL, Dectin-1; members of the lectin-complement pathway of innate immunity) in the integument of six marine and freshwater aquatic mammals (Northern fur seal, Common seal, Walrus, Coypu, Capybara, Otter), but only weakly in two dolphin species. Most of the non-dolphin mammals exhibited strong reactions, especially with regard to the skin glands (tubular apocrine glands, sebaceous glands), for L-Ficolin/P35 and MBL. Distinct reaction staining could also be observed in the epidermis and the outer epithelial sheath of primary hair follicles. Positive Dectin-1 staining was limited to secretory cells of the apocrine tubular glands, and to peripheral and central cells of sebaceous glands of the seals. The Capybara was the only animal to show a clear Dectin reaction in the epidermis (stratum granulosum).

Meyer, W., Kloepper, J. E., & Fleischer, L. G. (2008). Demonstration of Beta-Glucan Receptors in the Skin of Aquatic Mammals - a Preliminary Report. *European Journal of Wildlife Research, 54*(3), 479-486. https://doi.org/10.1007/s10344-008-0173-z

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Meyer, W., Seegers, U., Schnapper, A., Neuhaus, H., Himstedt, W., & Toepfer-Petersen, E. (2007). Possible Antimicrobial Defense by Free Sugars on the Epidermal Surface of Aquatic Vertebrates. *Aquatic Biology, 1*(2), 167-175. https://doi.org/10.3354/ab00021

Biochemical, lectin histochemical, and densitometrical methods demonstrated contents and spectra of free sugars in the skin of aquatic vertebrates (fishes: cod, marine trout, freshwater trout, perch; amphibians: Koa-Tao-Island caecilian, smooth newt, edible frog, South-African clawed toad; mammals: northern fur seal, common seal, otter, Capybara). Total free sugar contents, particularly sialic acids, were relatively higher in freshwater species (perch, Capybara) than in marine species. In amphibians, the caecilian and the newt showed higher amounts of free sugars than the anurans; strong reactions indicated a specific involvement of alpha-L-fucose in mucus functions. Lectin histochemistry demonstrated positive reactions in the stratum superficiale, the outer stratum spinosum, and specific cells of the fish epidermis. The integumental free sugar spectrum of the amphibians was narrow, with generally lower reaction intensities, except for mucus glands. In the mammals, the epidermal cells exhibited rather weak lectin histochemical staining, except for the northern fur seal and the Capybara, where the upper vital epidermis and corneal cells reacted strongly. The mammalian apocrine skin glands, particularly, exhibited positive reaction staining in their secretory endpiece. The free sugar spectrum was similar in all species: alpha-D-mannose, beta-D-N-acetylglucosamine, alpha-D-N-acetylgalactosamine, alpha-D-galactose, beta-D-galactose, alpha-D-fucose, sialic acids (mainly in fish epidermis and skin glands). High concentrations of free sugars on the skin surface possibly impede attacks of commensal skin micro-inhabitants (bacteria, fungi) against the integrity of the epidermis. This features a basic or general biological mechanism that operates before the specific immune system is activated.

Miller, N. J., Daniels, C. B., Schurch, S., Schoel, W. M., & Orgeig, S. (2006). The Surface Activity of Pulmonary Surfactant from Diving Mammals. *Respiratory Physiology & Neurobiology, 150*(2-3), 220-232. https://doi.org/10.1016/j.resp.2005.03.002

Pinnipeds (seals and sea lions) have developed a specialised respiratory system to cope with living in a marine environment. They have a highly reinforced lung that can completely collapse and reinflate during diving without any apparent side effects. These animals may also have a specialised surfactant system to augment the morphological adaptations. The surface activity of surfactant from four species of pinniped (California sea lion, Northern elephant seal, Northern fur seal and Ringed seal) was measured using a captive bubble surfactometer (CBS), and compared to two terrestrial species (sheep and cow). The surfactant of Northern elephant seal, Northern fur seal and Ringed seal was unable to reduce surface tension (gamma) to normal levels after 5 min adsorption (61.2, 36.7, and 46.2 +/- 1.7 mN/m, respectively), but Califomia sea lion was able to reach the levels of the cow and sheep (23.4 mN/m for California sea lion, 21.6 +/- 0.3 and 23.0 +/- 1.5 mN/m for cow and sheep, respectively). All pinnipeds were also unable to obtain the very low gamma(min) achieved by cow (1.4 +/- 0.1 mN/m) and sheep (1.5 +/- 0.4 mN/m). These results suggest that reducing surface tension to very low values is not the primary function of surfactant in pinnipeds as it is in terrestrial mammals, but that an anti-adhesive surfactant is more important to enable the lungs to reopen following collapse during deep diving.

Miller, S., Colitz, C. M. H., St Leger, J., & Dubielzig, R. (2013). A Retrospective Survey of the Ocular Histopathology of the Pinniped Eye with Emphasis on Corneal Disease. *Veterinary Ophthalmology, 16*(2), 119-129. https://doi.org/10.1111/j.1463-5224.2012.01040.x

Objective A retrospective review of globes from 70 pinnipeds submitted to the Comparative Ocular Pathology Laboratory of Wisconsin (COPLOW) describing the type and frequency of ocular disease.

Animals studied The study included 50 California sea lions, four animals listed only as sea lion', nine Northern elephant seals, five harbor seals, 1 Northern fur seal, and 1 Hooded seal. Procedures Globes were classified by microscopic findings. Categories were not mutually exclusive. Results The largest category was corneal disease (63 globes from 40 pinnipeds). The second largest was cataractous changes (35 globes from 23 pinnipeds). Additional ocular diseases included traumatic ocular injuries (nine globes from eight animals), phthisis bulbi (nine globes from eight pinnipeds), neoplasia (nine globes from six adult California sea lions), amyloid deposition in the corneal stroma, ciliary body, or both locations (five globes from four pinnipeds), and fungal disease (three globes from two pinnipeds). Pinnipeds with corneal disease were further categorized: stromal pathology (39 globes from 27 pinnipeds); epithelial pathology (37 globes from 27 pinnipeds); Descemet's pathology (11 globes from eight pinnipeds); endothelial attenuation or absence (33 globes from 22 pinnipeds); presence of retrocorneal membranes (15 globes from 10 pinnipeds); anterior synechia (eight globes from six animals), and keratitis (seven globes from five pinnipeds). Conclusions This is the first report of ocular amyloid in pinniped eyes. All cases of neoplasia were in a pattern suggesting metastatic disease. In this study, there was a higher prevalence of ocular disease in captive pinnipeds, particularly in the posterior cornea.

Minor, C., Kersh, G. J., Gelatt, T., Kondas, A. V., Pabilonia, K. L., Weller, C. B., . . . Duncan, C. G. (2013). *Coxiella burnetii* in Northern Fur Seals and Steller Sea Lions of Alaska. *Journal of Wildlife Diseases, 49*(2), 441-446. https://doi.org/10.7589/2012-09-226

Coxiella burnetii, a zoonotic bacterium, has recently been identified in several marine mammal species on the Pacific Coast of North America, but little is known about the epidemiology, transmission, and pathogenesis in these species. We tested sera archived from northern fur seals (NFS,*Callorhinus ursinus*; n=236) and Steller sea lions (SSL, Eumetopias jubatus; n=72) sampled in Alaska for C. burnetii antibodies, and vaginal swabs from NFS (n=40) for C. burnetii by qPCR. The antibody prevalence in NFS samples from 2009 and 2011 (69%) was significantly higher than in 1994 (49%). The antibody prevalence of SSL samples from 2007 to 2011 was 59%. All NFS vaginal swabs were negative for C. burnetii, despite an 80% antibody prevalence in the matched sera. The significant increase in antibody prevalence in NFS from 1994 to 2011 suggests that the pathogen may be increasingly common or that there is marked temporal variation within the vulnerable NFS population. The high antibody prevalence in SSL suggests that this pathogen may also be significant in the endangered SSL population. These results confirm that C. burnetii is more prevalent within these populations than previously known. More research is needed to determine how this bacterium may affect individual, population, and reproductive health of marine mammals.

Misarti, N., Finney, B., Maschner, H., & Wooller, M. J. (2009). Changes in Northeast Pacific Marine Ecosystems over the Last 4500 Years: Evidence from Stable Isotope Analysis of Bone Collagen from Archeological Middens. *Holocene, 19*(8), 1139-1151. https://doi.org/10.1177/0959683609345075

Changes in food web dynamics and ocean productivity over the past 4500 years are investigated using stable isotope analysis of nitrogen and carbon in collagen from animal bones preserved in coastal archeological middens on Sanak Island, along the eastern edge of the Aleutian archipelgo. Samples included Steller sea lions, Harbor seals, Northern fur seals, sea otters, Pacific cod and sockeye salmon. Sea otters had the highest delta C-13 (-11.9 +/- 0.7 parts per thousand) and lowest delta N-15 values

(14.5 +/- 1.4 parts per thousand), Northern fur seals had the lowest delta C-13 values (-13.6 +/- 1.4 parts per thousand), and Steller sea lions had the highest delta N-15 values (18.4 +/- 1.4 parts per thousand) of the marine mammals. Cod isotope values were consistent with those of demersal organisms from near shore habitats (-12.5 +/- 0.9 parts per thousand delta C-13, 16.1 +/- 1.4 parts per thousand delta N-15), while salmon values were consistent with those of organisms existing in an open ocean habitat and at a lower trophic level (-15.2 +/- 1.4 parts per thousand d13C, 11.5 +/- 1.7 parts per thousand delta N-15). When comparing six different prehistoric time periods, two time periods had significantly different delta C-13 for salmon. Otters had significantly different delta N-15 values in two out of the six prehistoric time periods but no differences in delta C-13. The mean delta C-13, corrected for the oceanic Suess Effect, of modern specimens of all species (except Northern fur seals) were significantly lower than prehistoric animals. Several hypotheses are explored to explain these differences including a reduction in productivity during the twentieth century in this region of the Gulf of Alaska. If true, this suggests that North Pacific climate regimes experienced during the twentieth century may not be good analogs of North Pacific marine ecosystems during the late Holocene.

Mitani, Y. (2016). Northern Fur Seal: International Conservation History and Current Status. *Aquabioloy/Kaiyo to Seibutsu, 38*(3), 256-260. Retrieved from https://search.proquest.com/docview/1846404449?accountid=28258

Northern fur seal (*Callorhinus ursinus*) is distributed along the north Pacific Ocean, the Bering Sea and the Sea of Okhotsk. They were over-harvested for the fur trade of the 18th and 19th centuries and the North Pacific Fur Seal Treaty was signed by the United States, Russia, Japan and the United Kingdom on behalf of Canada in 1911. Recently, competition between fisheries and seals has been reported along the Japan Sea coast of Hokkaido. To understand their ecology and current status, various studies have been carried since 2008.

Mizukawa, H., Ikenaka, Y., Kakehi, M., Nakayama, S., & Ishizuka, M. (2017). Characterization of Species Differences in Xenobiotic Metabolism in Non-Experimental Animals. *Yakugaku Zasshi-Journal of the Pharmaceutical Society of Japan, 137*(3), 257-263. https://doi.org/10.1248/yakushi.16-00230-2

The ability to metabolize xenobiotics in organisms has a wide degree of variation among organisms. This is caused by differences in the pattern of xenobiotic bioaccumulation among organisms, which affects their tolerance. It has been reported in the veterinary field that glucuronidation (UGT) activity in cats, acetylation activity in dogs and sulfation (SULT) activity in pigs are sub-vital in these species, respectively, and require close attention when prescribing the medicine. On the other hand, information about species differences in xenobiotics metabolism remains insufficient, especially in non-experimental animals. In the present study, we tried to elucidate xenobiotic metabolism ability, especially in phase II UGT conjugation of various non-experimental animals, by using newly constructed in vivo, in vitro and genomic techniques. The results indicated that marine mammals (Steller sea lion, northern fur seal, and Caspian seal) showed UGT activity as low as that in cats, which was significantly lower than in rats and dogs. Furthermore, UGT1A6 pseudogenes were found in the Steller sea lion and Northern fur seal; all Otariidae species are thought to have the UGT1A6 pseudogene as well. Environmental pollutants and drugs conjugated by UGT are increasing dramatically in the modern world, and their dispersal into the environment can be of great consequence to Carnivora species, whose low xenobiotic glucuronidation capacity makes them highly sensitive to these compounds.

Mordy, C. W., Cokelet, E. D., De Robertis, A., Jenkins, R., Kuhn, C. E., Lawrence-Slavas, N., . . . Wangen, I. (2017). Advances in Ecosystem Research: Saildrone Surveys of Oceanography, Fish, and Marine Mammals in the Bering Sea. *Oceanography, 30*(2), 113-115. https://doi.org/10.5670/oceanog.2017.230

Saildrones are unmanned surface vehicles engineered for oceanographic research and powered by wind and solar energy. In the summer of 2016, two Saildrones surveyed the southeastern Bering Sea using passive acoustics to listen for vocalizations of marine mammals and active acoustics to quantify the spatial distribution of small and large fishes. Fish distributions were examined during foraging trips of northern fur seals (*Callorhinus ursinus*), and initial results suggest these prey distributions may influence the diving behavior of fur seals. The Saildrone is faster, has greater instrument capacity, and requires less support services than its counterparts. This innovative platform performed well in stormy conditions, and it demonstrated the potential to augment fishery surveys and advance ecosystem research.

Moss, M. L., Yang, D. Y., Newsome, S. D., Speller, C. F., McDechnie, I., McMillan, A. D., . . . Koch, P. L. (2006). Historical Ecology and Biogeography of North Pacific Pinnipeds: Isotopes and Ancient DNA from Three Archaeological Assemblages. *Journal of Island & Coastal Archaeology, 1*(2), 165-190. https://doi.org/10.1080/15564890600934129

Zooarchaeology has the potential to make significant contributions to knowledge of pinniped biogeography of import to both archaeologists and environmental scientists. We analyzed northern fur seal remains found in three archaeological sites located along the outer coast of the Northeast Pacific Ocean: Cape Addington Rockshelter in southeast Alaska, Ts'ishaa on the west coast of Vancouver Island, and the Netarts Sandspit site on the Oregon Coast. These three sites occur along an 850 km stretch of coastline between 45° to 55° N. and 123° to 134° W., far southeast of the primary breeding area for northern fur seals today, located on the Pribilof Islands at 57° N. 170° W. We use ancient DNA (aDNA) and carbon (δ13C) and nitrogen (δ15N) isotopes to investigate whether northern fur seal remains from these archaeological sites originated with migratory Pribilof Islands populations. For sites located in Oregon and points north, the isotope values are not distinct from those of the Pribilof fur seals. Although aDNA was recovered from three pinniped species (northern fur seal, Steller sea lion, and Guadalupe fur seal), the paucity of published genetic data from modern northern fur seals prevents us from distinguishing the archaeological specimens from modern Pribilof seals.

Mulsow, J., & Reichmuth, C. (2010). Psychophysical and Electrophysiological Aerial Audiograms of a Steller Sea Lion (*Eumetopias jubatus*). *Journal of the Acoustical Society of America, 127*(4), 2692-2701. https://doi.org/10.1121/1.3327662

A within-subject comparison of auditory steady-state response (ASSR) and psychophysical measurements of aerial hearing sensitivity was conducted with an individual of the largest otariid species, the Steller sea lion. Psychophysical methods were used to obtain an unmasked aerial audiogram at 13 frequencies, spanning a range of 0.125-34 kHz. The subject had a hearing range (frequencies audible at 60 dB(rms) re 20 mu Pa) of about 0.250-30 kHz, and a region of best hearing sensitivity from 5-14.1 kHz. The psychophysical aerial audiogram of this Steller sea lion was remarkably similar to aerial

audiograms previously obtained for California sea lions and northern fur seals, suggesting that the otariid pinnipeds form a functional hearing group. ASSR thresholds, measured at frequencies of 1, 2, 5, 10, 20, and 32 kHz, were elevated relative to corresponding psychophysical thresholds, ranging from +1 dB at 20 kHz, to +31 dB at 1 kHz. The ASSR audiogram accurately predicted the subject's high-frequency cutoff, and provided a reasonable estimate of hearing sensitivity at frequencies above 2 kHz. In testing situations where psychophysical methods are not possible, ASSR methods may provide an objective and efficient estimate of behavioral hearing sensitivity in otariid pinnipeds.

Muto, M., Helker, V. T., Angliss, R. P., Allen, B. A., Boveng, P. L., Breiwick, J. M., . . . Zerbini, A. N. (2016). *Alaska Marine Mammal Stock Assessments, 2015*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-323. http://doi.org/10.7289/V5/TM-AFSC-323

On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new sections. This new regime replaced the interim exemption that has regulated fisheries-related incidental takes since 1988. Section 117, Stock Assessments, required the establishment of three regional scientific review groups to advise and report on the status of marine mammal stocks within Alaska waters, along the Pacific Coast (including Hawaii), and the Atlantic Coast (including the Gulf of Mexico). This report provides information on the marine mammal stocks of Alaska under the jurisdiction of the National Marine Fisheries Service. Each stock assessment includes, when available, a description of the stock's geographic range, a minimum population estimate, current population trends, current and maximum net productivity rates, optimum sustainable population levels and allowable removal levels, and estimates of annual human-caused mortality and serious injury through interactions with commercial fisheries and subsistence hunters. These data will be used to evaluate the progress of each fishery towards achieving the MMPA's goal of zero fishery-related mortality and serious injury of marine mammals.

Muto, M. M., Helker, V. T., Angliss, R. P., Allen, B. A., Boveng, P. L., Breiwick, J. M., . . . Zerbini, A. N. (2017). *Alaska Marine Mammal Stock Assessments, 2016*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-355. https://doi.org/10.7289/V5/TM-AFSC-355

On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new sections. This new regime replaced the interim exemption that has regulated fisheriesrelated incidental takes since 1988. Section 117, Stock Assessments, required the establishment of three regional scientific review groups to advise and report on the status of marine mammal stocks within Alaska waters, along the Pacific Coast (including Hawaii), and the Atlantic Coast (including the Gulf of Mexico). This report provides information on the marine mammal stocks of Alaska under the jurisdiction of the National Marine Fisheries Service. Each stock assessment includes, when available, a description of the stock's geographic range; a minimum population estimate; current population trends; current and maximum net productivity rates; optimum sustainable population levels and allowable removal levels; estimates of annual human-caused mortality and serious injury through interactions with commercial, recreational, and subsistence fisheries, takes by subsistence hunters, and other human-caused events (e.g., entanglement in marine debris, ship strikes); and habitat concerns. The commercial fishery interaction data will be used to evaluate the progress of each fishery towards achieving the MMPA's goal of zero fishery-related mortality and serious injury of marine mammals.

Muto, M. M., Helker, V. T., Angliss, R. P., Allen, B. A., Boveng, P. L., Breiwick, J. M., . . . Zerbini, A. N. (2018). *Alaska Marine Mammal Stock Assessments, 2017*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-378. https://doi.org/10.7289/V5/TM-AFSC-378

On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new sections. This new regime replaced the interim exemption that has regulated fisheries-related incidental takes since 1988. Section 117, Stock Assessments, required the establishment of three regional scientific review groups to advise and report on the status of marine mammal stocks within Alaska waters, along the Pacific Coast (including Hawaii), and the Atlantic Coast (including the Gulf of Mexico). This report provides information on the marine mammal stocks of Alaska under the jurisdiction of the National Marine Fisheries Service. Each stock assessment includes, when available, a description of the stock's geographic range; a minimum population estimate; current population trends; current and maximum net productivity rates; optimum sustainable population levels and allowable removal levels; estimates of annual human-caused mortality and serious injury through interactions with commercial, recreational, and subsistence fisheries, takes by subsistence hunters, and other human-caused events (e.g., entanglement in marine debris, ship strikes); and habitat concerns. The commercial fishery interaction data will be used to evaluate the progress of each fishery towards achieving the MMPA's goal of zero fishery-related mortality and serious injury of marine mammals.

Muto, M. M., Helker, V. T., Angliss, R. P., Boveng, P. L., Breiwick, J. M., Cameron, M. F., . . . Zerbini, A. N. (2019). *Alaska Marine Mammal Stock Assessments, 2018*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-393. Retrieved from https://repository.library.noaa.gov/view/noaa/20606

On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new sections. This new regime replaced the interim exemption that has regulated fisheries-related incidental takes since 1988. Section 117, Stock Assessments, required the establishment of three regional scientific review groups to advise and report on the status of marine mammal stocks within Alaska waters, along the Pacific Coast (including Hawaii), and the Atlantic Coast (including the Gulf of Mexico). This report provides information on the marine mammal stocks of Alaska under the jurisdiction of the National Marine Fisheries Service.

Myers, E., Ehrhart, E. J., Charles, B., Spraker, T., Gelatt, T., & Duncan, C. (2013). Apoptosis in Normal and *Coxiella burnetii*-Infected Placentas from Alaskan Northern Fur Seals (*Callorhinus ursinus*). *Veterinary Pathology, 50*(4), 622-625. https://doi.org/10.1177/0300985812465323

In 2010, Coxiella burnetii was identified in 75% of northern fur seal placentas from a single rookery in Alaska, but nothing was known about the significance of this organism in the population. Although many infectious organisms cause increased cell death, C. burnetii has been shown to suppress apoptosis of the host macrophages as an intracellular survival mechanism. To determine if infection induces a similar functional change in the placenta, immunohistochemistry for antibodies to cleaved caspase-3 (activated caspase-3) and the (TDT)-mediated dUTP-digoxigenin nick end labeling (TUNEL) technique were used to

compare the amount of placental apoptosis in infected and noninfected placentas. There was a statistically significant difference in the frequency of apoptotic cells between infected and uninfected placentas, with more apoptosis identified in the uninfected placentas. This finding suggests that the survival mechanism of C. burnetii in host macrophages to reduce apoptosis may also be utilized in trophoblasts. The significance of decreased trophoblastic apoptosis for the northern fur seal fetus requires further investigation.

Nachman, C. A., & Wieting, D. (2014). *Issuance of Regulations and a Letter of Authorization to the U.S. Air Force to Take Marine Mammals Incidental to Launches, Aircraft and Helicopter Operations and Harbor Activities at Vandenberg Air Force Base, California : Environmental Assessment*. National Marine Fisheries Service Office of Protected Resources. Retrieved from https://repository.library.noaa.gov/view/noaa/4867

This Environmental Assessment analyzes the environmental impacts of the National Marine Fisheries Service, Office of Protected Resources proposal to issue regulations and a Letter of Authorization to the U.S. Air Force for the taking of marine mammals, incidental to conducting launches, aircraft and helicopter operations, and harbor activities at Vandenberg Air Force Base, year round. lead agency: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, in consultation with the Marine Mammal Commission; prepared by: Candace Nachman, Fisheries Biologist, Incidental Take Program, Permits and Conservation Division, Office of Protected Resources.

Nadler, S. A., Lyons, E. T., Pagan, C., Hyman, D., Lewis, E. E., Beckmen, K., . . . Beron-Vera, B. (2013). Molecular Systematics of Pinniped Hookworms (Nematoda: *Uncinaria*): Species Delimitation, Host Associations and Host-Induced Morphometric Variation. *International Journal for Parasitology, 43*(14), 1119-1132. https://doi.org/10.1016/j.ijpara.2013.08.006

Hookworms of the genus Uncinaria have been widely reported from juvenile pinnipeds, however investigations of their systematics has been limited, with only two species described, *Uncinaria lucasi* from northern fur seals (*Callorhinus ursinus*) and *Uncinaria hamiltoni* from South American sea lions *(Otaria flavescen*s). Hookworms were sampled from these hosts and seven additional species including Steller sea lions *(Eumetopias jubatu*s), California sea lions *(Zalophus californianu*s), South American fur seals *(Arctocephalus australi*s), Australian fur seals *(Arctocephalus pusillu*s), New Zealand sea lions *(Phocarctos hooker*i), southern elephant seals *(Mirounga leonin*a), and the Mediterranean monk seal *(Monachus monachu*s). One hundred and thirteen individual hookworms, including an outgroup species, were sequenced for four genes representing two loci (nuclear ribosomal DNA and mitochondrial DNA). Phylogenetic analyses of these sequences recovered seven independent evolutionary lineages or species, including the described species and five undescribed species. The molecular evidence shows that *U. lucas*i parasitises both *C. ursinu*s and *E. jubatus*, whereas *U. hamiltoni* parasitises *O. flavescen*s and *A. australi*s. The five undescribed hookworm species were each associated with single host species *(Z. californianus, A. pusillus, P. hookeri, M. leonin*a and *M. monachu*s). For parasites of otarids, patterns of Uncinaria host-sharing and phylogenetic relationships had a strong biogeographic component with separate clades of parasites from northern versus southern hemisphere hosts. Comparison of phylogenies for these hookworms and their hosts suggests that the association o*f U. lucas*i with northern fur seals results from a host-switch from Steller sea lions. Morphometric data for U. lucasi shows marked host-associated size differences for both sexes, with U. lucasi individuals from *E. jubatu*s

significantly larger. This result suggests that adult growth of *U. lucasi* is reduced within the host species representing the more recent host parasite association. Intraspecific host-induced size differences are inconsistent with the exclusive use of morphometrics to delimit and diagnose species of Uncinaria from pinnipeds.

National Marine Fisheries Service Alaska Region. (2007). *Conservation Plan for the Eastern Pacific Stock of the Northern Fur Seal (*Callhorinus ursinus*)*. Retrieved from https://repository.library.noaa.gov/view/noaa/17351

On June 17, 1988, the National Marine Fisheries Service (NMFS) declared the northern fur seal stock of the Pribilof Islands, Alaska (St. Paul and St. George Islands) (*Callorhinus ursinus*), to be depleted under the Marine Mammal Protection Act (MMPA) of 1972. NMFS designated the Pribilof Islands northern fur seal population depleted because it declined to less than 50 percent of levels observed in the late 1950s. Amendments to the MMPA on November 23, 1988 (Public Law 100-711), directed the Secretary of Commerce to develop a conservation plan on northern fur seals for "conserving and restoring the species or stock to its optimum sustainable population." The amendments further specified that the plan include information on the status of fur seals on the Pribilof Islands, causes of declines, threats to the species, critical information gaps, and research and management recommendations for meeting the objectives of the plan. Accordingly, NMFS published a conservation plan for the northern fur seal in 1993. Having acquired substantial new information and with the greater inclusion of tribal governments in management of the stock, NMFS now publishes this revision of the 1993 conservation plan. This revision has been prepared with valuable input from the Tribal Governments of St. Paul and St. George Island and incorporates substantial new information, research results, and management structures to serve as a guide for interested parties to assist in the implementation of conservation actions. In 1994, NMFS used the phylogeographic stock definition approach proposed by Dizon et al. (1992) to reclassify the Pribilof Islands population into the Eastern Pacific Stock (Pribilof Islands and Bogoslof Island) and the San Miguel Island Stock. The Eastern Pacific stock is presently declining for unknown reasons after a period of stability in pup production from 1984 to 1998. Harvest practices contributed significantly to the declines of fur seal abundance in the Pribilof Islands prior to the 1970s; however, they do not appear to be currently limiting the population. The goal of this revised conservation plan will be met when northern fur seals are at abundance levels that justify their re-designation as a non-depleted stock. The shared resources and cooperative involvement of federal, state, and local governments, fishing industry, Alaska Natives, academia, non-governmental organizations, and other interested individuals will be required throughout the recovery period. NMFS makes this conservation plan available to the public for reference.

National Marine Fisheries Service Alaska Region. (2014). *Final Supplemental Environmental Impact Statement: Management of the Subsistence Harvest of Northern Fur Seals on St. George Island, Alaska*. Retrieved from https://alaskafisheries.noaa.gov/sites/default/files/fsealfseis2014.pdf

The National Marine Fisheries Service (NMFS) proposes to improve the management of the subsistence harvest for the Eastern Pacific stock of northern fur seals (*Callorhinus ursinus*). NMFS, in conjunction with the Pribilof Island Aleut Community of St. George Island, Traditional Council, is proposing new management measures that (1) provide harvest flexibility, (2) use both Alaska Native and scientific experience to develop best harvest practices, and (3) create firm regulatory measures to conserve the fur seal population and maintain sustainable subsistence harvest on St. George Island consistent with

the community's subsistence needs. NMFS and the Traditional Council would continue to co-manage the harvest consistent with new regulatory controls to reduce the accidental killing of females, reduce localized harvest pressures, and prohibit harvest at small breeding areas. The new subsistence management regime would maintain the existing range of permissible subsistence harvest, allow a portion of the harvest to be comprised of young of the year male fur seals consistent with traditional practices, reduce impacts to females, reduce harassment to non-target seals, and schedule harvesting to promote scientific coordination and monitoring.

National Marine Fisheries Service Office of Protected Resources. (2007). *Final Programmatic Environmental Impact Statement (PEIS) for Steller Sea Lion and Northern Fur Seal Research*. National Marine Fisheries Service Office of Protected Resources. Retrieved from https://repository.library.noaa.gov/view/noaa/17331

This executive summary provides an overview of the findings contained in the Steller Sea Lion (SSL), Eumetopias jubatus, and Northern Fur Seal (NFS),*Callorhinus ursinus*, Research Programmatic Environmental Impact Statement (PEIS). This PEIS evaluates the effects of the type and range of SSL and NFS research activities (i.e., the alternative actions) that may be exercised in current and future grants. This PEIS assesses the direct and indirect effects of various levels of funding and different research techniques on SSLs and NFSs throughout the entire range of these species in United States (U.S.) waters and on the high seas, which includes parts of Alaska, Washington, Oregon, and California. The effects of research on these species as well as other components of the marine ecosystem and human environment are presented. The PEIS assesses the contribution of research activities to the cumulative effects on these species and resources, including effects from past, present, and reasonably foreseeable future events and activities that are external to the research activities. National Marine Fisheries Service (NMFS) also acknowledges that other views of science exist than are contained in this review, including Alaska Native traditional knowledge. NMFS is committed to working with Alaska Native communities and strives to incorporate Native traditional knowledge into environmental documents.

National Marine Fisheries Service Office of Protected Resources. (2007). *Steller Sea Lion and Northern Fur Seal Research: Draft Programmatic Environmental Impact Statement*. Retrieved from https://www.arlis.org/docs/vol1/84748712/

[NO ABSTRACT AVAILABLE]

National Marine Fisheries Service Office of Protected Resources. (2007). *Steller Sea Lion and Northern Fur Seal Research: Final Programmatic Environmental Impact Statement*. Retrieved from https://repository.library.noaa.gov/view/noaa/17331

This PEIS evaluates the effects of the type and range of SSL and NFS research activities (i.e., the alternative actions) that may be exercised in current and future grants. This PEIS assesses the direct and indirect effects of various levels of funding and different research techniques on SSLs and NFSs throughout the entire range of these species in United States (U.S.) waters and on the high seas, which includes parts of Alaska, Washington, Oregon, and California. The effects of research on these species as well as other components of the marine ecosystem and human environment are presented. The PEIS assesses the contribution of research activities to the cumulative effects on these species and resources,

including effects from past, present, and reasonably foreseeable future events and activities that are external to the research activities. National Marine Fisheries Service (NMFS) also acknowledges that other views of science exist than are contained in this review, including Alaska Native traditional knowledge. NMFS is committed to working with Alaska Native communities and strives to incorporate Native traditional knowledge into environmental documents.

National Marine Fisheries Service Office of Protected Resources. (2009). *Endangered Species Act Section 7 Biological Opinion: Full Implementation of the Preferred Alternative of the Programmatic Environmental Impact Statement for Research on Steller Sea Lions and Northern Fur Seals Pursuant to the Marine Mammal Protection Act and Section 10(a)(1)(a) of the Endangered Species Act*. Retrieved from https://repository.library.noaa.gov/view/noaa/17160

This document is the product of a consultation pursuant to section 7(a)(2) of the ESA and implementing regulations found at 50 Code of Federal Regulations (CFR) Part 402. For the actions evaluated in this consultation, the action agency is NMFS Permits, Conservation, and Education Division of the Office of Protected Resources (Permits Division) and the consulting agency is NMFS Alaska Region, Protected Resources Division (PRD). This document evaluates the Permits Division's proposal to fully implement the Research Permits program as described in the Preferred Alternative (Alternative 4) of NMFS' 2007 Final Programmatic Environmental Impact Statement (FPEIS) on Steller Sea Lion and Northern Fur Seal Research for any subsequent permit applications. The new permits that would be issued under the preferred alternative of the Final PEIS would be valid up to the five year limit under their regulations for marine mammal research.

National Research Council of the National Academies. (2014). *Responding to Oil Spills in the U.S. Arctic Marine Environment*. Washington, DC: National Academies Press. https://doi.org/10.17226/18625

This report examines environmental conditions and natural resources in the US Arctic, Arctic oil spill response research, operations, logistics and coordination in an Arctic spill, and strategies for response and mitigation.

Newman, K., & Springer, A. M. (2008). Nocturnal Activity by Mammal-Eating Killer Whales at a Predation Hot Spot in the Bering Sea. *Marine Mammal Science, 24*(4), 990-999. https://doi.org/10.1111/j.1748-7692.2008.00236.x

The article discusses a study on the nocturnal predatory behavior of transient killer whales in the Bering Sea. A Marine Autonomous Recording Unit was deployed in order to record killer whale calls and whistles. It was found that vocalizations of killer whales were more frequent between midnight and noon, with most detections occurring one hour after civil sunset. It is said that killer whales are active at night because they are adapted for conditions with low lighting. Also, other marine mammals on which they prey, such as sea otters, sea lions harbor seals and northern fur seals, are active at night as well.

Newman, K. A., Springer, A., Matkin, C., & Durban, J. (2010). First You Look, and Then You Listen: The Value of Using Passive Acoustics to Monitor Killer Whale Predation on Northern Fur Seals at the Pribilof Islands in the Bering Sea. *Proceedings from the 2010 AGU Ocean Sciences Meeting.*

Washington, DC. American Geophysical Union. Retrieved from https://search.proquest.com/docview/754898119?accountid=28258

Passive acoustic recording has become an important aid in describing vocal patterns of remote, undocumented cetacean populations, thereby increasing our understanding of spatial and temporal aspects of distribution and behavior. We deployed four marine autonomous recording units to record killer whale vocalizations near northern fur seal rookeries at the Pribilof Islands, Alaska from June 6 to August 4, 2008 as a way to estimate predation rates, describe diurnal calling patterns, document Pribilof Island killer whale call types, and compare summer visitation rates of killer whales at two islands. The Pribilof Islands are home to the worlds largest concentration of northern fur seals, and the locale is a predation hot spot where transient killer whales regularly prey upon them. Although this predator prey relationship has garnered recent attention in light of the sharp decline of the Pribilof fur seal population, it has been difficult to quantify predation rates. Twenty-two predation events were documented visually and tracked with GPS by ship-board observers during a concurrent study in July. We recorded vocalizations during 16 of those predation events, and were able to extend our observation window beyond the scope of visual efforts, detecting whales on at least 12 days that visual observers did not, and recording continued killer whale feeding sounds after visual observations ceased. This study helped us evaluate the efficacy of using remote acoustic recordings to quantify feeding behavior and thus inform us about the role killer whales might play in dynamics of the declining fur seal population at the Pribilof Islands. With further refinement, it should be possible to model predation impacts with data obtained by passive recorders that would otherwise be missed.

Newsome, S. D., Etnier, M. A., Gifford-Gonzalez, D., Phillips, D. L., van Tuinen, M., Hadly, E. A., . . . Koch, P. L. (2007). The Shifting Baseline of Northern Fur Seal Ecology in the Northeast Pacific Ocean. *Proceedings of the National Academy of Sciences of the United States of America, 104*(23), 9709-9714. https://doi.org/10.1073/pnas.0610986104

Historical data provide a baseline against which to judge the significance of recent ecological shifts and guide conservation strategies, especially for species decimated by pre-20th century harvesting. Northern fur seals (NFS;*Callorhinus ursinus*) are a common pinniped species in archaeological sites from southern California to the Aleutian Islands, yet today they breed almost exclusively on offshore islands at high latitudes. Harvest profiles from archaeological sites contain many unweaned pups, confirming the presence of temperate-latitude breeding colonies in California, the Pacific Northwest, and the eastern Aleutian Islands. Isotopic results suggest that prehistoric NFS fed offshore across their entire range, that California populations were distinct from populations to the north, and that populations breeding at temperate latitudes in the past used a different reproductive strategy than modern populations. The extinction of temperate-latitude breeding populations was asynchronous geographically. In southern California, the Pacific Northwest, and the eastern Aleutians, NFS remained abundant in the archaeological record up to the historical period approximate to 200 years B.P.; thus their regional collapse is plausibly attributed to historical hunting or some other anthropogenic ecosystem disturbance. In contrast, NFS populations in central and northern California collapsed at approximate to 800 years B.P., long before European contact. The relative roles of human hunting versus climatic factors in explaining this ecological shift are unclear, as more paleoclimate information is needed from the coastal zone.

Newsome, S. D., Etnier, M. A., Kurle, C. M., Waldbauer, J. R., Chamberlain, C. P., & Koch, P. L. (2007). Historic Decline in Primary Productivity in Western Gulf of Alaska and Eastern Bering Sea: Isotopic Analysis of Fur Seal Teeth. *Marine Ecology Progress Series, 332*, 211-224. https://doi.org/10.3354/meps332211

The cause(s) for the declines in marine mammal populations in the North Pacific and Bering Sea over the past 30 yr are unknown, despite progress in understanding the present ecology of this system. Explanations that attribute the declines to long-term decreases in marine productivity and/or short-term shifts in oceanographic conditions have been offered, but few studies have explored the issue from an explicitly historical perspective. Here we present a high-resolution, 52 yr time series of VC and 815 N values for teeth of juvenile male northern fur seal *Callorhinus ursinus* collected from a single colony on Saint Paul Island, Alaska in the eastern Bering Sea. Mean annual delta C-13 declined by similar to 1.1%. from 1948 to 2000, while long-term mean annual delta N-15 did not significantly change. The relatively small but significant long-term decrease in delta C-13 most likely reflects anthropogenically-driven changes in surface ocean carbon reservoirs and not a decline in primary productivity in the North Pacific and Bering Sea system. To assess short-term shifts in the time series, we detrended the delta C-13 data; the delta N-15 time series did not require a correction. The corrected delta C-13 and uncorrected 615 N values showed low amplitude oscillations with a frequency of similar to 20 to 25 yr that are roughly in phase through time. The relative timing of these oscillations suggest they may be driven by shifts in the Pacific Decadal Oscillation (PDO); however, the frequency of cycles in our time series is approximately half as long as the frequency of the PDO. Finally, mean delta C-13 and delta N-15 values suggest that juvenile males modify their migration patterns by Age 3 (GL3, the third year of growth). Specifically, they remain in high-latitude waters year-round (southern Bering Sea and/or western Gulf of Alaska).

Newsome, S. D., Koch, P. L., Etnier, M. A., & Aurioles-Gamboa, D. (2006). Using Carbon and Nitrogen Isotope Values to Investigate Maternal Strategies in Northeast Pacific Otariids. *Marine Mammal Science, 22*(3), 556-572. https://doi.org/10.1111/j.1748-7692.2006.00043.x

Abstract We examine the utility of stable carbon and nitrogen isotope variations to characterize the length of the nursing/lactation period and age at weaning for two northern Pacific otariid species, the northern fur seal (*Callorhinus ursinus*) and California sea lion (Zalophus californianus). We used two sampling strategies to measure ontogenetic trends in isotope value, and compared our results to observational data on the reproductive strategies used by these otariids. For Zalophus, we found evidence for 15N enrichment and 13C-depletion in bone collagen representing the first and second year of growth, which is consistent with the ~12-14-mo weaning age in this population after a suitable turnover rate for bone collagen is considered. Analysis of individual tooth annuli from a different suite of Zalophus specimens suggests that half of the individuals were weaned at ~12 mo of age, and half were dependent on milk for a portion of their second year. For Callorhinus, bone collagen for age classes that contain pre-weaned individuals were 15N-enriched, but values were significantly lower in specimens between 6 and 20 mo of age. These 15N-enriched values, presumably acquired during nursing between 0 and 4 mo of age in Callorhinus, were not present in specimens older than 12 mo of age. Thus complete bone collagen turnover in young-of-the-year occurs in 8-10 mo. 15N enrichment is evident in the first annulus of female Callorhinus individuals, but is not detectable in males. Analyses of Callorhinus tooth annuli show no ontogenetic trends in delta13C values. Our study indicates that nitrogen, and in some cases carbon, isotopes can be used to assess reproductive strategies in marine mammals. When coupled with accurate age estimates based on bone growth regressions, this isotopic technique can be applied to

historical or fossil otariids to gain insight into the flexibility of maternal strategies within and across species.

Nikol'skii, A. A., & Lisitsyna, T. Y. (2011). The Parallelisms in of Sound Signal of Domestic Sheep and Northern Fur Seals. *Zhurnal Obshchei Biologii, 72*(1), 40-50.

The parallelisms in communicative behavior of domestic sheep and Northern fur seals within a herd are accompanied by parallelisms in parameters of sound signal, the calling scream. This signal ensures ties between babies and their mothers at a long distance. The basis of parallelisms is formed by amplitude modulation at two levels: the one being a direct amplitude modulation of the carrier frequency and the other - modulation of the carrier frequency oscillation. Parallelisms in the signal oscillatory process result in corresponding parallelisms in the structure of its frequency spectrum.

Nomiyama, K., Kanbara, C., Ochiai, M., Eguchi, A., Mizukawa, H., Isobe, T., . . . Tanabe, S. (2014). Halogenated Phenolic Contaminants in the Blood of Marine Mammals from Japanese Coastal Waters. *Marine Environmental Research, 93*, 15-22. https://doi.org/10.1016/j.marenvres.2013.08.016

Information on accumulation of halogenated phenolic contaminants in the blood of marine mammal is limited. The present study, we determined the residue levels and patterns of chlorinated and brominated phenolic contaminants (OH-PCBs, OH-PBDEs and bromophenols) in the blood collected from pinnipeds (northern fur seal, spotted seal, Steller sea lion and ribbon seal) and small cetaceans (harbor porpoise and Dall's porpoise) from Japanese coastal waters. Concentrations of PCBs and OH-PCBs found in pinnipeds were the same as in small cetaceans living in the same coastal area. However, significantly lower concentrations of brominated compounds (PBDEs, MeO-PBDEs, OH-PBDEs) were found in the blood of pinnipeds than the levels found in cetacean species which live same area ($p < 0.05$). This difference of accumulation pattern suggested pinnipeds have an enhanced capability to degrade organobromine compounds relative to cetaceans..

Norberg, S. E., Burkanov, V. N., & Andrews, R. D. (2009). Serum Chemistry Values of Free-Ranging, Lactating Northern Fur Seals (*Callorhinus ursinus*). *Journal of Wildlife Diseases, 45*(3), 843-848. https://doi.org/10.7589/0090-3558-45.3.843

Reference range clinical serum chemistry values were established for freeranging lactating northern fur seals (*Callorhinus ursinus*). Fur seals sampled for this study were part of a healthy and growing population in the Kuril Islands of far-east Russia. Blood was collected from 45 females between June and August 2005 to 2007. Fresh serum was assayed for 16 components. Packed-cell volume was determined from fresh whole blood. Results are made available for future comparisons with the declining population of northern fur seals on the Pribilof Islands and are compared with published values for other otariid species.

Norberg, S. E., Burkanov, V. N., Tuomi, P., & Andrews, R. D. (2011). Hematology of Free-Ranging, Lactating Northern Fur Seals,*Callorhinus ursinus*. *Journal of Wildlife Diseases, 47*(1), 217-221. https://doi.org/10.7589/0090-3558-47.1.217

Thirteen standard hematology values were determined for a healthy and growing population of free-ranging, lactating northern fur seals (*Callorhinus ursinus*) from Lovushki Island in the Kuril Islands of far-east Russia. Results are presented from 24 females sampled between June and August during the 3-yr period of 2006-08. Hematologic values have been made available for future comparisons with the declining population of northern fur seals on the Pribilof Islands, Alaska, and are compared with published values for other otariid species.

Nordstrom, C. A., Battaile, B. C., Cotte, C., & Trites, A. W. (2013). Foraging Habitats of Lactating Northern Fur Seals Are Structured by Thermocline Depths and Submesoscale Fronts in the Eastern Bering Sea. *Deep-Sea Research Part II-Topical Studies in Oceanography, 88-89*, 78-96. https://doi.org/10.1016/j.dsr2.2012.07.010

The relationships between fine-scale oceanographic features, prey aggregations, and the foraging behavior of top predators are poorly understood. We investigated whether foraging patterns of lactating northern fur seals (*Callorhinus ursinus*) from two breeding colonies located in different oceanographic domains of the eastern Bering Sea (St. Paul Island-shelf; Bogoslof Island-oceanic) were a function of submesoscale oceanographic features. We tested this by tracking 87 lactating fur seals instrumented with bio-logging tags (44 St Paul Island, 43 Bogoslof Island) during July-September, 2009. We identified probable foraging hotspots using first-passage time analysis and statistically linked individual areas of high-use to fine-scale oceanographic features using mixed-effects Cox-proportional hazard models. We found no overlap in foraging areas used by fur seals from the two islands, but a difference in the duration of their foraging trips trips from St. Paul Island were twice as long (7.9 d average) and covered 3-times the distance (600 km average) compared to trips from Bogoslof Island. St. Paul fur seals also foraged at twice the scale (mean radius= 12 km) of Bogoslof fur seals (6 km), which suggests that prey were more diffuse near St Paul Island than prey near Bogoslof Island. Comparing first passage times with oceanographic covariates revealed that foraging hotspots were linked to thermocline depth and occurred near submesoscale surface fronts (eddies and filaments). St Paul fur seals that mixed epipelagic (night) and benthic (day) dives primarily foraged on-shelf in areas with deeper thermoclines that may have concentrated prey closer to the ocean floor, while strictly epipelagic (night) foragers tended to use waters with shallower thermodines that may have aggregated prey closer to the surface. Fur seals from Bogoslof Island foraged almost exclusively over the Bering Sea basin and appeared to hunt intensively along submesoscale fronts that may have converged prey within narrow bands near the surface. Bogoslof fur seals also foraged closer to their island which was surrounded by strong surface fronts, while fur seals from St Paul Island traveled > 100 km and extended some trips off-shelf to the basin to forage at similar oceanographic features. The relative distribution and accessibility of prey-concentrating oceanographic features can account for the observed inter-island foraging patterns, which may in turn have population level consequences for the two fur seal colonies.

Nordstrom, C. A., Benoit-Bird, K. J., Battaile, B. C., & Trites, A. W. (2013). Northern Fur Seals Augment Ship-Derived Ocean Temperatures with Higher Temporal and Spatial Resolution Data in the Eastern Bering Sea. *Deep-Sea Research Part II-Topical Studies in Oceanography, 94*, 257-273. https://doi.org/10.1016/j.dsr2.2013.03.022

Oceanographic data collected by marine vertebrates are increasingly being used in biological and physical studies under the assumption that data recorded by free-ranging animals are comparable to

those from traditional vertical sampling. We tested this premise by comparing the water temperatures measured during a 2009 oceanographic cruise with those measured during 82 foraging trips by instrumented northern fur seals (*Callorhinus ursinus*) in the eastern Bering Sea. The animal-borne data loggers were equipped with a fast-response temperature sensor and recorded 6492 vertical profiles to depths >= 50 m during long distance (up to 600 km) foraging trips. Concurrent sampling during the oceanographic cruise collected 247 CTD casts in the same 5-week period. Average temperature differences between ship casts and seal dives (0.60 +/- 0.61 degrees C), when the two were within 1 day and 10 km of each other (n=32 stations), were comparable to mean differences between adjacent 10 km ship casts (0.46 +/- 0.44 degrees C). Isosurfaces were evaluated at region wide scales at depths of 1 m and 50 m while the entire upper 100 m of the water column was analyzed at finer-scales in highly sampled areas. Similar patterns were noted in the temperature fields produced by ships or seals despite the differences in sampling frequency and distribution. However, the fur seal dataset was of higher temporal and spatial resolution and could therefore be used to visualize finer detail with less estimated error than ship-derived data, particularly in dynamic areas. Integrating the ship and seal datasets provided temperature maps with an unprecedented combination of resolution and coverage allowing fine-scale processes on-shelf and over the basin to be described simultaneously. Fur seals (n=65 trips) also collected 4700 additional profiles post-cruise which allowed >= 1 degrees C warming of the upper 100 m to be documented through mid-September, including regions where ship sampling has traditionally been sparse. Our data show that hydrographic information collected by wide-ranging, diving animals such as fur seals can contribute physical data comparable to, or exceeding those, of traditional sampling methods at regional or finer scales when the questions of interest coincide with the ecology of the species.

Nymo, I. H., Rodven, R., Beckmen, K., Larsen, A. K., Tryland, M., Quakenbush, L., & Godfroid, J. (2018). *Brucella* Antibodies in Alaskan True Seals and Eared Seals-Two Different Stories. *Frontiers in Veterinary Science, 5* https://doi.org/10.3389/fvets.2018.00008

Brucella pinnipedialis was first isolated from true seals in 1994 and from eared seals in 2008. Although few pathological findings have been associated with infection in true seals, reproductive pathology including abortions, and the isolation of the zoonotic strain type 27 have been documented in eared seals. In this study, a Brucella enzyme-linked immunosorbent assay (ELISA) and the Rose Bengal test (RBT) were initially compared for 206 serum samples and a discrepancy between the tests was found. Following removal of lipids from the serum samples, ELISA results were unaltered while the agreement between the tests was improved, indicating that serum lipids affected the initial RBT outcome. For the remaining screening, we used ELISA to investigate the presence of Brucella antibodies in sera of 231 eared and 1,412 true seals from Alaskan waters sampled between 1975 and 2011. In eared seals, Brucella antibodies were found in two Steller sea lions (Eumetopias jubatus) (2%) and none of the 107 Northern fur seals (*Callorhinus ursinus*). The low seroprevalence in eared seals indicate a low level of exposure or lack of susceptibility to infection. Alternatively, mortality due to the Brucella infection may remove seropositive animals from the population. Brucella antibodies were detected in all true seal species investigated; harbor seals (Phoca vitulina) (25%), spotted seals (Phoca largha) (19%), ribbon seals (Histriophoca fasciata) (16%), and ringed seals (Pusa hispida hispida) (14%). There was a low seroprevalence among pups, a higher seroprevalence among juveniles, and a subsequent decreasing probability of seropositivity with age in harbor seals. Similar patterns were present for the other true seal species; however, solid conclusions could not be made due to sample size. This pattern is in accordance with previous reports on B. pinnipedialis infections in true seals and may suggest environmental exposure to B. pinnipedialis at the juvenile stage, with a following clearance of infection.

Furthermore, analyses by region showed minor differences in the probability of being seropositive for harbor seals from different regions regardless of the local seal population trend, signifying that the Brucella infection may not cause significant mortality in these populations. In conclusion, the Brucella infection pattern is very different for eared and true seals.

Ochiai, H., Hishiyama, N., Higa, K., Hisamatsu, S., Koyama, K., Seita, M., & Fujise, H. (2006). Cation Transport and Regulatory Volume Increase in Red Blood Cells of Northern Fur Seals (*Callorhinus ursinus*). *Comparative Clinical Pathology, 15*(2), 76-81. https://doi.org/10.1007/s00580-006-0615-5

We investigated the membrane transport of Na and K ions in red blood cells (RBCs) of northern fur seal (*Callorhinus ursinus*) by measurement of unidirectional fluxes. Like red blood cells of other carnivores, those of northern fur seal contain high Na and low K concentrations, which result from the lack of Na-K ATPase activity on their membranes. In physiological conditions, activities of bumetanide-sensitive Na, K-Cl cotransport and amiloride-sensitive Na/H exchange were measured. K-Cl cotransport and Na-Cl cotransport were not detected. Hypertonicity activated only Na/H exchange. We further examined the ion transport systems for regulatory volume increase (RVI) in red blood cells. In the hyperosmotic condition, shrunken RBCs restored their original cell volume in Na medium but not in Na-free medium, and this restoration with Na medium was inhibited by amiloride. From these results, it is suggested that RVI in northern fur seal RBCs are performed by amiloride-sensitive Na/H exchanger but not Na, K-Cl cotransporter.

Ochiai, H., Hishiyama, N., Higa, K., Koyama, K., Seita, M., & Fujise, H. (2007). Regulatory Volume Decrease in Northern Fur Seal (*Callorhinus ursinus*) Red Blood Cells. *Comparative Clinical Pathology, 16*(1), 61-63. https://doi.org/10.1007/s00580-006-0643-1

The cation transport and regulatory volume decrease (RVD) were investigated in the red blood cells (RBCs) of northern fur seals (*Callorhinus ursinus*). Extracellular Ca-dependent Na efflux was increased to threefold by hypotonicity. K–Cl cotransport activity was not detected by hypotonic medium, but measured only by nitrite or N-ethylmaleimide stimulation. RBCs were restored to their original volume after being swollen in hypoosmotic medium with Ca, though this recovery was inhibited by the addition of quinidine. Based on these results, Na/Ca exchange transporter played the major role in the regulatory volume decrease in the RBCs of northern fur seals.

Olesiuk, P. F. (2008). *Preliminary Assessment of the Recovery Potential of Northern Fur Seals* (Callorhinus ursinus) *in British Columbia.* DFO, Ottawa, ON (Canada) Retrieved from https://waves-vagues.dfo-mpo.gc.ca/Library/334864.pdf

The reasons for the decline of fur seals breeding on the Pribilof Islands is unknown. Only small numbers of subadult males are taken for subsistence and bycatch in fisheries is minimal, so its unlikely direct human-induced mortality is driving the decline. Prey availability in the Bering Sea may have changed, perhaps due to changes in ocean conditions or as a result of commercial fisheries, as evident from declines of other pinnipeds in the Gulf of Alaska and Bering Sea. Female fur seals from the Pribilof Islands may also be experiencing greater intra- and inter-specific competition for prey resources. Relative numbers and biomass of male fur seals in the Bering Sea is predicted to have increased

substantially since commercial harvests were terminated. California and Steller sea lions, which often feed on the same prey as northern fur seals, have increased in abundance along the west coast of North America. The degree of competition between these apex predators warrants further study.Original Abstract: Le declin du taux de reproduction des otaries a fourrure dans les iles Pribilof demeure inexplique. Seule une tres petite quantite de males prereproducteurs est chassee a des fins de subsistance et le nombre de captures accessoires des peches est relativement minime. Il est donc peu probable que le taux de mortalite directement cause par l'homme puisse etre un important facteur de ce declin. La disponibilite des proies dans la mer de Bering pourrait avoir connu certaines fluctuations, repercussion possible de changements survenus dans le milieu oceanique ou des peches commerciales, comme en temoigne la diminution d'abondance d'autres pinnipedes du golfe d'Alaska et de la mer de Bering. Les otaries a fourrure femelles des iles Pribilof pourraient egalement etre victimes d'une concurrence intra ou interspecifique pour les memes proies. L'on estime que le nombre relatif et la biomasse des otaries a fourrure males dans la mer de Bering aurait connu un essor considerable suivant l'interdiction de la chasse commerciale. L'otarie de Californie et l'otarie de Steller, qui se nourrissent souvent des memes proies que l'otarie a fourrure du Nord, ont augmente en abondance le long de la cote ouest d'Amerique du Nord. Le degre de concurrence entre ces predateurs du sommet de la chaine alimentaire justifie une etude plus approfondie.

Olesiuk, P. F. (2012). *Habitat Utilization by Northern Fur Seals (*Callorhinus ursinus) *in the Northeastern Pacific Ocean and Canada.* Fisheries and Oceans Canada. Retrieved from http://waves-vagues.dfo-mpo.gc.ca/Library/347187.pdf

Historic sealing logbooks from 1882-1911, NPFSC research collections and sightings from 1958-1974, the NMML platform of opportunity sighting database from 1957-2007, and published reports on satellite tags deployed since 1991 are used to describe the distribution and migration patterns of northern fur seals in the northeastern Pacific Ocean. GIS analysis identified several important foraging areas used by high densities of fur seals migrating along the west coast of North America. The highest densities occurred on what sealer's referred to as the Vancouver ground on the continental shelf from the Columbia River to La Perouse Bank off southern Vancouver Island. The area is used predominately by adult females during spring as they gain weight prior to making the trip to breeding sites.Original Abstract: Afin de decrire la repartition et les habitudes migratoires des otaries a fourrure dans le nord-est de l'ocean Pacifique, on se sert des journaux de bord historiques de la chasse au phoque qui s'est deroulee entre 1882 et 1911, des collections de recherche et des observations de 1958 a 1974 de la Commission du phoque a fourrure / otarie / du Pacifique Nord, de la base de donnees des observations occasionnelles survenues entre 1957 et 2007 et des rapports publies sur les etiquettes emettrices fixees aux animaux depuis 1991. L'analyse du SIG a permis de decouvrir un certain nombre d'aires d'alimentation ou se nourrissent de grands nombres d'otaries a fourrure qui migrent le long de la cote Ouest de l'Amerique du Nord. Les plus grands nombres ont ete observes sur ce que les chasseurs de phoques appellent la terre de Vancouver du plateau continental entre le fleuve Columbia et le banc La Perouse, au large de la partie sud de l'ile de Vancouver. Dans cette zone on retrouve surtout des femelles adultes au printemps qui prennent du poids en vue de leur deplacement vers les lieux de reproduction.

Olesiuk, P. F. (2012). *Population Viability Analysis for Northern Fur Seals* (Callorhinus ursinus) *in Canada.* Fisheries and Oceans Canada. Retrieved from http://waves-vagues.dfo-mpo.gc.ca/Library/347188.pdf

A population viability analysis (PVA) was conducted for northern fur seals to assess risk of extirpation in Canada. The PVA is based on the diffusion model developed by Dennis et al. (1991) that projects populations along a trajectory based on recent trends with drift due to natural variability. The North Pacific fur seal population was considered a meta-population, with each breeding site representing a subpopulation (the smallest breeding site at San Miguel Island was excluded from the analysis). Recent trends for each subpopulation were estimated from pup counts using density independent or dependent models, and unexplained variation was assumed to represent natural variability (demographic stochasticity or environmental variability) after adjusting for measurement error. Models were fitted to the most recent 10-year, 30-year and 50-year time-series of pup counts. Monte Carlo techniques were used to project each subpopulation 200 years into the future, and risk of quasi-extinction estimated for the first 100 years.Original Abstract: Une analyse de la viabilite de la population d'otaries a fourrure du Nord a ete effectuee afin d'evaluer le risque de disparition de ces dernieres du Canada. L'analyse est fondee sur le modele de diffusion presente dans Dennis et coll. (1991). Ce modele presente une projection des populations le long d'une trajectoire etablie selon des tendances recentes, dont les variations sont attribuables a la variabilite naturelle. La population d'otaries a fourrure du Pacifique Nord etait consideree comme une metapopulation, et chaque aire de reproduction representait une sous-population (la plus petite aire de reproduction situee a l'ile San Miguel a ete exclue de l'analyse). Les tendances recentes relatives a chacune des sous-populations ont ete estimees a partir du nombre de petits en utilisant des modeles qui dependent ou non de la densite. On a suppose que la variation inexpliquee representait la variabilite naturelle (stochasticite demographique ou variabilite environnementale) apres avoir fait les ajustements necessaires pour les erreurs de mesure. Les modeles ont ete adaptes aux plus recentes series chronologiques du nombre de petits qui etaient echelonnees sur 10 ans, 30 ans et 50 ans. Les techniques de Monte Carlo ont ete utilisees pour projeter l'evolution de chacune des sous-populations 200 ans dans l'avenir, et pour estimer le risque de quasi-extinction au cours des 100 premieres annees de la projection.

Oliveira, L. R., & Brownell, R. L. (2014). Taxonomic Status of Two Subspecies of South American Fur Seals: *Arctocephalus australis australis* vs. *A. a. gracilis. Marine Mammal Science, 30*(3), 1258-1263. https://doi.org/10.1111/mms.12098

The article reports on two subspecies of South American fur seals (Arctocephalus australis). This nominal species was originally described from a specimen collected from the Falkland Islands and is one of three fur seals described in the latter half of the 18th century.*Callorhinus ursinus* and Arctocephalus pusillus are the other two northern fur seals.

Park, J., Kim, K., Sohn, H., Kim, H. W., An, Y. R., Kang, J. H., . . . Kim, H. (2018). Deciphering the Evolutionary Signatures of Pinnipeds Using Novel Genome Sequences: The First Genomes of Phoca Largha, *Callorhinus ursinus*, and *Eumetopias jubatus*. *Scientific Reports, 8* https://doi.org/10.1038/s41598-018-34758-0

The pinnipeds, which comprise seals, sea lions, and walruses, are a remarkable group of marine animals with unique adaptations to semi-aquatic life. However, their genomes are poorly characterized. In this study, we sequenced and characterized the genomes of three pinnipeds (Phoca largha, *Callorhinus ursinus*, and Eumetopias jubatus), focusing on site-wise sequence changes. We detected rapidly evolving genes in pinniped lineages and substitutions unique to pinnipeds associated with amphibious sound

perception. Phenotypic convergence-related sequence convergences are not common in marine mammals. For example, FASN, KCNAS, and IL17RA contain substitutions specific to pinnipeds, yet are potential candidates of phenotypic convergence (blubber, response to hypoxia, and immunity to pathogens) in all marine mammals. The outcomes of this study will provide insight into targets for future studies of convergent evolution or gene function.

Peck, R. M. (2014). A Painter in the Bering Sea: Henry Wood Elliott and the Northern Fur Seal. *Polar Record, 50*(3), 311-318. https://doi.org/10.1017/s0032247413000703

Henry Wood Elliott (1846-1930), a U. S. Treasury official assigned to monitor the harvest of northern fur seals on the Pribilof Islands in the 1870s, became a self-taught expert on, and defender of, the species. His careful documentation of the seals' breeding behaviour, and of their commercial harvest, complemented by hundreds of detailed and evocative watercolours, provides a unique record of this once abundant species and the lucrative industry that revolved around it. Elliott's outspoken lobbying on behalf of the seals' protection is often credited with saving the species from extinction. His paintings of the seals, the seal harvest, and life on the Pribilof Islands in the second half of the nineteenth century constitute an unmatched historical record of this remote region. Elliott was able to witness two full breeding seasons (and harvesting) of the fur seals during his initial stay on the Pribilofs from April 1872 to October 1873. He returned to the islands to conduct a follow-up census of the seals, on behalf of the U. S. Government, in the summer of 1874. He traveled there unofficially and at his own expense in 1876. His fourth trip to the Pribilofs was in the spring of 1890 (again on behalf of the U. S. Department of the Treasury), in response to news of a dramatic decline of the seal populations. In April, 1891, because of his public revelation of mismanagement of the fur seal harvest, Elliott was fired by the Treasury. He continued his tireless lobbying on behalf of the fur seals as a private citizen for the rest of his life. He visited the Pribilofs for the last time on behalf of the House Committee on Expenditures in the Department of Commerce and Labor in the summer of 1913. Born in Cleveland Ohio on November 13, 1846, Elliott died in Seattle Washington on May 25, 1930.

Pelland, N. A., Sterling, J. T., Lea, M. A., Bond, N. A., Ream, R. R., Lee, C. M., & Eriksen, C. C. (2014). Fortuitous Encounters between Seagliders and Adult Female Northern Fur Seals (*Callorhinus ursinus*) Off the Washington (USA) Coast: Upper Ocean Variability and Links to Top Predator Behavior. *PLoS One, 9*(8) https://doi.org/10.1371/journal.pone.0101268

Behavioral responses by top marine predators to oceanographic features such as eddies, river plumes, storms, and coastal topography suggest that biophysical interactions in these zones affect predators' prey, foraging behaviors, and potentially fitness. However, examining these pathways is challenged by the obstacles inherent in obtaining simultaneous observations of surface and subsurface environmental fields and predator behavior. In this study, migratory movements and, in some cases, diving behavior of 40 adult female northern fur seals (NFS;*Callorhinus ursinus*) were quantified across their range and compared to remotely-sensed environmental data in the Gulf of Alaska and California Current ecosystems, with a particular focus off the coast of Washington State (USA) - a known foraging ground for adult female NFS and where autonomous glider sampling allowed opportunistic comparison of seal behavior to subsurface biophysical measurements. The results show that in these ecosystems, adult female habitat utilization was concentrated near prominent coastal topographic, riverine, or inlet features and within 200 km of the continental shelf break. Seal dive depths, in most ecosystems, were moderated by surface light level (solar or lunar), mirroring known behaviors of diel vertically-migrating

prey. However, seal dives differed in the California Current ecosystem due to a shift to more daytime diving concentrated at or below the surface mixed layer base. Seal movement models indicate behavioral responses to season, ecosystem, and surface wind speeds; individuals also responded to mesoscale eddies, jets, and the Columbia River plume. Foraging within small scale surface features is consistent with utilization of the inner coastal transition zone and habitats near coastal capes, which are known eddy and filament generation sites. These results contribute to our knowledge of NFS migratory patterns by demonstrating surface and subsurface behavioral responses to a spatially and temporally dynamic ocean environment, thus reflecting its influence on associated NFS prey species.

Pinsky, M. L., Newsome, S. D., Dickerson, B. R., Fang, Y., Van Tuinen, M., Kennett, D. J., . . . Hadly, E. A. (2010). Dispersal Provided Resilience to Range Collapse in a Marine Mammal: Insights from the Past to Inform Conservation Biology. *Molecular Ecology, 19*(12), 2418-2429. https://doi.org/10.1111/j.1365-294X.2010.04671.x

Population loss is often a harbinger of species extinction, but few opportunities exist to follow a species' demography and genetics through both time and space while this occurs. Previous research has shown that the northern fur seal (*Callorhinus ursinus*) was extirpated from most of its range over the past 200-800 years and that some of the extirpated populations had unique life history strategies. In this study, widespread availability of subfossils in the eastern Pacific allowed us to examine temporal changes in spatial genetic structure during massive population range contraction and partial recovery. We sequenced the mitochondrial control region from 40 ancient and 365 modern samples and analyzed them through extensive simulations within a serial Approximate Bayesian Computation framework. These analyses suggest that the species maintained a high abundance, probably in subarctic refugia, that dispersal rates are likely 85% per generation into new breeding colonies, and that population structure was not higher in the past. Despite substantial loss of breeding range, this species' high dispersal rates and refugia appear to have prevented a loss of genetic diversity. High dispersal rates also suggest that previous evidence for divergent life history strategies in ancient populations likely resulted from behavioral plasticity. Our results support the proposal that panmictic, or nearly panmictic, species with large ranges will be more resilient to future disturbance and environmental change. When appropriately verified, evidence of low population structure can be powerful information for conservation decision-making.

Ramos, P., Lynch, M., Hu, M., Arnould, J. P. Y., Norman, R., & Beveridge, I. (2013). Morphometric and Molecular Characterization of the Species of *Uncinaria* Frolich, 1789 (Nematoda) Parasitic in the Australian Fur Seal *Arctocephalus pusillus doriferus* (Schreber), with Notes on Hookworms in Three Other Pinniped Hosts. *Systematic Parasitology, 85*(1), 65-78. https://doi.org/10.1007/s11230-013-9407-x

This study presents morphological and molecular data on hookworms from the Australian fur seal Arctocephalus pusillus doriferus (Schreber) currently identified in Australian waters as Uncinaria hamiltoni Baylis, 1933. Additional specimens from the Australian sea lion Neophoca cinerea (P,ron) and the New Zealand fur seal Arctocephalus forsteri (Lesson) from Australia, and the Southern elephant seal Mirounga leonina (Linnaeus) from Antarctica, were included. Using the internal transcribed spacer (ITS), hookworms from A. p. doriferus, N. cinerea and A. forsteri were found to be genetically similar but distinct from Uncinaria spp. found in M. leonina from Antarctica, as well as from Zalophus californianus

(Lesson) and *Callorhinus ursinus* (Linnaeus) from California. Few morphological differences were detected between these taxa.

Rausch, R. L., Adams, A. M., & Margolis, L. (2010). Identity of *Diphyllobothrium* ssp. (Cestoda: Diphyllobothriidae) from Sea Lions and People Along the Pacific Coast of South America. *Journal of Parasitology, 96*(2), 359-365. https://doi.org/10.1645/ge-2257.1

Host specificity evidently is not expressed by various species of *Diphyllobothrium* that occur typically in marine mammals, and people become infected occasionally when dietary customs favor ingestion of plerocercoids. This report mainly concerns 2 species, *Diphyllobothrium pacificum* and *Diphyllobothrium arctocephalinum*, for which sea lions (Otariidae) are final hosts. The taxonomic status of those cestodes has not been clearly discernible because of misinterpretation of relationships; complex synonymies have resulted from misidentification(s). Stiles and Hassall in 1899 obtained, but did not describe, cestodes from the northern fur seal (Otariidae; Pribilof Islands). That taxon was subsequently studied by several investigators, with diverse conclusions. The valid designation is *D. pacificum* (Nybelin, 1931). In 1937, Johnston and Drummond described separately 2 conspecific cestodes from sea lions near Australia, designated *D. arctocephalinum* and *Diphyllobothrium aretocephali*. Both names have been listed incorrectly as synonyms of *D. pacificum*.

Reiner, J. L., Becker, P. R., Gribble, M. O., Lynch, J. M., Moors, A. J., Ness, J., . . . Kucklick, J. R. (2016). Organohalogen Contaminants and Vitamins in Northern Fur Seals (*Callorhinus ursinus*) Collected During Subsistence Hunts in Alaska. *Archives of Environmental Contamination and Toxicology, 70*(1), 96-105. https://doi.org/10.1007/s00244-015-0179-y

During native subsistence hunts from 1987 to 2007, blubber and liver samples from 50 subadult male northern fur seals (*Callorhinus ursinus*) were collected on St. Paul Island, Alaska. Samples were analyzed for legacy persistent organic pollutants (POPs), recently phased-out/current-use POPs, and vitamins. The legacy POPs measured from blubber samples included polychlorinated biphenyl congeners, DDT (and its metabolites), chlorobenzenes, chlordanes, and mirex. Recently phased-out/current-use POPs included in the blubber analysis were the flame retardants, polybrominated diphenyl ethers, and hexabromocyclododecanes. The chemical surfactants, perfluorinated alkyl acids, and vitamins A and E were assessed in the liver samples. Overall, concentrations of legacy POPs are similar to levels seen in seal samples from other areas of the North Pacific Ocean and the Bering Sea. Statistically significant correlations were seen between compounds with similar functions (pesticides, flame retardants, vitamins). With sample collection spanning two decades, the temporal trends in the concentrations of POPs and vitamins were assessed. For these animals, the concentrations of the legacy POPs tend to decrease or stay the same with sampling year; however, the concentrations of the current-use POPs increased with sampling year. Vitamin concentrations tended to stay the same across the sampling years. With the population of northern fur seals from St. Paul Island on the decline, a detailed assessment of exposure to contaminants and the correlations with vitamins fills a critical gap for identifying potential population risk factors that might be associated with health effects.

Roe, W. D., Spraker, T. R., Duncan, C. G., Owen, M., & Charles, J. B. (2013). Postmortem Stability of S100B in the Aqueous Humor of Northern Fur Seals (*Callorhinus ursinus*). *Journal of Veterinary Diagnostic Investigation, 25*(5), 627-629. https://doi.org/10.1177/1040638713498600

Bycatch (accidental drowning in fishing nets) is a significant problem for some marine mammal species, but can be difficult to diagnose as there are no pathognomonic gross or histological lesions. In human medicine, biomarkers such as S100B are increasingly being used to investigate hypoxic-ischemic syndromes, but, to the authors' knowledge, studies using this marker have not been reported for marine mammal species. The aims of the current study were to determine baseline postmortem S100B levels in a pinniped species, and to determine whether S100B levels were stable over a postmortem interval of 48 hr. Aqueous humor, which is simple to collect and avoids many of the problems associated with postmortem collection of blood, was used as a surrogate for serum. S100B was detected in the aqueous humor of acute deaths (<15 min) and was stable for up to 48 hr, with a wider variation in values at the 48-hr time interval.

Rosen, D. A. S., Gerlinsky, C. G., & Trites, A. W. (2018). Telemetry Tags Increase the Costs of Swimming in Northern Fur Seals,*Callorhinus ursinus*. *Marine Mammal Science, 34*(2), 385-402. https://doi.org/10.1111/mms.12460

Animal-borne instruments have become a standard tool for collecting important data from marine mammals. However, few studies have examined whether placement of these data loggers affects the behavior and energetics of individual animals, potentially leading to biasing data. We measured the effect of two types of relatively small data loggers (<1% of animals' mass and front profile) on the swimming speeds and energy expenditure of four female northern fur seals (*Callorhinus ursinus*) while swimming at depth. Swim speeds and rates of oxygen consumption were measured as the trained fur seals repeatedly swam an underwater circuit, with or without the tags. We found the placement of either tested tag significantly affected both the behavior and energetics of the fur seals in our study. Diving metabolic rate increased an average of 8.1%–12.3% (depending on tag type) and swim speed decreased an average of 3.0%–6.0% when wearing the tags. The combined changes in velocities and metabolic rates resulted in a 12.0%–19.0% increase in the total energy required by the fur seals to swim a set distance. The demonstrated effects of tags on behavior and energy expenditure may bias data sets from wild animals and potentially incur longer-term impacts on the studied animals.

Rosen, D. A. S., & Tollit, D. J. (2012). Effects of Phylogeny and Prey Type on Fatty Acid Calibration Coefficients in Three Pinniped Species: Implications for the QFASA Dietary Quantification Technique. *Marine Ecology Progress Series, 467*, 263-276. https://doi.org/10.3354/meps09934

Quantitative fatty acid signature analysis (QFASA) has been proposed as a technique for determining the long-term diet of animals. The method compares the fatty acid (FA) profiles of predators and potential prey items to estimate relative prey intake. We tested the assumptions of a key step in QFASA, the correction of predator FA signatures for metabolic processes through sets of calibration coefficients (CCs). We conducted long-term controlled feeding studies with captive Steller sea lions consuming herring and eulachon and northern fur seals consuming herring. We compared the results with data from harbour seals eating herring to evaluate the effects of phylogeny and prey type on individual CCs. Even within the limited extended dietary FA subset recommended for use by other researchers, we found that at least 41% of the CCs differed by family (otariid vs. phocid seals) and 58% differed by predator species (sea lion vs. fur seal), suggesting that CCs may be highly species-specific. We also found that 64% of the CCs differed by prey type (sea lions consuming herring vs. eulachon), which raises some fundamental implementation issues. We also found significant differences in diet predictions when the

herring-and eulachon-derived sets of CCs were applied to an actual multi-species diet. CCs are presently used as a simple mathematical attempt to describe potentially complex biochemistry. The results of this study raise questions regarding the validity of using CCs derived from an alternative predator species, and highlight some fundamental issues regarding QFASA methodology that need to be addressed through further controlled studies.

Rosen, D. A. S., & Trites, A. W. (2014). Thermal Limits in Young Northern Fur Seals, *Callorhinus ursinus*. *Marine Mammal Science, 30*(3), 1014-1028. https://doi.org/10.1111/mms.12097

The thermoregulatory abilities of northern fur seals (*Callorhinus ursinus*) during their first two years in the frigid waters of the North Pacific Ocean may limit their geographic distribution and alter the costs for exploiting different species of prey. We determined the thermoneutral zone of six young northern fur seals by measuring their metabolism in ambient air and controlled water temperatures (0 degrees C-12 degrees C) from ages 8 to 24 mo. We found that the ambient air temperatures within our study (overall 1.5 degrees C-23.9 degrees C) did not affect resting metabolic rates. Calculated lower critical temperatures in water varied between 3.9 degrees C and 8.0 degrees C, while an upper critical temperature in water was only discernible during a single set of trials. These thermal responses provide insight into the possible physiological constraints on foraging ecology in young northern fur seals, as well as the potential energetic consequences of ocean climate change and altered prey distributions.

Rosen, D. A. S., Volpov, B. L., & Trites, A. W. (2014). Short-Term Episodes of Imposed Fasting Have a Greater Effect on Young Northern Fur Seals (*Callorhinus ursinus*) in Summer Than in Winter. *Conservation Physiology, 2.* https://doi.org/10.1093/conphys/cou021

An unexpected shortage of food may affect wildlife in a different way depending on the time of year when it occurs. We imposed 48 h fasts on six female northern fur seals (*Callorhinus ursinus*; ages 6–24 months) to identify times of year when they might be particularly sensitive to interruptions in food supply. We monitored changes in their resting metabolic rates and their metabolic response to thermal challenges, and also examined potential bioenergetic causes for seasonal differences in body mass loss. The pre-fast metabolism of the fur seals while in ambient air or submerged in water at 4°C was higher during summer (June to Sepember) than winter (November to March), and submergence did not significantly increase metabolism, indicating a lack of additional thermoregulatory costs. There was no evidence of metabolic depression following the fasting periods, nor did metabolism increase during the post-fast thermal challenge, suggesting that mass loss did not negatively impact thermoregulatory capacity. However, the fur seals lost mass at greater rates while fasting during the summer months, when metabolism is normally high to facilitate faster growth rates (which would ordinarily have been supported by higher food intake levels). Our findings suggest that summer is a more critical time of year than winter for young northern fur seals to obtain adequate nutrition.

Rosen, D. A. S., Young, B. L., & Trites, A. W. (2012). Rates of Maximum Food Intake in Young Northern Fur Seals (*Callorhinus ursinus*) and the Seasonal Effects of Food Intake on Body Growth. *Canadian Journal of Zoology, 90*(1), 61-91. https://doi.org/10.1139/Z11-112

Accurate estimates of food intake and its subsequent effect on growth are required to understand the interaction between an animal's physiology and its biotic environment. We determined how food intake

and growth of six young northern fur seals (*Callorhinus ursinus* (L., 1758)) responded seasonally to changes in food availability. Animals were given unrestricted access to prey for 8 h·day–1 on either consecutive days or on alternate days only. We found animals offered ad libitum food on consecutive days substantially increased their food intake over normal "training" levels. However, animals that fasted on alternate days were unable to compensate by further increasing their levels of consumption on subsequent feeding days. Absolute levels of food intake were highly consistent during winter and summer trials (2.7–2.9 kg·day–1), but seasonal differences in body mass meant that fur seals consumed more food relative to their body mass in summer (~27%) than in winter (~20%). Despite significant increases in absolute food intake during both seasons, the fur seals did not appear to efficiently convert this additional energy into mass growth, particularly in the winter. These seasonal differences in conversion efficiencies and estimates of maximum intake rates can be used to generate physiologically realistic predictions about the effect of changes in food availability on an individual fur seal, as well as the consequences for an entire population.

Ross, K. E. N. (2006). Fur Seal's Friend: Henry W. Elliot. In *Pioneering Conservation in Alaska.* (pp. 27-57): University Press of Colorado. Retrieved from http://www.jstor.org/stable/j.ctt1wn0r8r.12

One of the first great international wildlife controversies began immediately after the United States acquired Alaska. In various forms, it lasted more than a century. It gave birth to a prototype environmental campaign and an international treaty centered on a North Pacific sea mammal: the fur seal. Biologically related to the fur seals of the southern oceans, the northern fur seal gathered on a few subarctic islands each spring and summer for breeding and birth of pups. During the fall and winter the females and young migrated southward in the open ocean while most older males remained in the Bering Sea.

Ruedig, E., Duncan, C., Dickerson, B., Williams, M., Gelatt, T., Bell, J., & Johnson, T. E. (2016). Fukushima Derived Radiocesium in Subsistence-Consumed Northern Fur Seal and Wild Celery. *Journal of Environmental Radioactivity, 152*, 1-7. https://doi.org/10.1016/j.jenvrad.2015.10.024

In July 2014, our investigative team traveled to St. Paul Island, Alaska to measure concentrations of radiocesium in wild-caught food products, primarily northern fur seal (*Callorhinus ursinus*). The 2011 Fukushima Daiichi Nuclear Power Plant accident released radiocesium into the atmosphere and into the western Pacific Ocean; other investigators have detected Fukushima-derived radionuclides in a variety of marine products harvested off the western coast of North America. We tested two subsistence-consumed food products from St. Paul Island, Alaska for Fukushima-derived radionuclides: 54 northern fur seal, and nine putchki (wild celery, Angelica lucida) plants. Individual northern fur seal samples were below minimum detectable activity concentrations of Cs-137 and Cs-134, but when composited, northern fur seal tissues tested positive for trace quantities of both isotopes. Radiocesium was detected at an activity concentration of 37.2 mBq Cs-134 kg(-1) f.w. (95% CI: 35.9-38.5) and 141.2 mBq Cs-137 kg(-1) f.w. (95% CI: 135.5-146.8). The measured isotopic ratio, decay-corrected to the date of harvest, was 0.26 (95% CI: 0.25-0.28). The Fukushima nuclear accident released Cs-134 and Cs-137 in roughly equal quantities, but by the date of harvest in July 2014, this ratio was 0.2774, indicating that this population of seals has been exposed to small quantities of Fukushima-derived radiocesium. Activity concentrations of both Cs-134 and Cs-137 in putchki were below detection limits, even for composited samples. Northern fur seal is known to migrate between coastal Alaska and Japan and the trace Cs-134 in northern fur seal tissue suggests that the population under study had been minimally exposed

Fukushima-derived radionuclides. Despite this inference, the radionuclide quantities detected are small and no impact is expected as a result of the measured radiation exposure, either in northern fur seal or human populations consuming this species.

Ryazanov, S. D., Kirillova, A. D., Laskina, N. B., & Burkanov, V. N. (2018). Infanticide and Cannibalism in Steller Sea Lions (*Eumetopias jubatus*). *Marine Mammal Science, 34*(1), 200-207. https://doi.org/10.1111/mms.12437

Infanticide is widespread among mammals of different taxonomic groups (Lukas and Huchard 2014). In otariids intraspecific killing of pups appears primarily as the consequence of sexual behavior of subadult males, guarding of individual points of parturition by adult females, or the indirect effect of fighting by territorial bulls (e.g., Gisiner 1985, Campagna et al. 1988, Le Boeuf and Campagna 1994, Kiyota and Okamura 2005).

Sanfelice, D., & de Freitas, T. R. O. (2008). A Comparative Description of Dimorphism in Skull Ontogeny of *Arctocephalus australis*, *Callorhinus ursinus*, and *Otaria byronia* (Carnivora : Otariidae). *Journal of Mammalogy, 89*(2), 336-346. https://doi.org/10.1644/07-mamm-a-344.1

Ontogenetic differences between males and females result in sexual dimorphism, but this process is poorly understood in the majority of mammalian taxa. Sexual dimorphism is particularly extreme in the otariids (Carnivora: Otariidae), and to examine the origin, structure, and temporal patterns of otariid morphological diversity, we focus here on 3 otariid species: *Arctocephalus australis* (southern fur seal), *Callorhinus ursinus* (northern fur seal), and *Otaria byroni*a (southern sea lion). Our aims are to compare the ontogeny of skull shape across species, and to evaluate the ontogeny of sexual dimorphism, testing the hypothesis that dimorphism arises by extrapolation of a shared ontogeny to the larger sizes that are characteristic of males. We found that dimorphism increased over ontogeny but was not due solely to allometric extrapolation, because different rates of development were found in some species. Specifically, the relationships between changes in shape and size increase were different between sexes in *A. australi*s and *O. byroni*a, but equal in *C. ursinu*s. It is possible to implicate heterochrony in the origins of the modifications undergone during the ontogeny of males and females of *A. australis* and *O. byroni*a, considering the differences in the rates of development between the sexes of both species, but it is certain that allometric repatterning also is involved in these.

Sanfelice, D., & Freitas, T. R. O. (2007). The Ontogeny of Shape Disparity in Three Species of Otariids (Pinnipedia: Mammalia). *Latin American Journal of Aquatic Mammals, 6*(2), 139-154. http://dx.doi.org/10.5597/lajam00119

We compared skull ontogenies in three otariid species to identify evolutionary novelties and to understand their relationships with diversity. The species studied were Arctocephalus australis,*Callorhinus ursinus* and Otaria byronia. We analyzed evolutionary changes in three parameters of developmental trajectories of skull shape: shape at the outset of ontogeny, allometric pattern, and the amount of change undergone over the course of ontogeny, which depends on its duration (the length of the ontogenetic vector) and on the rate of development. Initial shapes were always very different among the species and the distances between shapes increased with time, independently from size. Furthermore, when the complete samples were considered, all the ontogenetic trajectories were

significantly different concerning the directions of the allometric vectors during ontogeny. Ontogenetic trajectories also differed significantly among almost all compared pairs, except for the trajectories of males of A. australis and C. ursinus. However, these differences are expected by chance (considering the range of angles within each sample). A similar pattern was found when the subadults were compared in pairs of species, as well as adult males of A. australis and O. byronia. The correlation found between ontogenies of juveniles was expected by chance, with exception of C. ursinus and O. byronia. The ontogenetic trajectory of C. ursinus is the shortest and that of O. byronia is the longest, with the latter being near the triple of the former. A. australis has an intermediary length of ontogenetic trajectory. Considering all three species, disparity increased significantly over ontogeny since the disparity of the adults is near double that between juveniles. However, the pattern of disparity did not change considerably during ontogeny. For any ontogenetical stage, O. byronia is the species that most contributed to the disparity of the group, followed by C. ursinus. Finally, ontogenies examined herein are clearly not constrained (almost every developmental parameter of shape that could evolve was observed) and perhaps the differences in patterns have additive effects in the differentiation of the ontogenies.Original

Sanfelice, D., Molina-Schiller, D., & de Freitas, T. R. O. (2018). Development and Growth in Skulls of Three Otariidae Species: A Comparative Morphometric Study. *Journal of the Marine Biological Association of the United Kingdom, 98*(7), 1801-1815. https://doi.org/10.1017/s0025315417001394

We examined the skulls of Arctocephalus australis, *Callorhinus ursinus* and Otaria byronia with the objectives of (1) estimating the development and growth rates and comparing these parameters among the species; (2) describing the development for each linear measure, for each species and sex; (3) determining which variables are best correlated with age; (4) determining age of physical maturity. We employed traditional and geometric morphometric techniques to study the skulls. In A. australis and C. ursinus, skulls of females mature at about 6 years of age, and those of males at about 8 years. Otaria byronia matures later, at about 9 years. Using geometric morphometric data sets, the rate and constant of growth in A. australis did not differ between the sexes.*Callorhinus ursinu*s and O. byronia showed rates significantly different between sexes concerning growth (and in the constant as well), but only O. byronia differed between sexes in both developmental model parameters (rates and constant). Comparisons between the growth and developmental models showed significant differences in slope and constant. In both treatments employed, a relationship between size and shape dimorphism could be inferred for the skulls of all three species. We conclude that rates or timing of growth and development evolves within a conserved spatiotemporal organization of morphogenesis.

Satterthwaite, W. H., & Mangel, M. (2012). Behavioral Models as a Common Framework to Predict Impacts of Environmental Change on Seabirds and Fur Seals. *Deep-Sea Research Part II-Topical Studies in Oceanography, 65-70*, 304-315. https://doi.org/10.1016/j.dsr2.2012.02.016

In this paper, we lay out the theoretical framework for using modeling approaches from behavioral ecology (in particular, state-dependent and game theoretical models) to predict the behavioral responses of central place foragers to changes in their food environment. We develop individual-based models of the state-dependent behavior of individual central place foragers over the course of a breeding season and show how our approach provides a framework for the prediction of trip lengths, foraging location, food delivery, and reproductive success. We formulate a common framework of

models for northern fur seals (*Callorhinus ursinus*), black-legged kittiwakes (Rissa tridactyla), and thick-billed murres (Uria lomvia), and provide worked examples parameterized to represent fur seals and murres. We then develop a game theoretic model at the colony-level for predicting the distribution of multiple individuals across space in the face of potential interference or facilitation, providing a worked example for kittiwakes. We demonstrate how these models can be used to predict near-term aspects of foraging behavior such as diet choice and trip destinations and durations at the individual and colony level. We show how (i) behavioral predictions can be translated into predictions of foraging success, (ii) foraging success can be scaled up to demographically relevant parameters such as survival and reproduction, and (iii) this approach can help predict impacts of environmental change on top-level predators.

Scharf, H., Hooten, M. B., & Johnson, D. S. (2017). Imputation Approaches for Animal Movement Modeling. *Journal of Agricultural Biological and Environmental Statistics, 22*(3), 335-352. https://doi.org/10.1007/s13253-017-0294-5

The analysis of telemetry data is common in animal ecological studies. While the collection of telemetry data for individual animals has improved dramatically, the methods to properly account for inherent uncertainties (e.g., measurement error, dependence, barriers to movement) have lagged behind. Still, many new statistical approaches have been developed to infer unknown quantities affecting animal movement or predict movement based on telemetry data. Hierarchical statistical models are useful to account for some of the aforementioned uncertainties, as well as provide population-level inference, but they often come with an increased computational burden. For certain types of statistical models, it is straightforward to provide inference if the latent true animal trajectory is known, but challenging otherwise. In these cases, approaches related to multiple imputation have been employed to account for the uncertainty associated with our knowledge of the latent trajectory. Despite the increasing use of imputation approaches for modeling animal movement, the general sensitivity and accuracy of these methods have not been explored in detail. We provide an introduction to animal movement modeling and describe how imputation approaches may be helpful for certain types of models. We also assess the performance of imputation approaches in two simulation studies. Our simulation studies suggests that inference for model parameters directly related to the location of an individual may be more accurate than inference for parameters associated with higher-order processes such as velocity or acceleration. Finally, we apply these methods to analyze a telemetry data set involving northern fur seals (*Callorhinus ursinus*) in the Bering Sea. Supplementary materials accompanying this paper appear online.

Scott, T. L., Yano, K. M., Baker, J., Rickey, M. H., Eames, M., & Fowler, C. W. (2006). *The Northern Fur Seal* (Callorhinus ursinus)*: A Bibliography*. National Marine Fisheries Service Alaska Fisheries Science Center. AFSC Processed Report 2006-05. Retrieved from http://www.afsc.noaa.gov/Publications/ProcRpt/PR%202006-05.pdf

Thus, our objective in assembling this bibliography is to provide a listing of publications that will facilitate access to the scientific and technical literature regarding northern fur seals. It is intended for technical users, especially scientists and managers, but includes materials which might be of use to individuals with other specialized interests. The wealth of information in this bibliography includes the fields of wildlife research, conservation, management, and resource utilization, as well as the more generalized topic of the history of science. Through the publication of this bibliography we want to

promote awareness of the research accomplished on this species as a source of valuable biological information.

Seltenrich, N. (2018). Fur-ious Comeback. *Bay Nature, 18*(3), 8-8. Retrieved from http://commerce.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=130790880&site=ehost-live&scope=site

The article focuses on the return of northern fur seals to the Farallon Islands, which signifies the great conservation success stories in San Francisco Bay Area in California.

Shelden, K. E. W., Agler, B. A., Brueggeman, J. J., Cornick, L. A., Speckman, S. G., & Prevel-Ramos, A. (2014). Harbor Porpoise, *Phocoena phocoena vomerina*, in Cook Inlet, Alaska. *Marine Fisheries Review, 76*(1/2), 22-50. Retrieved from https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/mfr761-22.pdf

Harbor porpoise, Phocoena phocoena vomerina, in Cook Inlet, Alaska, are managed as part of the Gulf of Alaska (GOA) stock. It is not known if this population is distinct from porpoise in the GOA stock found outside Cook Inlet. No longterm dedicated studies of harbor porpoise have occurred in Cook Inlet. The objective here is to provide a summary of occurrence in Cook Inlet derived from archaeological data, anecdotal reports, and systematic surveys. Maps were created for each dataset. For 1,500 years, Alutiiq Eskimo subsistence societies occupied lower Cook Inlet until abandoning the region around 600 A.D. During that time, harbor porpoise exploitation increased and eventually made up over one-third of the faunal remains by number at midden sites. The Dena'ina and Chugach Alutiiq continued porpoise hunting into the period of early contact in the late 1700's, after which there is no mention of continued exploitation. Harbor porpoise were rarely mentioned in expedition accounts collected by naturalists in the late 1800's and early 1900's. Beginning in 1958, pelagic fur seal,*Callorhinus ursinus*, investigators collected cetacean sightings in Alaska waters when seals were not present. However, none of the harbor porpoise sightings occurred in Cook Inlet. With the exception of one net entanglement in upper Cook Inlet in 1956, sightings and strandings (including fisheries bycatch) were not reported in the inlet until the mid- 1970's. Interactions with fisheries factored in a quarter of the stranded animals recovered in Cook Inlet. Systematic surveys of bird and marine mammal populations increased during the 1970's and continued sporadically to the present day. One dedicated harbor porpoise aerial survey conducted in August 1991 estimated the population at 136 (CV = 63.2%), but this survey did not include the shoreline and many of the bays throughout Cook Inlet. An uncorrected abundance of 249 (CV = 60.7%) in June 1998 was based on offshore sightings obtained during beluga whale, Delphinapterus leucas, aerial surveys. The largest abundance estimate, 428 harbor porpoise (95% C.I. 26-830), was obtained during vessel surveys designed to count seabirds in lower Cook Inlet during the summer of 1993. Harbor porpoise sighting rates, abundance, and density estimates often were limited by survey area, effort, research platform, and study design. Therefore, each of these estimates is likely biased downward. In the last decade the region has seen expansion of the Port of Anchorage, proposals to build a bridge crossing Knik Arm, plans to develop mining operations and supporting infrastructure, hydrokinetic energy generation proposals, oil and gas seismic exploration, and water quality effects from urban areas. The overall effect on harbor porpoise within the confines of Cook Inlet cannot be fully determined until we understand the genetic and demographic population structure of this highly mobile and cryptic species.

Sheridan, P., Ferguson, J. W., & Downing, S. L. (2007). *Report of the National Marine Fisheries Service Workshop on Advancing Electronic Tag Technologies and Their Use in Stock Assessment, August 23-25, 2005*. National Marine Fisheries Service. NMFS-F/SPO-82. Retrieved from https://spo.nmfs.noaa.gov/sites/default/files/tm82.pdf

This is a report on a workshop on the use of tags in stock assessments, with chapters on Acoustic Tags, Pop-up Satellite Tags, Radio Tags, Archival Tags, Linkages between Tagging and Environmental Data, and Stock Assessment and Ecosystem Applications.

Shero, M. R., Andrews, R. D., Lestyk, K. C., & Burns, J. M. (2012). Development of the Aerobic Dive Limit and Muscular Efficiency in Northern Fur Seals (*Callorhinus ursinus*). *Journal of Comparative Physiology B-Biochemical Systemic and Environmental Physiology, 182*(3), 425-436. https://doi.org/10.1007/s00360-011-0619-6

Northern fur seal (*Callorhinus ursinus*; NFS) populations have been declining, perhaps due to limited foraging ability of pups. Because a marine mammal's proficiency at exploiting underwater prey resources is based on the ability to store large amounts of oxygen (O-2) and to utilize these reserves efficiently, this study was designed to determine if NFS pups had lower blood, muscle, and total body O-2 stores than adults. Pups (<1-month old) had a calculated aerobic dive limit only similar to 40% of adult females due to lower blood and, to a much greater extent, muscle O-2 stores. Development of the Pectoralis (Pec) and Longissimus dorsi (LD) skeletal muscles was further examined by determining their myosin heavy chain (MHC) composition and enzyme activities. In all animals, the slow MHC I and fast-twitch IIA proteins typical of oxidative fiber types were dominant, but adult muscles contained more (Pec similar to 50%; LD similar to 250% higher) fast-twitch MHC IID/X protein characteristic of glycolytic muscle fibers, than pup muscles. This suggests that adults have greater ability to generate muscle power rapidly and/or under anaerobic conditions. Pup muscles also had lower aerobic and anaerobic ATP production potential, as indicated by lower metabolically scaled citrate synthase, beta-hydroxyacyl CoA dehydrogenase, and lactate dehydrogenase activities (all P values <= 0.001). In combination, these findings indicate that pups are biochemically and physiologically limited in their diving capabilities relative to adults. This may contribute to lower NFS first year survival.

Shero, M. R., Bergfelt, D. R., Testa, J. W., & Adams, G. P. (2018). Pairing Ultrasonography with Endocrinology to Elucidate Underlying Mechanisms of Successful Pregnancy in the Northern Fur Seal (*Callorhinus ursinus*). *General and Comparative Endocrinology, 255*, 78-89. https://doi.org/10.1016/j.ygcen.2017.10.007

Reproductive success is one of the central tenets of conservation management programs, yet the inability to study underlying physiological processes in a minimally-invasive manner and the unpredictable nature of wild animal populations leaves large gaps in our knowledge of factors critical to successful reproduction in wild species. This study integrated ultrasonography of the reproductive tract and analysis of reproductive hormones in 172 northern fur seals (*Callorhinus ursinus*) to identify intrinsic factors associated with reinitiating embryonic growth at the end of diapause. Within the first 3-4 weeks of active gestation, pregnant fur seals (n = 126) had a larger corpus luteum and fewer antral follicles than nonpregnant fur seals, or those still in diapause (n = 46). This suggests that the conceptus drives changes in ovarian status to convey its presence to the female. Morphological changes in the

reproductive tract associated with pregnancy were not reflected in differences in endocrine profiles (estradiol, estrone, progesterone, and relaxin) between pregnant and non-pregnant individuals. Hormone concentrations correlated more strongly with calendar date than with the presence or size of the conceptus, demonstrating that none of these reproductive hormones were reliable markers for early pregnancy diagnosis. Instead, the northern fur seal's long diestrus may serve to reduce the probability of a temporal mismatch between corpus luteum regression and embryo implantation. Indeed, conception rates were high and confirmed rates of pregnancy loss were relatively low (11%). In this study, minimally-invasive ultrasonography was used in wild pinnipeds to detect very early pregnancy (embryonic vesicles >2 mm) in combination with ovarian and endocrine dynamics at the time of embryo implantation, shedding light on mechanisms for maternal recognition of pregnancy. This study is also the first to track whether these same animals carried the embryo to term, by observing fur seals during the birthing season the following year. Data do not support the notion that decreased pregnancy rates or higher pregnancy loss rates are major contributing factors to the northern fur seal's population decline.

Shero, M. R., Lestyk, K. C., Andrews, R. D., & Burns, J. M. (2010). *Development of Oxygen Stores and Muscle in Northern Fur Seals (*Callorhinus ursinus*): Limits on Juvenile Foraging Ability?* https://doi.org/10.1093/icb/icq106

Northern fur seal (*Callorhinus ursinus*) population numbers have been declining, perhaps due to limited foraging ability of juveniles. Since a marine mammal's proficiency at exploiting prey resources in a hypoxic environment is based on the ability to store large amounts of oxygen (O2) and to utilize these reserves efficiently, this study was designed to determine if juvenile Northern fur seals (NFS) had lower blood, muscle, and total body O2 stores than adults. Pups (<1 month old) were found to have calculated aerobic dive limits ~40% those of adult females primarily due to lower blood and, to a much greater extent, muscle O2 stores. Development of the Pectoralis (Pec) and Longissimus dorsi (LD) muscles was further examined by determining their myosin heavy chain (MHC) composition and enzyme activities. In all animals, the oxidative MHC I and IIA fibers were dominant, but adult muscles contained significantly more (Pec: ~150%; LD:~350%) fast-twitch oxidative-glycolytic MHC IID/X protein than pup muscles. This suggests that adults have greater ability to generate muscle power rapidly and/or under anaerobic conditions. Pup muscles also had lower aerobic and anaerobic ATP production potential, as indicated by lower metabolically-scaled citrate synthase, β-hydroxyacyl CoA dehydrogenase, and lactate dehydrogenase activity (all P values <0.001). In combination, these findings support the hypothesis that juveniles are biochemically and physiologically limited in their diving capabilities relative to adults. This may contribute to lower first year survival.

Shulezhko, T. S., Permyakov, P. A., Ryazanov, S. D., & Burkanov, V. N. (2018). Bigg's Killer Whales (*Orcinus orca*) in the Kuril Islands. *Aquatic Mammals, 44*(3), 267-278. https://doi.org/10.1578/am.44.3.2018.267

This article summarizes our observations from land and vessels of transient (Bigg's) ecotype killer whales (Orcinus orca) in the Kuril Islands during the period 2002 to 2015. We also conducted a review of published information on the occurrence of these killer whales in the Kuril Islands. During 12 years of vessel observations, no cases of killer whales hunting marine mammals were observed. During land-based observations, Bigg's killer whales were observed from land near two Kuril Islands: Brat Chirpoev Island and Dolgaya Rock. In total, eight instances of Bigg's killer whale attacks on pinnipeds were observed: seven were directed toward Steller sea lions (Eumetopias jubatus) and one toward northern

fur seals (*Callorhinus ursinus*). The behavior of killer whales during hunting corresponded to published descriptions of the tactics used by killer whales in other regions. According to the photo identification analysis in July 2009 and July 2011, the same group of four Bigg's killer whales was observed near Brat Chirpoev Island. These individuals were not found in any of the published catalogues of killer whales inhabiting the North Pacific. According to both the information collected by us and that in published literature, the predominant ecotype of killer whales summering in the Kuril Islands is the fish-eating (resident) ecotype.

Siddon, E., & Zador, S. (2017). *Ecosystem Considerations 2017 Status of the Eastern Bering Sea Marine Ecosystem*. National Marine Fisheries Service. Retrieved from https://repository.library.noaa.gov/view/noaa/19464

The eastern Bering Sea was characterized by moderately warm conditions in 2017. The PDO remained positive, although the magnitude decreased. Weak La Niña conditions are predicted for the winter of 2017-2018. Sea ice extended over the southern shelf during the winter and spring and resulted in an extensive, although narrow, cold pool during summer 2017. Acoustic estimates of euphausiids from the 2016 summer trawl survey were the lowest in the time series. RZA assessments showed comparable euphausiid abundances over the middle shelf between 2016 and 2017. The biomass of motile epifauna remains above the long-term mean, with an increasing trend in the past 5 years. Brittle star biomass remains above average, with a slight (9%) decline from 2016–2017. Urchins, sand dollars, and cucumbers are also above their long-term mean, with a 12% increase from 2016–2017. King and tanner crabs decreased (28% and 21%, respectively). The biomass of benthic foragers dipped in 2015, but has remained at a near-average level in2016 and 2017. The decline in 2015 was due to a 25% decline in Northern rock sole, which continued to decline in 2017 (by 7.5%). The overall return to an average level was due to a 112% increase in “miscellaneous flatfish” (e.g., Bering flounder, Longhead dab, Slender sole, Starry flounder) and 24% increase in Flathead sole between 2016 and 2017. The biomass of pelagic foragers remains at its 34-year mean in 2017. A large increase in Pacific herring was off-set by a decrease in Capelin. The biomass of fish apex predators declined, largely driven by a 35% reduction in Pacific cod biomass and 11% reduction in Arrowtooth flounder biomass. The multivariate seabird breeding index remains below the long term mean, indicating that seabirds bred later and less successfully in 2017. Seabirds showed overall poor reproductive success at St. Paul and St. George Islands in 2017, with the exception of red-faced cormorants. Northern fur seal pup production for St. Paul Island in 2016 remained low with a decrease of 12.1% from 2014. Pup production on St. George Island increased 8.2% between 2014 and 2016. Seafloor habitat disturbance due to fishing gear (pelagic and non-pelagic trawl, longline, and pot) shows interactions have remained below the long-term average since 2011.

Sinclair, E. H., Vlietstra, L. S., Johnson, D. S., Zeppelin, T. K., Byrd, G. V., Springer, A. M., . . . Hunt, G. L., Jr. (2008). Patterns in Prey Use among Fur Seals and Seabirds in the Pribilof Islands. *Deep-Sea Research Part II-Topical Studies in Oceanography, 55*(16-17), 1897-1918. https://doi.org/10.1016/j.dsr2.2008.04.031

We explored correlation in diet trends for five piscivorous predators that reproduce on the Pribilof Islands as illustrative of the shifting structure of the Bering Sea ecosystem. We evaluated the size and species of prey consumed by adult female and juvenile northern fur seals (*Callorhinus ursinus*) and adults and chicks of black-legged kittiwakes (Rissa tridactyla), red-legged kittiwakes (Rissa brevirostris),

thick-billed murres (Uria lomvia), and common murres (Uria aalge) from data collected between July and October 1960-2000. Sample sources included stomachs from seals and seabirds collected on pelagic foraging grounds in the eastern Bering Sea, seal scats from rookeries and seabird regurgitations and whole prey from nest sites on St. Paul and St. George Islands of the Pribilof Island archipelago. Typical prey included small fish and invertebrates (<= 20 cm for seals and <= 12 cm for seabirds) that concentrate along frontal boundaries of the continental shelf/slope and in the epi-pelagic zone. Squids and fishes including walleye pollock (Theragra chalcogramma), capelin (Mallotus villosus), and sand lance (Ammodytes hexapterus) were variably important in the diet of all five predators. Some prey, such as capelin, were principal in predator diets during the 1960s (seals) and into the early 1980s (seabirds), but declined or disappeared from all predator diets thereafter while others, such as walleye pollock, occurred with increasing frequency from the 1970s forward. As the number of individuals consuming walleye pollock increased, the overall volume of pollock in seabird diets declined. This decline was coincident with a decrease in the age and body size of pollock consumed by both seabirds and fur seals. Squid and pollock were negatively correlated in the diets of their primary consumers, northern fur seals (Pearson's coefficient -0.71, p = 0.016) and thick-billed murres (Pearson's coefficient = -0.74, p = 0.015) from the 1970s forward. Inter-island variation in diet was evident to varying degrees for all predators, with a prevalence of fish on St. Paul Island and invertebrates on St. George Island. Bayesian time-series analysis of synthesized data described significant temporal cross-correlation in diet among northern fur seals, red- and black-legged kittiwakes, and thick-billed murres. For all correlated predators except common murres, beta-binomial modeling indicated that trends in the occurrence of four of the five primary prey (sand lance, capelin, squid, and pollock) evaluated, were significantly associated with eastern Bering Sea time-series trends in sea surface temperature, ice retreat or a combination of both. Data synthesis highlighted potential competition and a scenario for the effects of an altered prey field on the population stability of predators. The association between correlated diet changes among predators and indices of oceanographic shifts in the 1970s and the 1990s allow scrutiny of hypotheses concerning causal mechanisms in population declines.

Sinclair, E. H., York, A. E., & Antonelis, G. A. (2011). Otolith Size and Location in Digestive Tracts of Northern Fur Seals (*Callorhinus ursinus*): Implications for Dietary Interpretations. *Marine Mammal Science, 27*(2), 421-430. https://doi.org/10.1111/j.1748-7692.2010.00418.x

Walleye pollock (*Theragra chalcogramma*) otoliths (n = 2,706) recovered from stomachs, small intestines, and colons of 43 northern fur seals (*Callorhinus ursinus*) were evaluated for size and wear by location in the digestive tract. Pollock fork length was regressed on otolith length after correction for erosion, and age was estimated from the calculated body size. Age-1+ pollock otoliths (>= 6.3-mm length) were concentrated in stomachs while age-0 otoliths (< 6.2-mm length) were concentrated in colons. Less than 10% of otoliths were found in the small intestines. Pollock age decreased with progression along seal gastrointestinal tracts. Otolith quality increased along gastrointestinal tracts in numbers >= 20, which was typical of age-0 otoliths recovered from colons. Otolith distribution by age and quality along gastrointestinal tracts suggests that small (< 12 cm) schooling prey are consumed in large volume and passed as a bolus rapidly through the digestive tract before significant erosion of bony remains occurs; while larger prey are eaten in smaller volume and subjected to otolith erosion due to longer retention in the stomach. Our results illustrate the importance of multiple sampling strategies to comprehensively represent prey size in pinniped diet.

Skinner, J. P., Burkanov, V. N., & Andrews, R. D. (2012). Influence of Environment, Morphology, and Instrument Size on Lactating Northern Fur Seal *Callorhinus ursinus* Foraging Behavior on the Lovushki Islands, Russia. *Marine Ecology Progress Series, 471*, 293-308. https://doi.org/10.3354/meps10038

Food limitation may be one of the causes of declines in northern fur seal populations on the Pribilof Islands. This hypothesis could be tested by comparing foraging behavior from decreasing Pribilof fur seal populations and an increasing population, such as on the Lovushki Islands, Russia, but factors other than prey availability that differ between sites may also influence behavior. Therefore, we evaluated such factors, including lunar cycle, weather, seal body size, and size of recording instruments, by studying 41 lactating northern fur seals on Lovushki Island over 4 summer breeding seasons using instrument packages of various sizes. With greater moonlight, seals increased foraging trip duration, dive depth, dive duration, and time spent on the bottom of dives but decreased descent rate and diving bout duration. Larger females made shorter shore visits, spent a greater proportion of time at sea diving, and had longer dive bouts than smaller females. Tags with larger frontal surface areas and higher drag caused seals to dive longer and to descend and ascend faster during dives but did not affect foraging trip durations or mass change rates. Seals, therefore, appeared capable of compensating for instrument effects on the scale of individual dives. Although lactating seals from Lovushki Island appeared to spend less foraging effort than seals from the Pribilofs, future studies should control for methodological factors and local environmental conditions before concluding whether food limitation could explain differences in population trajectories.

Skinner, J. P., Mitani, Y., Burkanov, V. N., & Andrews, R. D. (2014). Proxies of Food Intake and Energy Expenditure for Estimating the Time-Energy Budgets of Lactating Northern Fur Seals *Callorhinus ursinus*. *Journal of Experimental Marine Biology and Ecology, 461*, 107-115. https://doi.org/10.1016/j.jembe.2014.08.002

Northern fur seal *Callorhinus ursinus* numbers on the Pribilof Islands have been in decline over the past two decades while numbers have increased at other sites, such as in the Kuril Islands in Russia and at Bogoslof Island in the Aleutian Islands. Although these divergent abundance trends remain unexplained, the potential influence of food limitations could be studied by examining the time-energy budgets of individual lactating fur seals. Our goal was to find suitable proxies for food intake and energy expenditure of lactating seals so that we might provide time and energy budgets of an increasing population on Lovushki Island, Russia that could be compared with the declining Pribilof fur seal population. Between 2005 and 2008, we outfitted 13 lactating fur seals with instruments that collected data on depth, external temperature, stomach temperature, GPS location, and acceleration. With these data we investigated proxies for 1) food intake, including time spent at sea, time spent diving, vertical travel distance (VTD), wiggle behavior, and changes in stomach temperature; 2) involuntary costs, including indices of basal metabolism (BMCI), thermal exposure, and instrument hydrodynamic drag (TAG); and 3) locomotive costs, including overall dynamic body acceleration (ODBA), horizontal travel distance, and flipper strokes. We also considered an index of work (WORK) calculated using horizontal distance, ODBA, and seal mass. Multimodel inference was used to determine which proxies best described changes in seal mass at sea when considering two sets of candidate models that differed by excluding or including locomotive costs (n = 13 and n = 7, respectively). Seal mass changes were positively associated with VTD and TAG and negatively associated with BMCI ($p < 0.001$, adjusted $R\text{-}2 = 0.84$) when locomotive proxies were excluded. With locomotive proxies considered, models were improved and mass changes were best described by being positively related to VTD and negatively

associated with WORK ($p < 0.001$, adjusted R-2 = 0.95). We suggest that relative energy budgets for individual lactating northern fur seals could be compared using proxies for energetics that are easily monitored with standard data logging instruments.

Small, R. J., Boveng, P. L., Byrd, G. V., & Withrow, D. E. (2008). Harbor Seal Population Decline in the Aleutian Archipelago. *Marine Mammal Science, 24*(4), 845-863. https://doi.org/10.1111/j.1748-7692.2008.00225.x

Populations of Steller sea lions, northern fur seals, and northern sea otters declined substantially during recent decades in the Bering Sea and Aleutian Islands region, yet the population status of harbor seals has not been assessed adequately. We determined that counts obtained during skiff-based surveys conducted in 1977-1982 represent the earliest estimate of harbor seal abundance throughout the Aleutian Islands. By comparing counts from 106 islands surveyed in 1977-1982 (8,601 seals) with counts from the same islands during a 1999 aerial survey (2,859 seals), we observed a 67% decline over the similar to 20-yr period. Regionally, the largest decline of 86% was in the western Aleutians (n = 7 islands), followed by 66% in the central Aleutians (n = 64 islands), and 45% in the eastern Aleutians (n = 35 islands). Harbor seal counts decreased at the majority of islands in each region, the number of islands with > 100 seals decreased similar to 70%, and the number of islands with no seals counted increased similar to 80%, indicating that harbor seal abundance throughout the Aleutian Islands was substantially lower in the late 1990s than in the 1970s and 1980s.

Spraker, T. R., & Lander, M. E. (2010). Causes of Mortality in Northern Fur Seals (*Callorhinus ursinus*), St. Paul Island, Pribilof Islands, Alaska, 1986-2006. *Journal of Wildlife Diseases, 46*(2), 450-473. https://doi.org/10.7589/0090-3558-46.2.450

To determine whether infectious diseases might have contributed to the present-day decline of northern fur seals (*Callorhinus ursinus*), preweaned pups (n=2,735), subadult males (n=98), and adults (n=179) were examined postmortem from 1986 to 2006 on St. Paul Island, Alaska. Gross necropsy findings and histologic lesions were used to determine causes of death. Five general categories of mortality were identified for pups: emaciation (1,454 pups, 53%), trauma (497 pups, 18%), perinatal mortality (516 pups, 19%), infectious diseases (82 pups, 3%), and miscellaneous causes (186 pups, 7%). A condition of unknown etiology characterized by multifocal necrotizing myopathy and cardiomyopathy was found in 92 pups. Thirty-three congenital anomalies were identified in 49 pups, including a rare multicentric ganglioneuroblastoma. General linear models were used to examine change in pup mortality and condition (i.e., pup mass) over time. The prevalence of perinatal mortality appeared to increase during the study and relative to past reports. Trauma and infectious conditions appeared to decrease slightly from 1986 to 2006. Although relatively stable during this investigation, emaciation was greater than that reported for past studies. Emaciated pups weighed less than expected during 1988, 1996, and 2004 and more than expected during 1987, 1989, 1990, and 1994 ($P <= 0.003$). Average annual weights for all other categories of mortality did not change significantly from 1986 to 2006. Fatal conditions for subadult males included hyperthermia, blunt trauma, entanglement, and bite wounds; nonfatal conditions included seizures, orange discoloration of the blubber, neoplasia, and parasitism. Causes of mortality for most adults included bite wounds with cellulitis and secondary infections, pulmonary edema, dystocia, blunt trauma, and neoplasia. We found no evidence to implicate infectious diseases as a cause in the recent decline of northern fur seals.

Steinetz, B., Lasano, S., De Haas van Dorsser, F., Glickman, S., Bergfelt, D., Santymire, R., . . . Swanson, W. (2009). Relaxin Concentrations in Serum and Urine of Endangered and Crazy Mixed-up Species. *Annals of the New York Academy of Sciences, 1160*, 179-185. https://doi.org/10.1111/j.1749-6632.2008.03824.x

The human population explosion has pushed many mammalian wildlife species to the brink of extinction. Conservationists are increasingly turning to captive breeding as a means of preserving the gene pool. We previously reported that serum immunoactive relaxin provided a reliable means of distinguishing between true and pseudopregnancy in domestic dogs, and this method has since been found to be a reliable indicator of true pregnancy in endangered Asian and African elephants and Sumatran rhinoceroses. Our canine relaxin radioimmunoassay (RIA) has now been adapted and validated to measure relaxin in the serum and urine of felids, including domestic and wild species. Moreover, a commercially available canine serum relaxin kit (Witness® Relaxin Kit; Synbiotics, San Diego, CA), has been adapted for reliable detection of relaxin in urine of some felid species. Our porcine relaxin RIA has also been utilized to investigate the role of relaxin in reproductive processes of the spotted hyena, a species in which the female fetuses are severely masculinized in utero. Indeed, this species might well now be extinct were it not for the timely secretion of relaxin to enable copulation and birth of young through the clitoris. Additional studies have suggested relaxin may be a useful marker of pregnancy in the northern fur seal and the maned wolf (the former species has been designated as "depleted" and the latter as "near threatened"). Given appropriate immunoassay reagents, relaxin determination in body fluids thus provides a powerful tool for conservationists and biologists investigating reproduction in a wide variety of endangered and exotic species.

Sterling, J. T. (2009). *Northern Fur Seal Foraging Behaviors, Food Webs, and Interatctions with Oceanographic Features in the Eastern Bering Sea.* (Ph.D.), University of Washington, Seattle, WA. Retrieved from https://search.proquest.com/openview/68a0d476987c13337b61ee4c256e0527/1?cbl=18750&diss=y&pq-origsite=gscholar

Foraging patterns of juvenile male and adult female northern fur seals (Callorhinus ursinus) captured on two St. Paul Island, AK rookeries and haul-out sites were examined during contrasting years of eastern Bering Sea shelf and basin domain oceanography and walleye pollock (Theragra chalcogramma) stock structure, distribution, and abundance. Satellite-dive recorders, time-depth recorders, and satellite transmitters were employed to monitor and record fur seal movements and their dive depths while on foraging trips. Juvenile male fur seals spent more time and had more dives outside those habitats most frequently used by adult females, but spent similar amounts of time and had similar numbers of dives as adult females within their foraging habitats. Diets were similar between the sexes suggesting that juvenile males were competing with adult females for prey, but due to differential constraints imposed on females to nourish their pups, males could travel farther and for longer while searching for prey. Fur seals spent significantly more time in some years foraging in the basin domain and mostly along anticyclonic eddy edges. However, autumnal storms in 2005 and 2006 disrupted basin foraging causing fur seals to spend more time at sea or shift their distribution from the basin domain to the middle and outer shelf domains. When foraging on the shelf, fur seals responded to the presence of the cold pool by spending more time in the outer domain and occupying similar thermal regimes to those preferred by walleye pollock. In addition, dive patterns were consistent with the dominant year class of walleye pollock and its age-related behavior in the vertical water column. These parallel behaviors between fur

seals and walleye pollock prompted and expanded the analysis to revisit previous reports of fur seal diet, adult female trip durations, and pup weights and examine their relationship to the estimated abundance of walleye pollock. In years with above average numbers of age-1-5 walleye pollock, fur seals showed a higher frequency of occurrence of walleye pollock in their diet, adult females had shorter trips to sea, and pups weights were heavier. Thus, the usage of satellite telemetry and dive recorders on juvenile male and adult female northern fur seals revealed important biophysical relationships, supported historical observations, and generated new ideas to consider when examining the current northern fur seal population decline on the Pribilof Islands.

Sterling, J. T., Fadely, B. S., Ream, R. R., Alford, M. H., Lee, C. M., & Gelatt, T. S. (2006). *Enlisting the Northern Fur Seal* (Callorhinus ursinus) *as an Oceanographic Probe.* Paper presented at the Ocean Sciences Meeting. Retrieved from https://search.proquest.com/docview/19623259/D9C7A761C4284CFFPQ/1?accountid=28258

This study utilized northern fur seals to help define and guide research on small and large scale oceanographic processes. Fur seals breeding on islands in the Bering Sea segregate summer foraging areas and undergo seasonal migrations into the North Pacific Ocean, and thus interact with a variety of distinct oceanographic habitats. By attaching satellite transmitters and archival tags to fur seals we identified oceanographic features and speculate on their ecological significance. Fur seal behavior measured by these instruments identified several habitat-edge areas presumably important for successful foraging such as the western edge of the Bering Sea "cold pool", edges of cyclonic and anticyclonic eddies, and the edge of the sub-arctic boundary of the transition zone chlorophyll front. In addition, interannual variation in fur seal migratory patterns may correspond to large scale oceanographic differences in the North Pacific Ocean. These results advance our knowledge of northern fur seal foraging ecology and support the idea that marine predators can be enlisted to direct biological and oceanographic sampling. It is also now possible to remotely guide autonomous underwater vehicles (AUVs) to obtain additional sampling of features identified by marine predator behavior. This concept was opportunistically evaluated by integrating remotely-sensed (sea surface height and chlorophyll a) and in-situ data collected by two AUVs (Seagliders) with northern fur seal migratory movement patterns. The results support some of the speculation on the ecological significance of the previously mentioned oceanographic features, but also demonstrate the mutual benefits across disciplines of using marine top- predators to direct biological and oceanographic sampling.

Sterling, J. T., Ream, R. R., Johnson, D. S., & Gelatt, T. S. (2007, October 2007). *The Role of Physical Processes in the Summertime Life of the Northern Fur Seal.* Paper presented at the PICES 16th Annual Meeting. Retrieved from https://search.proquest.com/docview/20706870/ADA907620B84002PQ/1?accountid=28258

In the eastern Bering Sea, the extent and duration of winter sea ice, cyclonic and anticyclonic eddies, episodic storm systems, and on-shelf physical processes play a significant role in the timing and distribution of the spring bloom and in sustaining primary and secondary production throughout the summer. We examined the hypothesis that these oceanographic and atmospheric processes further influence the spatial and temporal dynamics of food webs supporting northern fur seals (*Callorhinus ursinus*) resulting in seasonal and inter-annual variability in fur seal foraging areas. Satellite telemetry data collected from two rookeries (Reef and Vostochni) on St. Paul Island, AK over 8 seasons was modeled at hourly intervals. Storm events and cold and warm years were identified, and remotely

sensed sea surface height data, walleye pollock biomass, and on-shelf bottom temperatures were spatially and temporally joined with seal locations. Findings indicate that in cold years the spatial distribution of the "cold pool", a seasonal product of the winter ice cover, can occupy similar to 46% of Vostochni foraging habitat causing walleye pollock and in turn fur seals to shift westward into warmer waters. In oceanic waters, seals foraged mostly along the edges of eddies. Both oceanic and shelf foragers changed their foraging distribution after strong storms passed through the region - shelf foragers shifted northward while oceanic foragers became more dispersed and spent less time foraging at eddy edges. Consequently, meteorological variability and coupled physical oceanographic processes in the Bering Sea influence both the distribution and foraging success of northern fur seals.

Sterling, J. T., Springer, A. M., Iverson, S. J., Johnson, S. P., Pelland, N. A., Johnson, D. S., . . . Bond, N. A. (2014). The Sun, Moon, Wind, and Biological Imperative-Shaping Contrasting Wintertime Migration and Foraging Strategies of Adult Male and Female Northern Fur Seals (*Callorhinus ursinus*). *PLoS One, 9*(4). https://doi.org/10.1371/journal.pone.0093068

Adult male and female northern fur seals (*Callorhinus ursinus*) are sexually segregated in different regions of the North Pacific Ocean and Bering Sea during their winter migration. Explanations for this involve interplay between physiology, predator-prey dynamics, and ecosystem characteristics, however possible mechanisms lack empirical support. To investigate factors influencing the winter ecology of both sexes, we deployed five satellite-linked conductivity, temperature, and depth data loggers on adult males, and six satellite-linked depth data loggers and four satellite transmitters on adult females from St. Paul Island (Bering Sea, Alaska, USA) in October 2009. Males and females migrated to different regions of the North Pacific Ocean: males wintered in the Bering Sea and northern North Pacific Ocean, while females migrated to the Gulf of Alaska and California Current. Horizontal and vertical movement behaviors of both sexes were influenced by wind speed, season, light (sun and moon), and the ecosystem they occupied, although the expression of the behaviors differed between sexes. Male dive depths were aligned with the depth of the mixed layer during daylight periods and we suspect this was the case for females upon their arrival to the California Current. We suggest that females, because of their smaller size and physiological limitations, must avoid severe winters typical of the northern North Pacific Ocean and Bering Sea and migrate long distances to areas of more benign environmental conditions and where prey is shallower and more accessible. In contrast, males can better tolerate often extreme winter ocean conditions and exploit prey at depth because of their greater size and physiological capabilities. We believe these contrasting winter behaviors 1) are a consequence of evolutionary selection for large size in males, important to the acquisition and defense of territories against rivals during the breeding season, and 2) ease environmental/physiological constraints imposed on smaller females.

Stewardson, C. L., Prvan, T., & Ritchie, R. J. (2010). Bacular Measurements for Age Determination and Growth in the Male South African Fur Seal, *Arctocephalus pusillus pusillus* (Pinnipedia: Otariidae). *Proceedings of the Linnean Society of New South Wales, 131*, 141-157. Retrieved from https://www.biodiversitylibrary.org/item/110718#page/147/mode/1up

Morphology, relative size and growth of the baculum in 103 South African fur seals, Arctocephalus pusillus pusillus, from the Eastern Cape coast of South Africa are described. Bacular measurements (n = 8 linear variables and mass) were examined In relation to standard body length (SBL), bacular length (BL) and chronological age (y) using linear regression. Animals ranged from < 1 month to >= 12 y. Bacular

shape was most similar to *Callorhinus ursinus* (Northern fur seal) and Zalophus californianus (California sea lion). For the range of ages represented in this study, the baculum continued to increase in size until at least 10 y; with growth slowing between 8-10 y, when social maturity (full reproductive capacity) is attained. Growth in bacular length (BL), distal height and bacular mass peaked at 8 y; middle shaft height and distal shaft height peaked at 9 y; proximal height, proximal width, distal width and proximal shaft height peaked at 10 y. In the largest animal (age >= 12 y), maximum bacular length was 139 mm and mass 12.5 g. Relative to SBL, bacular length (BL) increased rapidly in young animals, peaked at 9 y (6.9%), and then declined. Bacular mass and distal height expressed greatest overall growth, followed by proximal height, proximal shaft height and bacular length. At 9 y, mean bacular length and mass was 117 +/- 2.7 (+/- SE, n = 4) mm and 7 +/- 0.7 (4) g; growth rates in bacular length and mass were 311% and 7125% (relative to age zero), and 5% and 27% (between years); and bacular length (BL) was about 6.9% of SBL. For all males >= 12 months, most bacular variables grew at a faster rate than SBL and BL. Exceptions included proximal width which was isometric to SBL; distal width and distal shaft height which were isometric to bacular length; and proximal width which was negatively allometric relative to BL. Bacular length (BL) was found to be a useful predictor of SBL and seal age group (pup, yearling, subadult, adult), but only a 'rough indicator' of absolute age.

Testa, J. W. (2007). *Fur Seal Investigations, 2004-2005*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-174. Retrieved from https://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-174.pdf

Researchers from the Alaska Fisheries Science Center's National Marine Mammal Laboratory conduct field investigations on the population status of northern fur seals (*Callorhinus ursinus*) annually on the Pribilof Islands, Bogoslof Island in the eastern Bering Sea, and on San Miguel Island off the coast of California. The estimate of the total stock for the Pribilof Islands population in 2004 was ~756,000. The approximate total stock size for the United States was 823,000 northern fur seals. In 2004 and 2005, population parameters monitored on the Pribilof Islands included the size of the subsistence harvest and the number of adult male fur seals.

Testa, J. W. (2008). *Fur Seal Investigations, 2006-2007*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-188. Retrieved from http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-188.pdf

Researchers from the Alaska Fisheries Science Center's National Marine Mammal Laboratory conduct field investigations on the population status of northern fur seals (Callorhinus ursinus) annually on the Pribilof Islands, Bogoslof Island in the eastern Bering Sea, and on San Miguel Island off the coast of California. The estimate of the total stock for the Pribilof Islands population in 2006 was ~678,000. The approximate total stock size for the United States was 744,000 northern fur seals. In 2006 and 2007, population parameters monitored on the Pribilof Islands included the size of the subsistence harvest and the number of adult male fur seals.

Testa, J. W. (2011). *Fur Seal Investigations, 2008-2009*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-226. Retrieved from http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-226.pdf

Researchers from the Alaska Fisheries Science Center's National Marine Mammal Laboratory conduct field investigations on the population status of northern fur seals (*Callorhinus ursinus*) on the Pribilof Islands, Bogoslof Island in the eastern Bering Sea, and on San Miguel Island off the coast of California. This report summarizes these monitoring efforts. In 2008 and 2009, population parameters monitored on the Pribilof Islands included the size of the subsistence harvest and the number of adult male fur seals.

Testa, J. W. (2012). *Fur Seal Investigations, 2010-2011*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-241. Retrieved from http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-241.pdf

Researchers from the Alaska Fisheries Science Center's National Marine Mammal Laboratory conduct field investigations on the population status of northern fur seals (*Callorhinus ursinus*) on the Pribilof Islands, Bogoslof Island in the eastern Bering Sea, and on San Miguel Island off the coast of California. This report summarizes these monitoring efforts in 2010 and 2011. Population parameters monitored on the Pribilof Islands included the size of the subsistence harvest and the number of adult male fur seals.

Testa, J. W. (2013). *Fur Seal Investigations, 2012*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-257. Retrieved from http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-257.pdf

Researchers from the Alaska Fisheries Science Center's National Marine Mammal Laboratory conduct field investigations on the population status of northern fur seals (*Callorhinus ursinus*) on the Pribilof Islands, Bogoslof Island in the eastern Bering Sea, and on San Miguel Island off the coast of California. This report summarizes these monitoring efforts in 2012, and presents an introduction to ongoing demographics research based on tagged animals on the Pribilof Islands that began in 2007.

Testa, J. W. (2016). *Fur Seal Investigations, 2013-2014*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-316. https://doi.org/10.7289/V5/TM-AFSC-316

Researchers from the Alaska Fisheries Science Center's National Marine Mammal Laboratory conduct field investigations on the population status of northern fur seals (*Callorhinus ursinus*) on the Pribilof Islands (St. Paul and St. George) and Bogoslof Island in the eastern Bering Sea, and on San Miguel Island and the Farallon Islands off the coast of California. This report summarizes these monitoring efforts in 2013-2014. Population parameters monitored in 2013 and 2014 on the Pribilof Islands included the size of the subsistence harvest and the number of adult male fur seals. Biennial estimates of the number of pups including mortality, size, and sex ratio were made in 2014.

Testa, J. W. (2018). *Fur Seal Investigations, 2015-2016*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-375. https://doi.org/10.7289/V5/TM-AFSC-375

Researchers from the Alaska Fisheries Science Center's National Marine Mammal Laboratory conduct field investigations on the population status of northern fur seals (*Callorhinus ursinus*) on the Pribilof

Islands (St. Paul and St. George) and Bogoslof Island in the eastern Bering Sea, and on San Miguel Island and the Farallon Islands off the coast of California. This report summarizes these monitoring efforts in 2015-2016. Population parameters monitored in 2015 and 2016 on the Pribilof Islands included the size of the subsistence harvest and the number of adult male fur seals. Biennial estimates of the number of pups, including mortality, size, and sex ratio were made in 2016.

Testa, J. W., Adams, G. P., Bergfelt, D. R., Johnson, D. S., Ream, R. R., & Gelatt, T. S. (2010). Replicating Necropsy Data without Lethal Collections: Using Ultrasonography to Understand the Decline in Northern Fur Seals. *Journal of Applied Ecology, 47*(6), 1199-1206. https://doi.org/10.1111/j.1365-2664.2010.01888.x

Many valuable contributions to the biology and conservation of harvested or previously harvested species have come from examination of specimens obtained by lethal collections. The northern fur seal *Callorhinus ursinus* on the Pribilof Islands, Alaska, has a long history of exploitation, including a large (> 320 000) experimental harvest of females from 1955 to 1968 when the population was at a peak (similar to 2 million seals). The decline caused by this harvest was followed in 1977 by another major decline, apparently unrelated to harvest, that has recently accelerated. 2. To obtain current reproductive data that could be compared directly with historic estimates, we used imaging ultrasonography to estimate pregnancy rate in 171 adult fur seals captured on St. Paul Island, Alaska, in November, near the end of embryonic diapause. A modified logistic regression of pregnancy by date was used to estimate asymptotic pregnancy rate; a Bayesian hierarchical model based on date and size of embryonic vesicle was also used to account for pregnancies that were not detectable on the date of examination. 3. Pregnancy rate was high [0.85 (SE = 0.05), 0.88 (SE = 0.05) or 0.92 (SE = 0.04), depending on method] and there was little statistical support for the hypothesis that the current pregnancy rate is lower than the pre-decline rate (0.84, SE = 0.012) or contributing significantly to the present decline. 4. Synthesis and applications. Further study on intrauterine losses and pupping rates is necessary and ongoing, but reproductive ultrasonography provided an early comparative assessment important for the conservation management of this fur seal stock. It narrows the search for demographic and ecological causes of the population decline and allows research priorities to evolve in response to the likelihood of those causes. The field and analytic methods described have application to population assessments of other mammalian species, including those considered threatened or serving as ecosystem indicators.

Tomita, N., Kohyama, K., Koido, T., & Takemura, A. (2011). Effect of Photoperiod on Gonadal Steroid Hormone Levels and Reproductive Cycles of Northern Fur Seals (*Callorhinus ursinus*). *Mammal Study, 36*(4), 223-228. https://doi.org/10.3106/041.036.0405

The northern fur seal (*Callorhinus ursinus*) is a migratory marine mammal belonging to the family Otariidae that breeds on the islands in the North Pacific Ocean, Bering Sea, Sea of Okhotsk, and near the coast of California during summer (Peterson 1968; Gentry 1998). Their reproduction is characterized by extreme polygyny and highly synchronized annual cycles that are concentrated around the boreal summer (Peterson 1968; Trites 1992; Gentry 1998). Females arrive at breeding sites in early July, give birth within 36 hours, and then enter estrus and copulate within a few days (Peterson 1968). Although active gestation persists for approximately eight months, the total duration of gestation period is approximately one year because of the embryonic diapause (delayed implantation), which accurately synchronizes the annual reproductive cycle (Craig 1964; Boyd 1991). Males return to the breeding sites

approximately one month before females, establish their territories in the breeding area, and maintain breeding activities for approximately two months (Peterson 1968).

Towell, R., & Ream, R. (2015). *Bogoslof Island Research: 2015*. National Marine Fisheries Service Alaska Fisheries Science Center. AFSC Quarterly Report. Retrieved from http://www.afsc.noaa.gov/Quarterly/JAS2015/divrptsNMML2.htm

Bogoslof Island is a small, remote, volcanic island in the Bering Sea, approximately 60 nautical miles west of Dutch Harbor, Alaska. Despite its small size, Bogoslof Island teems with wildlife and is home to seabird, Steller sea lion, and northern fur seal breeding colonies. Northern fur seals only colonized the island relatively recently, but the species has thrived there over the past three decades. From 1976 to 1982, small numbers of northern fur seals were documented on Bogoslof Island, with only two and three pups recorded in 1980 and 1982, respectively. However, despite significant volcanic activity on Bogoslof Island in 1992, the growth of the northern fur seal population on the island has been rapid and continuous since then, resulting in dense aggregations that are typical for the species at other established breeding colonies. The most recent northern fur seal pup production estimate for Bogoslof Island in 2011 was 22,905 pups.

Towell, R. G. (2007). *Population Dynamics of Northern Fur Seals (Callorhinus ursinus) on the Pribilof Islands, Alaska.* (M.S. thesis), University of Washington, Seattle, WA. Retrieved from https://alliance-primo.hosted.exlibrisgroup.com/permalink/f/kjtuig/CP71136412310001451

[NO ABSTRACT AVAILABLE]

Towell, R. G., Ream, R. R., & York, A. E. (2006). Decline in Northern Fur Seal (*Callorhinus ursinus*) Pup Production on the Pribilof Islands. *Marine Mammal Science, 22*(2), 486-491. https://doi.org/10.1111/j.1748-7692.2006.00026.x

The article explains the lack of population recovery after the cessation of the harvest of female population of northern fur seals on the Pribilof Islands in Alaska. The decline in pup production on the Pribilof Islands was substantial during 1998-2004. However, the magnitude of this recent decline is particularly noteworthy given the population dynamics observed over the past three decades. It is unclear why pup production has declined on the Pribilof Islands. Fur seal condition, survival, or reproductive rates may have been affected by factors such as climate change.

National Oceanic and Atmospheric Administration, & Aleutian Pribilof Islands Association (Eds.). (2008). *St. Paul Island, Seal Islands National Historic Landmark*.

[NO ABSTRACT AVAILABLE]

, National Oceanic and Atmospheric Administration, & National Marine Fisheries Service (Eds.). (2006). *Draft Conservation Plan for the Eastern Pacific Stock of the Northern Fur Seal* (Callhorinus ursinus).

[NO ABSTRACT AVAILABLE]

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, St. George Tanaq Alaska, Aleutian Pribilof Islands Association, & National Park Service (Eds.). (2008). *St. George Sealing Plant, Pribilof Islands: Seal Islands National Historic Landmark*. [Alaska?]: NOAA, Aleutian Pribilof Islands Assn.

[NO ABSTRACT AVAILABLE]

Ungurean, G., & Rattenborg, N. C. (2018). Neuroethology: Fur Seals Don't Lose Sleep over REM Lost at Sea. *Current Biology, 28*(12), R699-R701. https://doi.org/10.1016/j.cub.2018.05.006

Northern fur seals forego large amounts of rapid eye movement (REM) sleep when sleeping in water, but remain healthy and do not recover this loss once back on land, challenging current theories for the function of REM sleep.

Volodin, I. A., Kalashnikova, M. V., Klinkova, E. S., Goltsman, A. M., Goltsman, M. E., & Kruchenkova, E. P. (2013). Structure of Arctic Fox (*Alopex lagopus beringensis*) Colonies in the Northern Extremity of Bering Island. *Biology Bulletin, 40*(7), 614-625. https://doi.org/10.1134/s106235901307008x

Data on the spatial structure of an Arctic fox (Alopex lagopus beringensis) colony were obtained in July-August 1995, using walk counts and observations near living dens around the Northern rookery of the northern fur seals located on Bering Island (Commander Islands). The home ranges of 31 Arctic fox families (61 adults and 145 pups inhabiting 66 dens) were found over 27 km of the coastline. Sixty individuals (3 adults and 57 pups) were marked by color ear-tags. Among adult foxes, 24 (39.3%) were recognized as females and 12 (19.7%) as males; the sex of 25 (41.0%) foxes was not recognized. Among 57 marked cubs, 26 (45.6%) were females and 31 (54.4%) were males. The best studied families (13) had 3-11 pups (6.7 +/- 0.7, on average). The survival of cubs at an age younger than 2.0-2.5 months was 82.5%; 30.8% of the families consisted of more than two adults. The distribution of the Arctic fox dens and home ranges along the coastline has been studied; specific features of the location of dens have been described. In the studied area, Arctic foxes have been foraging on birds (67.6% of dens with food remains), northern fur seals (40.5), other marine mammals (13.5), Pacific salmon (29.7), and reindeer (2.7%), as well as on amphipods and voles. Rich constant food sources (rookeries, marine bird colonies, and spawning places of the blueback salmon) were found in 7 home ranges of the Arctic fox; 6 home ranges included temporary food sources (spawning streams of the humpback salmon); and 18 home ranges were poor in food resources. Arctic foxes whose home ranges lie within 6-7 km around a "food patch" used the concentrated food resources together. Food resources are supposed to become important only after the raised pups turn to self-feeding. Differences in the use of space, foraging and breeding of the two Arctic fox subspecies (A. l. beringensis and A. l. semenovi), and arrangement of colonies around the northern fur seal rookeries are discussed.

Wada, K., Hoshino, H., Kuboshima, E., & Wada, A. (2013). Of the Rookery Distribution Differences in Northern Fur Seals and Steller Sea Lions in the Waters of the Russian Far East. *Mammalia, 77*(3), 253-259. https://doi.org/10.1515/mammalia-2012-0098

We investigated factors influencing differences in the rookery distribution patterns between northern fur seals and Steller sea lions in the waters of the Russian far east. The limited distribution of northern fur seal rookeries observed during 1991-2001 resulted from the need for shallow tide pools near the shore for pups to practice swimming. In addition, the large and concentrated populations of the seals required large flat areas and a high degree of natal site fidelity. In contrast, in the case of Steller sea lion rookeries observed along the Kuril islands in 2001, the pups were able to swim under maternal care, and their populations were smaller and had a lower degree of natal site fidelity. So, from our observations, their rookeries, unlike those of northern fur seals, are therefore widely distributed across diverse topographical conditions in the waters of Russian far east.

Waite, J. N., Burkanov, V. N., & Andrews, R. D. (2010). *Dietary Resource Partitioning between Sympatrically Breeding Steller Sea Lions* (Eumetopias jubatus) *and Northern Fur Seals* (Callorhinus ursinus) *on Lovushki Island, Russia.* Paper presented at the Integrative and Comparative Biology. Retrieved from http://www.sicb.org/meetings/2010/schedule/abstractdetails.php3?id=1284

Steller sea lions (SSL, Eumetopias jubatus) and northern fur seals (NFS,*Callorhinus ursinus*) breed sympatrically on Lovushki Island, Russia. A large population of non-breeding juvenile NFS is also present during the breeding season. After experiencing a dramatic population decline over most of their range in the last 4 decades, the SSL population on Lovushki Island has begun to increase slowly in recent years. Simultaneously, the NFS population has been increasing at a rapid pace, creating the potential for intra- and inter-specific foraging competition. The dietary resource partitioning between these three groups was examined through the analysis of undigested prey remains recovered from scats and spews collected on the rookery. The prey selection of breeding SSL and breeding NFS suggests a partitioning of dietary resources based both on prey selection and spatial foraging location. There was a significant dietary overlap between breeding SSL and non-breeding NFS (Pianka's niche overlap index Oij = 0.939) but not between breeding SSL and breeding NFS (Oij = 0.231). SSL and juvenile NFS fed primarily on Atka mackerel (Pleurogrammus monopterygius) and walleye pollock (Theragra chalcogramma). Both of these species are low- to moderate-energy prey items that inhabit shallow, near-shore waters. Adult female NFS fed primarily on higher-energy northern smoothtongue (Leuroglossus schmidti) and cephalopods, both of which occur offshore in pelagic waters. While the dietary overlap between breeding SSL and non-breeding NFS is high, without knowledge of foraging locations and times, a high level of competition for prey resources cannot be inferred.

Waite, J. N., Burkanov, V. N., & Andrews, R. D. (2012). Prey Competition between Sympatric Steller Sea Lions (*Eumetopias jubatus*) and Northern Fur Seals (*Callorhinus ursinus*) on Lovushki Island, Russia. *Canadian Journal of Zoology, 90*(1), 110-127. https://doi.org/10.1139/z11-117

Approximately 1 000 Steller sea lions (*Eumetopias jubatus* (Schreber, 1776); SSL) and 14 000 northern fur seals (*Callorhinus ursinus* (L., 1758); NFS) breed sympatrically on Lovushki Island in the Russian Far East, creating the potential for interspecific competition for prey. An additional 13 000 – 14 000 juvenile NFS are present during the breeding season. The diets of breeding SSL and both breeding and juvenile

NFS were examined through analysis of scats and spews collected during the breeding seasons of 2003, 2005, and 2007–2008. There were significant overlaps in the prey species and size selection of SSL and juvenile NFS. There were significant differences between the diets of SSL and breeding NFS. SSL and juvenile NFS fed primarily on Atka mackerel (*Pleurogrammus monopterygius* (Pallas, 1810)), while breeding NFS fed on cephalopods, salmon (genus *Oncorhynchus Suckley*, 1861), Atka mackerel, and northern smoothtongue (*Leuroglossus schmidti* Rass, 1955). The partitioning of resources between breeding animals has allowed both species to coexist within the same region and likely reflected differences in foraging abilities and provisioning strategies of the adults and the fasting abilities of their pups. However, continued growth of the NFS population may lead to the exclusion of SSL owing to interspecific competition for prey.

Waite, J. N., Trumble, S. J., Burkanov, V. N., & Andrews, R. D. (2012). Resource Partitioning by Sympatric Steller Sea Lions and Northern Fur Seals as Revealed by Biochemical Dietary Analyses and Satellite Telemetry. *Journal of Experimental Marine Biology and Ecology, 416*, 41-54. https://doi.org/10.1016/j.jembe.2012.02.009

Over 1000 endangered Steller sea lions (SSL, Eumetopias jubatus Schreber, 1776) and approximately 14000 northern fur seals (NFS,*Callorhinus ursinus* L., 1758) breed sympatrically at the Lovushki Island complex, located in the northern Kuril Island chain in the Russian Far East, creating the potential for inter-specific competition for prey resources. The diets and foraging locations of both species were examined through the analysis of delta N-15 and delta C-13 stable isotope (SI) ratios of vibrissae, fatty acid (FA) profiles of blubber biopsies, and telemetry data collected during the breeding seasons of 2007 and 2008. There were significant differences in the mean delta N-15 and delta C-13 values between SSL and NFS. Adult female SSL were significantly enriched in both delta N-15 and delta C-13 over adult female NFS (by 2.04%+/- 0.23%. and 0.83%+/- 0.12%., respectively), which indicates that the sea lions were feeding at a higher trophic level and in a different geographical location than the fur seals. The higher mean delta C-13 levels found in the sea lion vibrissae suggest that they fed nearshore and benthically, while fur seals fed primarily offshore and pelagically. There were significant differences in the blubber FA profiles between SSL and NFS, indicating that the two species have different foraging strategies with respect to the types and/or proportions of prey items consumed. Foraging behavior analysis also indicated that SSL foraged nearshore and benthically and breeding NFS foraged primarily offshore and pelagically. The combination of these methodologies suggests breeding NFS and SSL partition their forage resources by prey type, as well as spatially, which likely reflected the differences in provisioning strategies of the adults and the fasting abilities of their pups.

Waite, J. N., Waits, L. P., Bozza, M., & Andrews, R. D. (2011). Differentiating between Steller Sea Lion (*Eumetopias jubatus*) and Northern Fur Seal (*Callorhinus ursinus*) Scats through Analysis of Faecal DNA. *Molecular Ecology Resources, 11*(1), 166-170. https://doi.org/10.1111/j.1755-0998.2010.02874.x

We describe a method to determine the species of pinniped from faeces collected from sympatric Steller sea lion (Eumetopias jubatus) and northern fur seal (*Callorhinus ursinus*) rookeries using newly developed species-specific primers that amplify a 667-669-base pair segment from the mitochondrial DNA (mtDNA) cytochrome B (cytB) gene region. The primers yielded the correct species in 100% of tissue samples from 10 known animals and 100% of faecal samples from 13 known animals. Species could be identified unequivocally for 87.7% of faecal samples from 122 unknown individuals. The ability

to differentiate between scats of sympatrically breeding Steller sea lions and northern fur seals will contribute to the range-wide knowledge of the foraging strategies of both species as well as allow researchers to examine the niche partitioning and potential resource competition between the two predators.

Wang, D., Shelver, W. L., Atkinson, S., Mellish, J.-A., & Li, Q. X. (2010). Tissue Distribution of Polychlorinated Biphenyls and Organochlorine Pesticides and Potential Toxicity to Alaskan Northern Fur Seals Assessed Using PCBs Congener Specific Mode of Action Schemes. *Archives of Environmental Contamination and Toxicology, 58*(2), 478-488. https://doi.org/10.1007/s00244-009-9396-6

The fur seal (*Callorhinus ursinus*) population has decreased in their primary breeding grounds in the Bering Sea; contamination is among suspected causes. Our goal was to better understand the extent of contamination of seal tissues with certain organochlorine compounds by measuring the concentrations of polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) in fur seal tissues from St. Paul Island, to gain a better perspective of tissue congener distribution and to evaluate the observed PCB levels against toxicologically significant levels for modes of action. Concentrations of 145 PCB congeners (a(145)PCBs) and 12 OCPs were measured with gas chromatography-ion trap mass spectrometry in 8 different tissues of 10 male northern fur seals. The mean concentrations of aOCPs [in ng/g lipid weight (lw)] were 1180 in blubber, 985 in the heart, 1007 in the liver, 817 in the kidney, 941 in muscle, 660 in reproductive tissues, 204 in the brain, and 322 in the lung. The mean concentrations of a(145)PCBs (in ng/g lw) were 823 in blubber, 777 in the liver, 732 in the heart, 646 in reproductive tissues, 638 in muscle, 587 in the kidney, 128 in the lung, and 74.3 in brain tissues. Concentrations of PCBs affecting the aryl hydrocarbon receptor expressed as total PCB toxic equivalents (aPCB-TEQs) ranged from 0.3 to 545 pg/g lw for the various tissues. The major contributors to aPCB-TEQs are CB-118 in muscle, brain, lung, kidney, and liver, CB-126 in blubber, and CB-118 and CB-126 equally in the heart and reproductive tissues. Concentrations of PCBs affecting Ca2+ homeostatsis expressed as the neurotoxic equivalent (NEQ) showed aPCB-NEQs ranged from 17.7 to 215 ng/g lw in all tissues. Although no composite measure of perturbation of thyroid function is available, sufficient amounts of congeners with high binding to the thyroxine transport system were present to warrant consideration of this mode of action in future studies. Analyses of 145 PCBs and mode of action evaluation suggest that PCB contamination could potentially exert an effect on the Alaskan northern fur seal population although the PCB concentrations have been decreasing in the fur seals over the last decade.

Ward, E. J., Hilborn, R., Towell, R. G., & Gerber, L. (2007). A State-Space Mixture Approach for Estimating Catastrophic Events in Time Series Data. *Canadian Journal of Fisheries and Aquatic Sciences, 64*(6), 899-910. https://doi.org/10.1139/f07-060

Catastrophic events are considered a major contributor to extinction threats, yet are rarely explicitly estimated in population models. We extend the basic state-space population dynamics model to include a mixture distribution for the process error. The mixture distribution consists of a "normal" component, representing regular process error variability, and a "catastrophic" component, representing rare events that negatively affect the population. Direct estimation of parameters is rarely possible using a single time series; however, estimation is possible when time series are combined in hierarchical models. We apply the catastrophic state-space model to simulated time series of abundance from simple, nonlinear population dynamics models. Applications of the model to these simulated time series indicate that

population parameters (such as the carrying capacity or growth rate) and observation and process errors are estimated robustly when appropriate time series are available. Our simulations indicate that the power to detect a catastrophe is also a function of the strength of catastrophes and the magnitude of observation and process errors. To illustrate one potential application of this model, we apply the state-space catastrophic model to four west coast populations of northern fur seals (*Callorhinus ursinus*).

Weber, M. L., & Laist, D. W. (2007). *The Status of Protection Programs for Endangered, Threatened, and Depleted Marine Mammals in U.S. Waters*. Marine Mammal Commission. Retrieved from http://www.mmc.gov/reports/workshop/pdf/WEBER%5f%20FINAL72407.pdf

This report is divided into three major sections. The first discusses provisions of the MMPA and the ESA that form the foundation for most marine mammal protection programs. The second profiles protection programs for all 22 listed taxa. Each profile summarizes information on the taxon's status, major threats, management framework, critical habitat, recovery planning, major management actions, and staffing and funding levels. The third summarizes overall trends in protection programs for the listed species and populations, based on those profiles. Appendices include tables and charts with estimates of expenditures for related conservation programs, additional details regarding key provisions of the MMPA and the ESA, and information on the status of the various taxa.

Winters, M., Barta, J. L., Monroe, C., & Kemp, B. M. (2011). To Clone or Not to Clone: Method Analysis for Retrieving Consensus Sequences in Ancient DNA Samples. *PLoS One, 6*(6). https://doi.org/10.1371/journal.pone.0021247

The challenges associated with the retrieval and authentication of ancient DNA (aDNA) evidence are principally due to postmortem damage which makes ancient samples particularly prone to contamination from "modern" DNA sources. The necessity for authentication of results has led many aDNA researchers to adopt methods considered to be "gold standards" in the field, including cloning aDNA amplicons as opposed to directly sequencing them. However, no standardized protocol has emerged regarding the necessary number of clones to sequence, how a consensus sequence is most appropriately derived, or how results should be reported in the literature. In addition, there has been no systematic demonstration of the degree to which direct sequences are affected by damage or whether direct sequencing would provide disparate results from a consensus of clones. To address this issue, a comparative study was designed to examine both cloned and direct sequences amplified from similar to 3,500 year-old ancient northern fur seal DNA extracts. Majority rules and the Consensus Confidence Program were used to generate consensus sequences for each individual from the cloned sequences, which exhibited damage at 31 of 139 base pairs across all clones. In no instance did the consensus of clones differ from the direct sequence. This study demonstrates that, when appropriate, cloning need not be the default method, but instead, should be used as a measure of authentication on a case-by-case basis, especially when this practice adds time and cost to studies where it may be superfluous.

Wolsan, M., Suzuki, S., Asahara, M., & Motokawa, M. (2015). Tooth Size Variation in Pinniped Dentitions. *PLoS One, 10*(8). https://doi.org/10.1371/journal.pone.0137100

It is contentious whether size variation among mammalian teeth is heterogeneous or homogeneous, whether the coefficient of variation is reliable, and whether the standard deviation of log-transformed

data and the residual of standard deviation on mean variable size are useful replacements for the coefficient of variation. Most studies of tooth size variation have been on mammals with complex-crowned teeth, with relatively little attention paid to taxa with simple-crowned teeth, such as Pinnipedia. To fill this gap in knowledge and to resolve the existing controversies, we explored the variation of linear size variables (length and width) for all teeth from complete permanent dentitions of four pinniped species, two phocids (Histriophoca fasciata, Phoca largha) and two otariids (*Callorhinus ursinus*, Eumetopias jubatus). Size variation among these teeth was mostly heterogeneous both along the toothrow and among species. The incisors, canines, and mesial and distal postcanines were often relatively highly variable. The levels of overall dental size variation ranged from relatively low as in land carnivorans (Phoca largha and both otariids) to high (Histriophoca fasciata). Sexual size dimorphism varied among teeth and among species, with teeth being, on average, larger in males than in females. This dimorphism was more pronounced, and the canines were larger and more dimorphic relative to other teeth in the otariids than in the phocids. The coefficient of variation quantified variation reliably in most cases. The standard deviation of log-transformed data was redundant with the coefficient of variation. The residual of standard deviation on mean variable size was inaccurate when size variation was considerably heterogeneous among the compared variables, and was incomparable between species and between sexes. The existing hypotheses invoking developmental fields, occlusal complexity, and the relative timing of tooth formation and sexually dimorphic hormonal activity do not adequately explain the differential size variation along the pinniped toothrow.

Wolsan, M., Suzuki, S., Asahara, M., & Motokawa, M. (2019). Dental Integration and Modularity in Pinnipeds. *Scientific Reports, 9.* https://doi.org/10.1038/s41598-019-40956-1

Morphological integration and modularity are important for understanding phenotypic evolution because they constrain variation subjected to selection and enable independent evolution of functional and developmental units. We report dental integration and modularity in representative otariid (Eumetopias jubatus, *Callorhinus ursinus*) and phocid (Phoca largha, Histriophoca fasciata) species of Pinnipedia. This is the first study of integration and modularity in a secondarily simplified dentition with simple occlusion. Integration was stronger in both otariid species than in either phocid species and related positively to dental occlusion and negatively to both modularity and tooth-size variability across all the species. The canines and third upper incisor were most strongly integrated, comprising a module that likely serves as occlusal guides for the postcanines. There was no or weak modularity among tooth classes. The reported integration is stronger than or similar to that in mammals with complex dentition and refined occlusion. We hypothesise that this strong integration is driven by dental occlusion, and that it is enabled by reduction of modularity that constrains overall integration in complex dentitions. We propose that modularity was reduced in pinnipeds during the transition to aquatic life in association with the origin of pierce-feeding and loss of mastication caused by underwater feeding.

Yang, L., Battaile, B. C., Trites, A. W., & Zidek, J. V. (2015). Bias Correction and Uncertainty Characterization of Dead-Reckoned Paths of Marine Mammals. *Animal Biotelemetry, 3*, 1-11. https://doi.org/10.1186/s40317-015-0080-5

Biologgers incorporating triaxial magnetometers and accelerometers can record animal movements at infra-second frequencies. Such data allow the Dead-Reckoned (DR) path of an animal to be reconstructed at high resolution. However, poor measures of speed, undocumented movements caused by ocean currents, confounding between movement and gravitational acceleration and measurement

error in the sensors, limits the accuracy and precision of DR paths. The conventional method for calculating DR paths attempts to reduce random errors and systematic biases using GPS observations without rigorous statistical justification or quantification of uncertainty in the derived swimming paths. Methods: We developed a Bayesian Melding (BM) approach to characterize uncertainty and correct for bias of DR paths. Our method used a Brownian Bridge process to combine the fine-resolution (but seriously biased) DR path and the sparse (but precise and accurate) GPS measurements in a statistically rigorous way. We also exploited the properties of underlying processes and some approximations to the likelihood to dramatically reduce the computational burden of handling large, high-resolution data sets. We implemented this approach in an R package "BayesianAnimal- Tracker", and applied it to bio-logging data obtained from northern fur seals (*Callorhinus ursinus*) foraging in the Bering Sea. We also tested the accuracy of our method using cross-validation analysis and compared it to the conventional bias correction of DR and linear interpolation between GPS observations (connecting two consecutive GPS observations by a straight line). Results: Our BM approach yielded accurate, high-resolution estimated paths with uncertainty quantified as credible intervals. Cross-validation analysis demonstrated the greater prediction accuracy of the BM method to reconstruct movements versus the conventional and linear interpolation methods. Moreover, the credible intervals covered the true path points albeit with probabilities somewhat higher than 95%. The GPS corrected high-resolution path also revealed that the total distance traveled by the northern fur seals we tracked was 40-50% further than that calculated by linear interpolation of the GPS observations.

Yano, K. M., Tingg, J. Y., & Fowler, C. W. (2009). *Northern Fur Seal Rookery Photo Archive: Aerial and Ground-Level Photos, Pribilof Islands, Alaska, 1895-2006*. National Marine Fisheries Service Alaska Fisheries Science Center. AFSC Processed Report 2009-03. Retrieved from http://www.afsc.noaa.gov/Publications/ProcRpt/PR2009-03.pdf

The northern fur seal (*Callorhinus ursinus*) has been the subject of recorded history for more than two centuries (Scheffer et al. 1984, Scott et al. 2006). It has a long history of being commercially harvested for its valuable pelts (Roppel 1984). Recently, however, fur seals are being seen as one of many species reflecting the conditions of their environment, especially an environment increasingly altered by human influence. The Pribilof Islands fur seal population is currently listed as depleted under terms of the U.S. Marine Mammal Protection Act owing to numbers greatly reduced from those observed historically (National Marine Fisheries Service 1993). As such, information that helps characterize, measure, and understand fur seal population change is valuable. This includes photographic records of fur seal rookeries showing their location, size, shape, and density of seals. In 1895 (Townsend 1896a), ground-level photographs were taken from vantage points overlooking selected areas of most of the fur seal rookeries on the Pribilof Islands of the eastern Bering Sea. This was a remarkable feat in view of the state of photography at that time and the logistical difficulty of getting to and working on these islands. Since that time, scientists and managers have returned to the same spots from which these early photos were taken and photographed the same views. The addition of aerial photography further enhanced perspective by adding images that displayed entire rookeries. This report documents the digital archival of most of the photographs and images/illustrations of the fur seal rookeries on the Pribilof Islands maintained by the National Marine Mammal Laboratory, Alaska Fisheries Science Center, in Seattle, Washington. Our primary objective was to preserve these historic photographs in digital form to make them widely available and reproducible. Scientists, historians, and others now have the option of making use of these records to take advantage of the information they contain without posing risk to the original materials.

Yonezaki, S., & Kiyota, M. (2014). Shift in Trophic Role of Northern Fur Seals in the Northwestern Pacific Ocean. *Bulletin of Fisheries Research Agency*(38), 115-117. Retrieved from https://www.fra.affrc.go.jp/bulletin/bull/bull38/38-03-09.pdf

Northern fur seals (Callorhinus ursinus, NFS) are the most abundant otariid species with recent population estimates reaching approximately 1.2 million (Angliss and Lodge, 2004). NFS are widely distributed in the subarctic zone of the North Pacific Ocean, with the northwestern Pacific Ocean (particularly the area off the Tohoku region of Japan) providing a major wintering and foraging area for NFS. Approximately 100,000 of fur seals, primarily adult females and juveniles, migrate to this area where they remain from the winter to early spring. Thus, NFS are important apex predators in the area, which corresponds to one of the most productive fishing grounds in the world due to mixing of the Kuroshio and Oyashio currents

Yonezaki, S., Kiyota, M., & Baba, N. (2008). Decadal Changes in the Diet of Northern Fur Seal (*Callorhinus ursinus*) Migrating Off the Pacific Coast of Northeastern Japan. *Fisheries Oceanography, 17*(3), 231-238. https://doi.org/10.1111/j.1365-2419.2008.00475.x

Decadal changes in northern fur seal (*Callorhinus ursinus*) diet were examined based on the stomach contents data collected off the Pacific coast of northeastern Japan from January to April, 1953-1988. Seventeen families of fish and seven families of squid were identified from the stomach contents. Dominant prey species in terms of percentage of occurrence and wet weight were Japanese sardine (Sardinops melanostictus), chub mackerel (Scomber japonicus), and myctophid fishes. Demersal fishes, sparkling enope squid (Watasenia scintillans), and oceanic squids were also preyed on at low incidences. Decadal-scale diet composition of northern fur seals revealed shifts in the significance of Japanese sardine and chub mackerel in parallel with the decadal alternation in the dominance of these species within the pelagic fish community off the Pacific coast of northeastern Japan. These results suggest that northern fur seals can use a variety of prey resources in this wintering area by switching the diet according to the distribution and abundance of prey species.

Yonezaki, S., Kiyota, M., Baba, N., Koido, T., & Takemura, A. (2011). Prey Size Reconstruction Based on Myctophid Otoliths in Scats of Northern Fur Seals (*Callorhinus ursinus*). *Mammal Study, 36*(3), 159-163. https://doi.org/10.3106/041.036.0307

The purpose of this study was to use experimentally designed meals and captive northern fur seals (*Callorhinus ursinus*) to calculate correction factors (CFs) for reconstruction of the myctophid fish size to compensate for the effects of digestion. Moreover, we apply the CFs to otoliths recovered from the large intestine contents of wild fur seal specimens, and estimated the size of the myctophid fish eaten. Myctophid fish used in the experiment are dominant components of micronekton communities in oceanic ecosystems and are important prey items of northern fur seals in the western North Pacific Ocean (Yonezaki et al. 2003; Yonezaki et al. 2008). Therefore, the calculation of CFs of myctophid fish otoliths enables data for use in the reconstruction of the diet of northern fur seals based on scats.

Yonezaki, S., Kiyota, M., & Okamura, H. (2015). Long-Term Ecosystem Change in the Western North Pacific Inferred from Commercial Fisheries and Top Predator Diet. *Deep-Sea Research Part II-Topical Studies in Oceanography, 113*, 91-101. https://doi.org/10.1016/j.dsr2.2014.10.027

Assessment of the current status of marine ecosystems is necessary for the sustainable utilization of ecosystem services through fisheries and other human activities under changing environmental conditions. Understanding of historical changes in marine ecosystems can help us to assess their current status. In this study, we analyzed Japanese commercial fishery catch data and scientific survey data of the diet of northern fur seal (*Callorhinus ursinus*, NFS) to investigate potential long-term ecosystem changes in the western North Pacific Ocean off northeastern Japan over the past 60 years. Total commercial catches experienced peaks around 1960 and during the 1980s, decreasing to low levels around 1970 and after 1990. Catches were substantively impacted by the Tohoku earthquake and tsunami in 2011. Species composition of the commercial catch changed over time, resulting in changes in the mean trophic level (MTL) of the catches. Trends in observed commercial catches were affected by many factors, including species population fluctuations potentially related to large-scale environmental shifts, migration and distribution patterns of species related to local oceanography, changes in fishing technology, and the introduction of fishery management frameworks. The composition of NFS diet also changed over time: although overall changes were small, MTL derived from NFS stomach contents declined from the early 1970s to the late 1980s. This fall in the MTL of the diet of NFS is suggestive of a shift in pelagic fish fauna from a "mackerel-dominant regime" to a "sardine-dominant regime". Inconsistencies between changes in species composition and MTLs of the commercial catch and NFS diet resulted from differences in commercial fishing targeting and NFS foraging behavior strategies. Although commercial catch is a valuable source of information for investigating historical changes in fisheries, biological resources, and ecosystems, catch data should be interpreted carefully and other relevant information available should also be considered.

Yonezaki, S., Kiyota, M., Okamura, H., & Baba, N. (2006). *Possibility of Diet Selection of Northern Fur Seals in the Northwestern Pacific*. Retrieved from: https://meetings.pices.int/publications/book-of-abstracts/PICES_15_Book_of_Abstracts.pdf

Northern fur seals (*Callorhinus ursinus*) have been considered as opportunistic feeders that prey on those species that are most available in their pelagic habitat. However, analysis of our long-term stomach contents data revealed that some prey species (e.g., Japanese anchovy (Engraulis japonicus)) were preyed infrequently in spite of their abundance in the Northwestern Pacific. The purpose of this study is to examine the possibility of prey preference of fur seals in the Northwestern Pacific. Diet composition in digestive tract contents of fur seals collected at sea was compared with composition of prey species in trawl net samples collected in the same area period. The trawl samples were taken at nighttime from the depths ranged of 0 to 60 m in consideration of the feeding depth of fur seals. The dominant diet species were lanternfishes (Myctophidae) and sparkling enope squid (Watasenia scintillans), while the main prey species in trawl samples were Japanese anchovy, lanternfishes, and sparkling enope squids. Statistical analysis on resource selection demonstrated significant negative selection of Japanese anchovy by northern fur seals. These results indicate a possibility that fur seals choose their diet from available prey species in their marine habitat. In the Northwestern Pacific, it was reported that the diet composition of fur seals changed according to the change in the long-term shifts in the food environment (e.g., Quasi-decadal alternations in dominant small pelagic fishes). Northern fur seals may be selecting the prey items that can be utilized most efficiently in a given food environment.

Yonezawa, T., Kohno, N., & Hasegawa, M. (2009). The Monophyletic Origin of Sea Lions and Fur Seals (Carnivora; Otariidae) in the Southern Hemisphere. *Gene, 441*(1-2), 89-99. https://doi.org/10.1016/j.gene.2009.01.022

The pinniped family Otariidae (sea lions and fur seals) is composed of 7 extant genera with 14 species. They are mainly distributed in the Southern Hemisphere, but the fossil record is only known from the Northern Hemisphere until Pliocene. To clarify the biological and zoogeographical events during their evolution, it is necessary to reconstruct a robust phylogenetic tree. However, phylogenetic relationships among otariids continue to be controversial, except for the basal position of the northern fur seal among the extant otariids. We reconstructed phylogenetic trees of otariids based on mitochondrial genomes and multiple nuclear genes (IRBP and type I STS markers). The monophyly of the otariids including both sea lions and fur seals in the Southern Hemisphere was strongly supported by both the mitochondrial and nuclear evidence. We propose a novel evolutionary and dispersal scenario of otariids based on this phylogenetic hypothesis, estimated divergence times, and fossil records. According to our results, the center of origin of the southern otariids is hypothesized to be the eastern South Pacific along the west coast of South America.

Zeppelin, T. K., Johnson, D. S., Kuhn, C. E., Iverson, S. J., & Ream, R. R. (2015). Stable Isotope Models Predict Foraging Habitat of Northern Fur Seals (*Callorhinus ursinus*) in Alaska. *PLoS One, 10*(6). https://doi.org/10.1371/journal.pone.0127615

We developed models to predict foraging habitat of adult female northern fur seals (*Callorhinus ursinus*) using stable carbon (δ13C) and nitrogen (δ15N) isotope values from plasma and red blood cells. Binomial generalized linear mixed models were developed using blood isotope samples collected from 35 adult female fur seals on three breeding colonies in Alaska during July-October 2006. Satellite location and dive data were used to define habitat use in terms of the proportion of time spent or dives made in different oceanographic/bathymetric domains. For both plasma and red blood cells, the models accurately predicted habitat use for animals that foraged exclusively off or on the continental shelf. The models did not perform as well in predicting habitat use for animals that foraged in both on- and off-shelf habitat; however, sample sizes for these animals were small. Concurrently collected scat, fatty acid, and dive data confirmed that the foraging differences predicted by isotopes were associated with diet differences. Stable isotope samples, dive data, and GPS location data collected from an additional 15 females during August-October 2008 validated the effective use of the models across years. Little within year variation in habitat use was indicated from the comparison between stable isotope values from plasma (representing 1-2 weeks) and red blood cells (representing the prior few months). Constructing predictive models using stable isotopes provides an effective means to assess habitat use at the population level, is inexpensive, and can be applied to other marine predators.

Zeppelin, T. K., & Orr, A. J. (2010). Stable Isotope and Scat Analyses Indicate Diet and Habitat Partitioning in Northern Fur Seals *Callorhinus ursinus* across the Eastern Pacific. *Marine Ecology Progress Series, 409*, 241-253. https://doi.org/10.3354/meps08624

We used stable isotope (SI) and scat analyses to describe and compare the foraging ecology of northern fur seals *Callorhinus ursinus* from different rookeries throughout their North American range, including rookeries on the following islands: Bogoslof Island (BI), Alaska; Reef and Vostochni on St. Paul Island

(SPI), Alaska; and San Miguel Island (SMI), California. SI samples were collected from 36 adult females and 37 juveniles in Alaska, and 9 adult females and 7 pups on SMI during fall 2006. Isotopic analyses of blood and fur indicated differences in stable carbon (delta C-13) and nitrogen (delta N-15) isotope values within an individual, between age classes, and among locations. At all sites, adult females generally had higher delta C-13 compared to their younger conspecifics for all tissues, suggesting that they forage in different locations. Mean delta N-15 values of adult females were lower compared to those of pups at SMI, higher than those of juveniles on SPI, and similar to those of juveniles on BI, suggesting differences in trophic level between age classes at all locations except on BI. We found differences in delta C-13 values at all islands, suggesting that animals at each location forage in different oceanic domains. The delta N-15 values of all age classes indicated that animals at SMI and Vostochni feed at similar trophic levels within their respective communities, but feed at higher trophic levels than animals at Reef and BI. Scat analysis supported SI results in that animals from each location were found to feed on species associated with unique oceanic features. By using scat and SI analyses, we were able to acquire a better understanding of the foraging ecology of different-aged conspecifics from multiple locations.

Zeppelin, T. K., & Ream, R. R. (2006). Foraging Habitats Based on the Diet of Female Northern Fur Seals (*Callorhinus ursinus*) on the Pribilof Islands, Alaska. *Journal of Zoology, 270*(4), 565-576. https://doi.org/10.1111/j.1469-7988.2006.00122.x

Scats (fecal samples) collected between 1987 and 2000 on northern fur seal *Callorhinus ursinus* rookeries of St Paul (n=2968) and St George Islands (n=1203), Alaska, were used to examine the relationship between breeding sites and food habits of adult female seals. On the basis of the frequency of occurrence (FO) and per cent minimum number of individual prey (%MNI) in scats, juvenile walleye pollock Theragra chalcogramma and gonatid squid Gonatopsis borealis/Berryteuthis magister and Gonatus madokai/Gonatus middendorffi were the dominant prey species consumed overall. Other primary prey (FO > 5%) included Pacific sand lance Ammodytes hexapteus, Pacific herring Clupea pallasi, northern smoothtongue Leuroglossus schmidti, Atka mackerel Pleurogrammus monopterygius, Pacific salmon (Oncorhynchus spp.) and other squid of the Gonatus genus. We identified five rookery complexes from a cluster analysis of the FO of primary prey in scats. Rookery complexes were separated geographically and each was further defined by characteristic patterns in the representation of prey types typically associated with specific hydrographic domains. Diet differences were observed among rookeries on the north and south side of St George Island and on the east, south and south-west side of St Paul Island. The rookery clusters observed in this study provide evidence of resource partitioning among adult female northern fur seals and have important implications for fur seal conservation and management.

Zhdanova, O. L., Kuzin, A. E., & Frisman, E. Y. (2017). Mathematical Modeling of the Variation in the Survival of Female Northern Fur Seals, *Callorhinus ursinus* (Linnaeus, 1758), on Tyuleniy Island. *Russian Journal of Marine Biology, 43*(5), 348-358. https://doi.org/10.1134/s1063074017050121

The dynamics of the survival and number of female northern fur seals, *Callorhinus ursinus*, on Tyuleniy Island have been studied. The data on the age structure and physiological condition of females (obtained during observations in 1958-1988) were used to estimate the model parameters. The adequacy of the model estimates of female number was evaluated using the data on the number of newborn pups at the rookery in 1958-2013. It has been found that a reduction in the survival rate of

individuals of younger age groups, a decrease in the proportion of females, as well as aging of the population occurred in the 1958-1988 period. The use of numerical simulation methods shows that the rate of survival of females among individuals under 3 years of age increased substantially after 1988, indicating a positive trend in the dynamics of their number.

Zhdanova, O. L., Kuzin, A. E., & Frisman, E. Y. (2017). The Survival Dynamics of Male Northern Fur Seals (*Callorhinus ursinus*) on Tyulenii Island, Sea of Okhotsk, Based on Long-Term Observations. *Biology Bulletin, 44*(9), 1174-1191. https://doi.org/10.1134/s1062359017090175

We discuss and improve the methods proposed previously for estimating the survival rate of male northern fur seals representing different age groups. Estimates of the number of pups and bulls per rookery are given, as well as information on the age structure of animals hunted during the coastal harvest. The data were obtained by researchers from the Pacific Research Fisheries Center over 56 years of observation of the fur seal (*Callorhinus ursinus*) herd on Tyulenii Island, located in the southwestern part of the Sea of Okhotsk, south of Cape Terpenia, 15 km from Sakhalin Island. Lander's method and its modifications were used for estimating the juvenile survival rate of male fur seals. This methodology was found to have not been working properly for the past several decades (since the end of the 1980s) due to changes in population harvesting. Satisfactory estimates for all characteristics of the male life cycle were obtained. Structural changes in survival ability were revealed as having occurred at the end of the 1980s, i.e., the survival of subadult and adult males increased slightly. New estimates of survival rates allow us to create a model of the dynamics of bull numbers that is in good agreement with that observed, its mean error of approximation equaling 3.2%.

Zhdanova, O. L., Kuzin, A. E., Skaletskaya, E. I., & Frisman, E. Y. (2017). Why the Population of the Northern Fur Seals (*Callorhinus ursinus*) of Tyuleniy Island Does Not Recover Following the Harvest Ban: Analysis of 56 Years of Observation Data. *Ecological Modelling, 363*, 57-67. https://doi.org/10.1016/j.ecolmodel.2017.08.027

Following many years of managed harvest, the population size of Northern fur seal on Tyuleniy Island appeared to be depressed. In order to preserve the population, the harvest was first significantly limited, and then banned altogether. However, the birth rates have never recovered. We perform the estimation and analysis of survival rates of different groups of males in the population with the goal of elucidating the underlying changes in intra-population dynamics. We use the estimated numbers of adult males and pups in the rookery along with the exact numbers and ages of animals, harvested over the years. Our investigation shows that the unexpectedly slow growth of the population is most likely not caused by an abrupt decline of survival rates of any age groups. There is no substantial change in juvenile survival, and the survival rates of the older animals are actually increasing. However, the analysis of density dependent factors of juvenile survival demonstrates significant increase in intra-species competition. This may be caused by change in environmental conditions such as quality and availability of food. Also, the dynamics of pups' viability is telling: it was the highest at the beginning of the period of observations, and then it sharply decreased following intensification of harvest, and finally started growing again in response to strong conservation measures, but never achieved its original level. These facts may be consequence of changes in the population gene pool, which shows the importance of research of the evolutionary consequences of harvest.