Steller Sea Lion Thirty Year Review

Bibliography

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Background & Scope

The goal of this bibliography is to provide a comprehensive review of the scientific literature published on the Steller sea lion (SSL), *Eumetopias jubatus*, in the past thirty years.

"The Steller (or northern) sea lion is the largest member of the family Otariidae, the 'eared seals,' which includes all sea lions and fur seals. Steller sea lions were first listed under the Endangered Species Act in 1990. In 1997 NOAA Fisheries recognized two populations, classifying the eastern population as threatened and the western population as endangered. The eastern population has since recovered and is no longer listed, which is a significant achievement under the ESA. The western population remains endangered." -NMFS

Sources Reviewed

The following databases were used to identify sources: 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. The bibliography includes English, Russian and Japanese language materials published since 1989 along with several key sources from the literature from prior years.

Section I – Abundance and Population Trends

This section contains relevant literature on population status and trends, and surveys.

Section II – Behavior

This section contains relevant literature on social behavior, territoriality, harassment, hauling out, and maternal attendance.

Section III - Bibliography and Encyclopedia Articles

This section contains bibliography and encyclopedia articles on SSLs.

Section IV - Fisheries Interactions and Deterrents

This section contains relevant literature on interactions and conflicts between SSLs and fisheries including prey availability to sea lions, fisheries damages, and marine mammal bycatch.

Section V - Food Habits and Diving

This section contains relevant literature on foraging, diet, SSL prey, and diving behavior.

Section VI – Genetics

This section contains relevant literature on genome mapping, population genetics, and viral genetics.

Section VII - Habitat and Critical Habitat

This section contains relevant literature on the spatial and ecological characteristics of SSL habitat.

Section VIII - Movements and Distribution

This section contains relevant literature on breeding philopatry, dispersal, regional differences, and geographic range.

Section IX - News Articles (Bites)

This section contains news articles on Steller sea lion conflicts with humans, specifically biting.

Section X – Physiology

This section contains relevant literature on endocrinology, blood cell morphology, growth, biomechanics, metabolism, thermoregulation, fasting, body composition, digestion, and the nervous system.

Section XI – Predation

This section contains relevant literature on killer whale (Orcinus orca) predation on SSLs.

Section XII – Program and Method Assessment

This section contains relevant literature on evaluations of management programs, research programs, and study methodology.

Section XIII – Survival Rates

This section contains relevant literature on survival, reproduction, and mortality among SSLs.

Section XIV – Threats

This section contains relevant literature on disease, noise, health risks including contaminants, and anthropogenic threats including entanglement, illegal shooting, pollution and climate change.

Section I: Abundance and Population Trends

Adams, T., Bradley, D., Brandon, E., Calkins, D., Castellini, M., Davis, R., . . . McAllister, D. (1996). Steller Sea Lion Recovery Investigations in Alaska, 1992-1994. Alaska Department of Fish and Game Division of Wildlife Conservation. Wildlife Technical Bulletin No. 13. Retrieved from <u>https://www.arlis.org/docs/vol1/41863234.pdf</u>

The United States population of Steller sea lions (SSL), *Eumetopias jubatus*, is classified as "threatened" under the Endangered Species Act" because of a recent 73% decline in numbers. National Marine Fisheries Service (NMFS) has recommended that the US population of SSL be divided into two stocks, with an east-west division at 1440 west longitude, based largely on genetic evidence. Since 1992, the Alaska Department of Fish & Game (ADF&G) and NMFS have been the recipients of congressional appropriations to study the decline and develop management strategies for population recovery. The basis for much of the research has been an "experimental/control" approach comparing population characteristics between the depressed western stock and the increasing Southeast Alaska (SEA) portion of the eastern stock. Research then could focus on those factors that are different between stocks to determine their role in the decline and eventually to develop appropriate strategies to enhance population recovery. In addition to ADF&G and NMFS several other scientific groups (cooperators), with specialized expertise, have joined the research effort. In this report we present findings from our research and that of our cooperators. Counts of SSL pups and nonpups were made at rookery and haulout sites in SEA between 1979 and 1995. Historical data on SSL abundance from earlier in the century were also examined. Counts of both pups and nonpups showed a positive trend (pups =+6.86%/yr, nonpups =+4.83%). The lower rate of increase for nonpups was probably due to the reduced presence of subadults from the depressed western stock. During this period two sites, White Sisters and Hazy Island, developed into significant rookeries. We estimate, based on total counts of pups, that in 1994 the SEA breeding population numbered approximately 17,000 animals. We conclude that SSL are abundant in SEA and are probably at the highest level of this century. These findings question the logic behind classification of the SEA subpopulation as threatened.

Alaska Fisheries Science Center. (2010). *Regional Trends in Adult and Juvenile Western Steller Sea Lion Counts, 2000-2008*. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from <u>https://alaskafisheries.noaa.gov/sites/default/files/trendsafsc2010.pdf</u>

AFSC examined regional trends in Steller sea lion adult and juvenile (non-pup) counts (at the 161 trend sites routinely surveyed since 1991) in the 2000s at three different spatial scales within the range of the western stock in AK: 1) Ten rookery cluster areas (RCAs) as defined for the fishery-sea lion-oceanographic analysis (labelled 1-10 from west to east) 2) Six NMML-defined sea lion areas that are also used in the Recovery Plan (eastern, central and western Gulf of Alaska (GOA) and Aleutian Islands (AI) areas) and 3) Three NMFS fishery management areas in the Aleutian Islands (543, 542, and 541). AFSC examined sea lion counts using three different methods: 1) A series of geometric Brownian motion (GDM) models were fit to each stock. This model allows for movement between areas and takes into account covariance between areas and within an area between years. The model was originally fit to all data collected 1991-2008 with separate decadal growth rates estimated, but all variance components are estimated using the entire time series. This analysis was done by D. Johnson ("An analysis of Steller sea lion population trends in the Western and Asian stocks in the 1990s and 2000s"). 2) Linear regression of the natural log of the count on the year. Growth rate is the slope of the line with 95% confidence bounds. This analysis was done by L. Fritz. 3) A model estimating abundance over time was

defined simply to relate observed counts by area and rookery versus non-rookery sites. Variance estimates of annual abundances were derived via the Delta method (asymptotic approximations using ADModel Builder) and by running a MonteCarlo Markov Chain to provide posterior marginal distributions of these quantities. This analysis was done by J. Ianelli ("Examining trend data in SSL counts by rookeries and haulouts").

Alaska Sea Grant. (1993). *Is It Food? Addressing Marine Mammal and Seabird Declines*. Alaska Sea Grant Report 93-01. <u>https://doi.org/10.4027/iif.1994</u>

The Is It Food? workshop was held on the University of Alaska Fairbanks campus March 11-14, 1991. Alaska Sea Grant director Ron Dearborn began the meeting by presenting the workshop plan to the participants. During the first half-day of the workshop, participants heard overviews on six subtopics: mammals, seabirds, forage fish, physical environment, fisheries, and modeling. After the information sessions, the participants divided into five interest groups for morning discussions: mammals. seabirds, fish, physical environment. and modeling. The reports in this book on fish, oceanography, and modeling came out of those discussions. The mammal and seabird contributions are the result of further interest group discussions. During the next two days all workshop participants joined seabird and mammal interest groups, where they discussed the importance of food in population declines of marine mammals and seabirds in Alaska. The session leaders then compiled the reports.

Allen, B. M., & Angliss, R. P. (2015). Alaska Marine Mammal Stock Assessments, 2014. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC 301. https://doi.org/10.7289/V5NSORTS

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.

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. <u>https://doi.org/10.7289/V5/TM-AFSC-168</u>

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.

Becker, E. F., Calkins, D. G., Cunningham, W., Krahn, M. M., McAllister, D., Milette, L. L., . . . Sheffield, G. (1997). Steller Sea Lion Recovery Investigations in Alaska, 1995-1996. Alaska Department of Fish and Game Division of Wildlife Conservation. Retrieved from https://www.arlis.org/docs/vol1/ADFG/WC/1997/62784236.pdf

The worldwide population of Steller sea lions (SSLs) has been divided into two stocks based on several biological factors, including differences in mitochondrial DNA. These include a eastern and western stock with a division at Cape Suckling, Alaska (144° west longitude). The western stock was recently (May 1997) reclassified as "endangered" under the U.S. Endangered Species Act while the eastern stock retained a "threatened" classification. Since 1992, the Alaska Department of Fish & Game (ADF&G) and National Marine Fisheries Service (NMFS) have been the recipients of congressional appropriations to study the decline and develop management strategies for population recovery. The basis for much of the research has been an "experimental/control" approach comparing population characteristics between the 'depressed western stock and the high density Southeast Alaska (SEA) portion of the eastern stock. Research then could focus on those factors that are different between stocks to determine their role in the decline and eventually to develop appropriate strategies to enhance population recovery. In addition to ADF&G and NMFS several other scientific groups (cooperators), with specialized expertise, have joined the research effort. In this report we present findings from our research and that of our cooperators. We used models that controlled for the effects of the environmental covariates date, time and tide at the time of the survey to analyze trends in numbers of Steller sea lions counted in Southeast Alaska between 1979 and 1996. Sea lions numbers increased by an average of 6.2% per year between 1979 and 1996 based on counts of pups on rookeries. However, numbers appeared stable between 1989 and 1996 based on counts of both pup and nonpup numbers. We estimated the Southeast Alaska breeding population of Steller sea lions at 1.6,700 (including pups), a level that is probably near the highest in recorded history.

Boltnev, A. I., & Mathisen, O. A. (1996). Historical Trends in Abundance of Steller Sea Lions (Eumetopias Jubatus) in the Northwest Pacific Ocean. *Ecology of the Bering Sea, a review of the Russian literature*. Alaska Sea Grant Report 96-01. https://search.proquest.com/docview/15579188?accountid=28258

Some historical trends in the abundance of Steller sea lions (*Eumetopias jubatus*) in the Northwest Pacific Ocean are analyzed here. Long-term study by biologist from KamchatNIRO and Kamchatrybvod revealed that sea lions moved to the Commander Islands in the first half of the 1960s and created a stable reproductive rookery on Medniy Island.

Boyd, I. L. (1995). Steller Sea Lion Research: A Report Prepared for the U.S. National Marine Fisheries Service National Marine Mammal Laboratory, Seattle. British Antarctic Survey National Marine Fisheries Service National Marine Mammal Laboratory Seattle. Retrieved from <u>http://hdl.handle.net/2027/uc1.31822035584366</u>

- This report addresses the decline of the Steller sea lion population, including population trends, causes of decline, historical context, management approaces, potential biological removals, subsistence harvest, illegal killing, abundance of food, estimation of abundance, predation, environment (critical habitat), food availability, and fisheries.
- Braham, H. W., Everitt, R. D., & Rugh, D. J. (1980). Northern Sea Lion Population Decline in the Eastern Aleutian Islands. *The Journal of Wildlife Management, 44*(1), 25-33. <u>https://doi.org/10.2307/3808347</u>

From June 1975 through June 1977, 6 aerial surveys were conducted along the eastern Aleutian Islands and north coast of the Alaska Peninsula to assess the distribution and abundance of northern sea lions (*Eumetopias jubatus*). Site-specific counts of sea lions on rookeries and haulout places were compared to counts made in 1957, 1960, 1965, and 1968. Analysis of total counts from sites replicated among survey years since 1957 indicated that a significant population decline occurred. The 1977 population estimate was below 25,000, whereas in the late 1950's and early 1960's the population exceeded 50,000. The 1977 population level was 44.9-54.7% of the 1957 estimate, and it appeared that the population decline has been greatest since 1968. No cause for the decline was apparent, but several contributing factors are discussed.

Burkanov, V. (2018). Brief Results on the Most Recent and Complete Steller Sea Lion Counts in Russia. Memo to Marine Mammal Laboratory, National Oceanic and Atmospheric Administration US Department of Commerce.

[NO ABSTRACT AVAILABLE]

Byrd, G. V., & Williams, J. C. (1997). *Wildlife Surveys at Bogoslof Island, Alaska, in 1997.* United States Fish and Wildlife Service. AMNWR 97/22.

Several species of marine mammals and seabirds were surveyed in 1997 at Bogoslof Island to evaluate the status of wildlife populations there. Adverse weather conditions precluded completing seabird population surveys, but data were obtained for the following conclusions: 1. It appeared surface-feeding seabirds (kittiwakes) were finding sufficient food. in 1997 to have relatively high reproductive success, assuming food resources persisted through the end of the nesting period. 2. Tufted puffin populations have increased substantially at Bogoslof since 1973, and, increases apparently have occurred even since 1994. In fall 1994 young greenling and sablefish were delivered to chicks. 3. Endangered Steller sea lions have continued to decline, even since 1994. 4. Northern fur seals have continued to increase since they first bred in 1980.

Calkins, D., Becker, E., Spraker, T., & Loughlin, T. (1994). Impacts on Steller Sea Lions. In *Marine Mammals and the Exxon Valdez.* T. Loughlin (Ed.), <u>https://doi.org/10.1016/B978-0-12-456160-1.50014-X</u> Our study began in June and July 1989 with aerial surveys of rookeries and haulout sites in the area affected by the EVOS. Surveys were also conducted in the remainder of the species' range that year (Loughlin et al. 1992). Beaches were searched and animals were collected and sampled for toxicological and histological impacts from the spilled oil. Recognizing the severe decline in sea lion abundance over much of the affected area, we attempted to measure changes beyond that which could be attributed to the ongoing decline. We used two approaches to measure effects of the spill on sea lions. The first was designed to detect effects at the population level and included assessment of sea lion numbers and their distribution. The objective was to determine if sea lion abundance on rookeries and haulout sites had changed significantly as a result of the spill. The second approach was designed to detect effects at the individual level. Sixteen sea lions were collected and 12 were found dead during response and clean-up efforts (Zimmerman et al., Chapter 2). When practical, tissue samples were taken from these animals and tested for toxicological effects through histological and hydrocarbon analyses. The objective was to determine if sea lions were accumulating hydrocarbon contaminants in their tissues and if tissue damage had resulted. We suspected that the toxic effects of hydrocarbons could have accelerated the already high rate of premature pupping in sea lions noted by Pitcher and Calkins (1981) and Calkins and Goodwin (1988) for the Gulf of Alaska.

Calkins, D. G., McAllister, D. C., Pitcher, K. W., & Pendleton, G. W. (1999). Steller Sea Lion Status and Trends in Southeast Alaska: 1979-1997. *Marine Mammal Science*, 15(2), 462-477. <u>https://doi.org/10.1111/j.1748-7692.1999.tb00813.x</u>

Steller sea lion (*Eumetopias jubatus*) numbers in the United States declined by about 75% over the past 20+ yr. They are classified, under the U.S. Endangered Species Act, as "threatened" in the eastern portion of their range and as "endangered" in the western portion. We analyzed trends in numbers of pup and non-pup Steller sea lions counted in Southeast Alaska between 1979 and 1997. Sea lion numbers, based on counts of pups on rookeries, increased by an average of 5.9% per year between 1979 and 1997. However, numbers of pups increased at a much slower rate (+1.7% per year) between 1989 and 1997. For counts of non-pup Steller sea lions we used models that controlled for the effects of date, time, and tide at the time of the survey to analyze trends. This technique reduced bias and increased precision of the resulting trend estimates. Numbers of sea lions were stable (+0.5%) between 1989 and 1996, based on counts of non-pups. We estimated the Southeast Alaska breeding population of Steller sea lions at about 19,000 animals of all ages in 1997, a level that is probably near the highest in recorded history.

Call, K. A., Fadely, B. S., Greig, A., & Rehberg, M. J. (2007). At-Sea and on-Shore Cycles of Juvenile Steller Sea Lions (*Eumetopias Jubatus*) Derived from Satellite Dive Recorders: A Comparison between Declining and Increasing Populations. *Deep-Sea Research Part II-Topical Studies in Oceanography*, 54(3-4), 298-310. <u>https://doi.org/10.1016/j.dsr2.2006.11.016</u>

We calculated the durations of time on-shore and at-sea for juvenile Steller sea lions (*Eumetopias jubatus*) using satellite dive recorders deployed between 2000 and 2002, and compared two genetically distinct populations; one increasing (eastern stock; n = 42) and one that experienced an 80% decline in population since the mid-1970s (western stock; n = 89). Data represented 24-h periods divided into 72 20-min increments indicating whether an animal was on-shore (dry) or at-sea (wet). Time apportioned between land and sea was described on a per-trip basis (rather than a 24-h cycle) and durations ranged

from 20 min to several days. We tested differences in the durations of on-shore and at-sea events among sex, geographic region, year, and age at capture using mixed-effects models. Animal identifier was included as a random effect to account for repeated measures on the same individual. Sea lions from the eastern Aleutian Islands, central Aleutian Islands, and central Gulf of Alaska hauled out just after sunrise, and departure times coincided with dusk. For Prince William Sound and Southeast Alaska animals, arrivals and departures occurred throughout the day and were not related to crepuscular period. Mean duration on-shore did not differ among sex, region, year or age, and was unrelated to previous trip duration. This may suggest a minimum rest period for juvenile Steller sea lions or that dependant animals are maximizing their time on-shore suckling. Time spent at-sea varied among individuals from both populations and development of maternal independence, inferred from significant increases in time spent at sea, occurred approximately 10 months later in individuals from Prince William Sound and Southeast Alaska than in the other regions, suggesting environmental and developmental differences among regions.

Chumbley, K., Sease, J., Strick, M., & Towell, R. (1997). *Field Studies of Steller Sea Lions (Eumetopias Jubatus) at Marmot Island, Alaska 1979 through 1994*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-77. Retrieved from https://www.afsc.noaa.gov/Publications/AFSC-77.

The Alaska Department of Fish and Game and the National Marine Fisheries Service conducted field studies of Steller sea lions (Eumeropias jubatus) on Marmot Island, Alaska, from 1979 through 1994. Marmot Island is one of 15 trend sites and four trend rookeries used to identify population trends in the central Gulf of Alaska. Prior to the 1970s Marmot Island was one of the largest Steller sea lion rookeries in Alaska. Since the 1970s numbers of non-pup (adults, sub-adults, and juvenile) sea lions observed on Marmot Island during the breeding season declined dramatically: 87.1% since 1979. From 1976 to 1994, non-pups declined 76.9% at the 14 other trend sites and 79.1% at the three other trend rookeries in the central Gulf of Alaska. The proportion of juvenile sea lions on Marmot Island also declined, from 15 to 35% of all nonpups during 1979 and 1983, respectively, to 5% or less during 1987 through 1994. The decline in pup numbers were commensurate with those for non-pups. From 1979 to 1994, pup numbers declined 88.1% at Marmot Island and 84.4% at the other three trend rookeries in the central Gulf of Alaska. From 1991 to 1994, pup production declined by 50.1% at Marmot Island and by 40-50% at two of the other central Gulf rookeries. Since 1979, four rookery sites on Marmot Island have either become haulouts or have been abandoned entirely. Non-pup counts were made from 12 through 29 June on Marmot Island since counts made during these dates were likely to be 90% or more of the maximum number of sea lions counted during the breeding season. The hours of 1100 to 1400 ADT or 0900 to 1700 ADT were optimal for observing 90% and 80%, respectively, of daily maximum counts. Optimal dates for counting pups were 29 June through 9 July. Beach 3Z, a rookery beach occupied by relatively few sea lions during the breeding season, was the preferred haul-out site from December through March or April. How and when sea lions make the fall and spring transitions between breeding season and non-breeding season distribution could not be determined. During June and July of 1987 and 1988, 751 pups (390 females, 361 males) were branded and tagged on Marmot Island. Through December 1994, 151 (20.1%: 78 females and 73 males) of these animals were resighted on 204 occasions. Most resightings (116 of 204: 56.9%) were from Marmot Island; an additional 33 resightings (16.2%) were from within a radius of about

DeMaster, D. P. (2009). Aerial Survey of Steller Sea Lions in Alaska, June-July 2009 and Update on the Status of the Western Stock in Alaska. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from https://repository.library.noaa.gov/view/noaa/18786

An aerial survey to assess Steller sea lion (*Eumetopias jubatus*) pup production in Alaska was conducted by the Alaska Fisheries Science Center (AFSC) from 24 June to 15 July 2009. A secondary objective was to survey adult and juvenile (non-pup) sea lions in southeast Alaska (part of the threatened eastern stock, or distinct population segment, DPS), and in the eastern and central Gulf of Alaska areas (part of the endangered western DPS) to further investigate seasonal movement of sea lions and ascertain its impact on determination of stock trends.

DeMaster, D. P. (2012). *Results of Steller Sea Lion Surveys in Aleutian Islands, Alaska, June 2012*. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from https://repository.library.noaa.gov/view/noaa/18788

Land-based and aerial surveys of Steller sea lions (*Eumetopias jubatus*) in the western Aleutian Islands (W ALEU) in Alaska were conducted by the Alaska Ecosystem Program (AEP), National Marine Mammal Laboratory (NMML), Alaska Fisheries Science Center (AFSC) in June 2012 (Figure 1). Landbased surveys (cliff counts of adult and juvenile (non-pup) sea lions and a ground count of live pups approximately 1 month old) were conducted at Buldir Island and at Cape Sabak, Agattu Island by AEPNMML aboard the USFWS RV Tiglax on 26-27 June 2012, while aerial surveys were conducted by AEP-NMML using a NOAA twin Otter aircraft on 25 June 2012. Due to persistent fog and low ceilings in the Aleutian Islands that precluded flights during most of the aerial survey period (17 June-9 July 2012), no sites east of 177°E were surveyed from the air in 2012. Survey and count methodologies in 2012 were identical to those used in 2011.

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

Sequential megafaunal collapse in the North Pacific Ocean: all 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.

Eberhardt, L. L., Sease, J. L., & DeMaster, D. P. (2005). Projecting the Trend of Steller Sea Lion Populations in Western Alaska. *Marine Mammal Science*, *21*(4), 728-738. https://doi.org/10.1111/j.1748-7692.2005.tb01262.x

This paper attempts to project the trends of Steller sea lion (*Eumetopias jubatus*) populations in six subdivisions of the western Alaska population. The overall Western Alaska population has declined dramatically since the 1970s. Trends in half of the areas appear to have leveled-off and possibly to be on the increase. Bootstrapping has been used to provide confidence intervals on predictions for the 2004 counts. For the three areas in which we expect increases, the 95% confidence intervals on predictions were: Eastern Gulf (2,430 - 3,740), Central Gulf (3,260 - 3,660) and Central Aleutians (5,160 - 6,580). The Western Gulf counts have been somewhat erratic, with a gradual rate of decrease (about 2176 per year) and wide confidence limits on a linear prediction (logarithmic scale) of 2,690 - 3,240. Trends in the Eastern Aleutians have been even more erratic, so that about all that can be inferred is that the population may be roughly stabilized. Only the Western Aleutians appear to be rapidly declining at about 10% per year, with a 95% confidence interval on a linear trend of 610 - 1,100. The predictions were made before the 2004 counts and are in reasonable accord with the 2004 counts. Age structure changes do not appear to provide a viable explanation for the changing trends.

Ferrero, R. C., & Fritz, L. W. (1994). Comparisons of Walleye Pollock, Theragra Chalcogramma, Harvest to Steller Sea Lion, Eumetopias Jubatus, Abundance in the Bering Sea and Gulf of Alaska. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC -43. Retrieved from https://repository.library.noaa.gov/view/noaa/6195

Steller sea lion, Eumetipias jubatus, counts made on rookeries in the Gulf of Alaska, Aleutian Islands, and the Bering Sea from 1976 to 1991 were compared to annual estimates of walleye pollock, Theragra Chalcogramma, harvest to examine possible relationships between Steller sea lion abundance and commercial pollock fishing. Comparisons were made between Steller sea lion counts and pollock fishery data from the sameyear and from 1 to 5 years prior. Two sets of study areas were used, one encompassing 60 nmi or 120 nmi blocks around six major rookeries and another with 13 sites defined by 20 nmi radius rings around major rookeries. Lacking accurate measures of local pollock biomass, harvest data were used as approximations of annual differences in pollock abundance. Following methods used in Loughlin and Merrick (1989), correlation coefficients werecalculated using a linear model and tested for significance using a 2-tailed null hypothesis (=0.05). However, since the data are probably not normally distributed, Kendall's coefficients of rank correlation were also calculated and tested for significance(=0.05).

Fritz, L., Brost, B., Laman, E., Luxa, K., Sweeney, K., Thomason, J., . . . Zeppelin, T.). (n.d.). A Re-Examination of the Relationship between Steller Sea Lion Diet and Population Trend Using Data from the Aleutian Islands. Manuscript.

Diet diversity and energy density have been directly linked with population trends of Steller sea lions (Eumetopias jubatus) in studies that spanned over 4,000 km of southern Alaska and utilized data collected in three different marine ecosystems. We chose to re-examine this relationship using data from a single ecosystem (Aleutian Islands) where there has been a strong west-to-east gradient in population trend between 1990 and 2015, yet evidence of a similar diet throughout the region. Hard parts of prey sieved from 2,913 fecal samples (scats) collected at terrestrial rookeries and haulouts in February through September 1990-2012 were identified to the lowest possible taxa and occurrences were aggregated into 14 prey groups. Diet and trend (June-July 1978-2015 counts of adults and juveniles) data were analyzed spatially (5 areas) and temporally by season (breeding season: May-August; non-breeding season: Feb April, September) and decade (1990s: 1990-1999; 2000s: 2000-2012). Diets during the breeding season 1990-2012 were dominated by Atka mackerel (Pleurogrammus monopterygius) throughout the Aleutian Islands and also had low diversity scores, a result that is consistent with previous studies. However, where breeding season diet diversity metrics were the greatest, population counts were essentially stable. Nonbreeding season diets had higher diversity scores than breeding season diets (they were actually similar in diversity to summer diets described for southeast Alaska and the Kodiak archipelago) and had greater spatial and decadal variability. Throughout most of the study period, diet diversity and energy density metrics were similar in the three westernmost Aleutian areas, where population counts declined throughout the course of the study, and the easternmost area, where population trends improved significantly. They differed in the 2000s nonbreeding season, when in the three western areas, the frequency of occurrence (FO) of Atka mackerel was half that of the 1990s, while the FO of smooth lumpsuckers (Aptocyclus ventricosus) increased. This greatly reduced the estimated non-breeding season diet energy density in the 2000s, but was associated with a less steep population decline than the 1990s. We compared traditional deterministic diet diversity metrics (that are assumed without error) with diversity scores based on an occupancy model that accounts for differences in sample size and uncertainty in prey group detection. This analysis indicated that there was no significant change in diet diversity over the 23-y study period, nor any significant differences across the Aleutian Islands, results that are consistent with prey abundance data from nine groundfish bottom trawl surveys conducted over the same period. While studies of diet detail what Steller sea lions have eaten and provide an estimate of their energy intake, they provide only limited information on the energy expended to obtain their food or the consequences of their diet and foraging ecology on individual or population fitness. In the Aleutians, it is the latter parameters that appear to have a much larger impact on reproduction and survival, and ultimately population trend, than the suite of species consumed.

Fritz, L., Lynn, M., Kunisch, E., & Sweeney, K. (2008). Aerial, Ship and Land-Based Surveys of Steller Sea Lions (Eumetopias Jubatus) in Alaska, June and July 2005–2007. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-183. Retrieved from <u>https://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-183.pdf</u>

The National Marine Fisheries Service (NMFS) conducted aerial, land, and shipbased surveys of Steller sea lions (*Eumetopias jubatus*) in Alaska during June and July 2005, 2006, and 2007. Surveys were timed

to assess trends in pup production (late June through mid-July) or abundance of adults and juveniles (non-pups; early through late June). The aerial photographic survey conducted in 2005 provided the first estimate of Steller sea lion pup (newborn) production at all rookeries and major haulouts in Alaska in a single year (n = 15,460; 5,510 in southeast Alaska, and 9,950 within the range of the western stock of Steller sea lion in Alaska (west of 144°W)). Pups were also surveyed during ship and land-based surveys at selected terrestrial locations in 2005 and 2007. Aerial surveys to count non-pups on terrestrial sites within the range of the western stock were conducted in both 2006 and 2007, but neither resulted in a range-wide assessment because of delays caused by weather, maintenance, and issuance of scientific permits. The non-pup aerial survey conducted in 2007 was the first to use both vertical digital and medium-format film photography (both with forward-motion compensation), allowing multiple comparisons of counts at the same sites.

Fritz, L., Sweeney, K., Johnson, D., Lynn, M., Gelatt, T., & Gilpatrick, J. (2013). Aerial and Ship-Based Surveys of Steller Sea Lions (Eumetopias Jubatus) Conducted in Alaska in June-July 2008 through 2012, and an Update on the Status and Trend of the Western Distinct Population Segment in Alaska. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from https://repository.library.noaa.gov/view/noaa/4410

There is strong evidence that both the western and eastern distinct population segments (DPSs) of Steller sea lion (*Eumetopias jubatus*) increased in overall abundance in Alaska between 2000 and 2012. Counts of both non-pups (adults and juveniles) and pups during the breeding season in the western DPS were lowest in 2000, and increased at average rates of 1.67% per year (95% credible interval of 1.01-2.38% per year) and 1.45% per year (0.69-2.22% per year), respectively through 2012. However, there was considerable regional variability in non-pup and pup trends in 2000-2012 across the western DPS, with strong evidence of increases in three of the four regions east of Samalga Pass (eastern and western Gulf of Alaska, and eastern Aleutian Islands; ranges of 2.39% per year to 4.51% per year for non-pups and 3.03% per year to 3.97% per year for pups) being offset somewhat by both weak and strong declines in the two regions west of Samalga Pass (central and western Aleutian Islands; slow, uncertain declines in the central [-0.56% per year and -0.46% per year for non-pups and pups, respectively] and steep, certain declines in the western Aleutians [-7.23% per year and -9.36% per year for non-pups and pups, respectively]). Within the central Aleutian Islands, non-pup and pup trends varied east and west of 177°W (roughly Tanaga Pass): in the two rookery cluster areas to the east, trends were generally positive (0.51% per year and 2.25% per year for non-pups, and 2.56% per year and 0.45% per year for pups), while to the west, there was strong evidence of decline (-4.48% per year and -3.24% per year for non-pups, and -4.83% per year and -1.74% per year for pups). In southeast Alaska (eastern DPS of Steller sea lion), both non-pup and pup counts increased between 2000 and 2010, continuing the upward trend begun in the mid-1970s.

Fritz, L., Sweeney, K., Lynn, M., Gelatt, T., Gilpatrick, J., & Towell, R. (2016). Counts of Alaska Steller Sea Lion Adults and Juvenile (Non-Pup) Conducted on Rookeries and Haulouts in Alaska Aleutian Islands, Bering Sea, and Others from 1904-01-01 to 2015-07-18. <u>https://doi.org/10.7289/V54F1NP1</u>

This dataset contains counts of adult and juvenile (non-pup) Steller sea lions on rookeries and haul-outs in Alaska made between 1904 and 2015. Non-pup counts have been conducted throughout the year. Breeding season (June-mid July) non-pup counts are used for population trend analysis, while counts at

other times are used for analyses of distribution and for other purposes. Non-pups are counted from the ground (by walking along the rookery), from cliff-side overlooks, and from aerial imagery (oblique and vertical orientation). Non-pup counts represent only a fraction of the total number of animals that may use a site. Sea lions haulout less frequently in winter than in summer; thus, winter counts represent a smaller fraction of the total population than summer counts.

Fritz, L., Sweeney, K., Towell, R., & Gelatt, T. (2015). Results of Steller Sea Lion Surveys in Alaska, June-July 2015. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/18789</u>

Aerial, ship, and land-based surveys to count Steller sea lion (*Eumetopias jubatus*) pups (~1 mo old) and non-pups (adults and juveniles ≥ 1 year old) on terrestrial rookery and haulout sites in Alaska were conducted by the MML in June-July 2015. The manned aerial survey was conducted from 24 June to 8 July in southeast Alaska north of Dixon Entrance through the Semidi Islands in the central Gulf of Alaska (between 132°W and 158°W), as well as in northern Bristol Bay (eastern Bering Sea). Shipbased surveys, which included the use of an unmanned aircraft system (UAS), were conducted from 20 June to 1 July in the Aleutian Islands between 172°E and 165°W, and from 13-18 July in the Pribilof Islands (eastern Bering Sea). In addition, Steller sea lions were counted on Round Island in Bristol Bay by Alaska Department of Fish and Game (ADFG) scientists studying Pacific walrus (Odobenus rosmarus divergens) and on St. George (Pribilof) Island by MML scientists studying northern fur seals (Callorhinus ursinus).

Fritz, L., Sweeney, K., Towell, R., & Gelatt, T. (2016). Aerial and Ship-Based Surveys of Steller Sea Lions (Eumetopias Jubatus) Conducted in Alaska in June-July 2013 through 2015, and an Update on the Status and Trend of the Western Distinct Population Segment in Alaska. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-321. https://doi.org/10.7289/V5/TM-AFSC-321

Surveys conducted during June-July 2013 through 2015 provided strong evidence that both the western and eastern distinct population segments (DPSs) of Steller sea lion (*Eumetopias jubatus*) continued to increase in overall abundance in Alaska. Between 2003 and 2015, counts of western DPS non-pups (adults and juveniles) and pups in Alaska increased at average rates of 2.25% per year (95% credible interval of 1.16%-3.29% per year) and 2.26% per year (1.43%-3.03% per year), respectively. If observed non-pup counts continue to increase in the western DPS (in both Alaska and Russia) through 2018, then the DPS-wide and the first of two regional demographic criteria for down-listing could be satisfied. However, persistent decreasing trends in the western Aleutians and the western half of the central Aleutian Islands may preclude it from satisfying the second regional demographic down-listing criterion. Furthermore, satisfying the demographic de-listing criteria by 2033 appears to be unlikely given the magnitude of the recent decline in the western Aleutians (-61% for non-pups between 2003 and 2015).

Fritz, L. W. (2003). Alaska Fisheries Science Center Steller Sea Lion Research Project Reports, Fiscal Year 2002. Alaska Fisheries Science Center. AFSC Processed Report 2003-08. Retrieved from https://repository.library.noaa.gov/view/noaa/11970

This report summarizes the activities, and in some cases, the principal results of the Steller sea lion research activities undertaken in FY02 by the AFSC.

Fritz, L. W., & Gelatt, T. S. (2010). Surveys of Steller Sea Lions in Alaska, June-July 2010. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/18787</u>

NMFS conducted surveys in summer 2010 to assess abundance, trends, and distribution of Steller sea lions (*Eumetopias jubatus*) in Alaska. An aerial photographic survey to assess adult and juvenile (non-pup) sea lions was conducted from southeast Alaska through Amchitka Pass in the Aleutian Islands from 7 June to 3 July 2010 using a NOAA Twin Otter aircraft. A second aerial survey was conducted from 10-13 July 2010 from the southwestern tip of the Kenai Peninsula through southeast Alaska to obtain a replicate, 'late' non-pup count to assess movement between the threatened eastern and endangered western distinct population segments (DPSs, or stocks) during the breeding season. An additional objective during the aerial surveys was to estimate pup production at sites surveyed at least 10 days after the mean sea lion birth date (which ranges between 4-14 June in Alaska). NMFS also counted pups and non-pups (on-site counts) at five rookeries and haulouts in the western Aleutian Islands on 22-24 June and counted pups at the Walrus Island rookery (near the Pribilof Islands in the Bering Sea) on 16 July using the USFWS RV Tiĝlâx.

 Hastings, K., Rehberg, M., O'Corry-Crowe, G., Pendleton, D., Jemison, L., & Gelatt, T. (2019).
Demographic consequences and characteristics of recent population mixing and colonization in Steller sea lions, Eumetopias jubatus. Manuscript submitted for publication.

Steller sea lions Eumetopias jubatus are composed of two genetically distinct metapopulations (an increasing "eastern" and a reduced and endangered "western" population, or stock for management purposes) that are only recently mixing at new rookeries in northern Southeast Alaska (SEAK), east of the current stock boundary. We used mark-recapture models and 18 years of resighting data of over 3,500 individuals marked at the new rookeries and at neighboring long-established rookeries in both populations to (1) examine morphology, survival and movement patterns of pups born at new rookeries based on whether they had mitochondrial DNA haplotypes from the western- or eastern-population (mtW or mtE), (2) examine survival effects of dispersal to the eastern stock region for western animals, and (3) estimate minimum proportions of animals with western genetic material in regions within SEAK. Pups born at new rookeries with mtW had slightly reduced body condition, similar mass, and reduced first-year survival (~ - 10%) compared to pups with mtE. MtW pups remained near or within their natal area whereas mtE pups ranged more widely, including more to the sheltered waters of Southeast Alaska's Inside Passage. Fitness benefits for females born west of the stock boundary that dispersed to SEAK were observed as higher female survival (+0.127, +0.099, and +0.032 at ages 1,2, and 3+) and higher survival of their female offspring to breeding age (+0.15) compared to females west of the boundary. We estimated that a minimum of 38% and 13% of animals in the northern Outer Coast/Glacier Bay and Lynn Canal/Frederick Sound regions in SEAK, respectively, carry genetic information unique to the western population. Despite fitness benefits to western females that dispersed east, asymmetric dispersal costs and/or other genetic or maternal effects may limit the growth of the western genetic lineage at the new rookeries, and these factors require further study.

 Hastings, K. K., & Sydeman, W. J. (2002). Population Status, Seasonal Variation in Abundance, and Long-Term Population Trends of Steller Sea Lions (*Eumetopias Jubatus*) at the South Farallon Islands, California. *Fishery Bulletin*, 100(1), 51-62. Retrieved from https://spo.NMFS.noaa.gov/sites/default/files/pdf-content/2002/1001/has.pdf

We examined seasonal and annual variation in numbers of Steller (northern) sea lions (Eumetopias jubutus) at the South Farallon Islands from counts conducted weekly from 1974 to 1996. Numbers of adult and sub-adult males peaked during the breeding season (May-July), whereas numbers of adult females and immature individuals peaked during the breeding season and from late fall through early winter (September-December). The seasonal pattern varied significantly among years for all sexes and age classes. From 1977 to 1996, numbers present during the breeding season decreased by 5.9% per year for adult females and increased by 1.9% per year for subadult males. No trend in numbers of adult males was detected. Numbers of immature individuals also declined by 4.5% per year during the breeding season but increased by 5.0% per year from late fall through early winter. Maximum number of pups counted declined significantly through time, although few pups were produced at the South Farallon Islands. The ratio of adult females to adult males averaged 5.2:1 and declined significantly with each year, whereas no trend in the ratio of pups to adult females was discernible. Further studies are needed to determine if reduced numbers of adult females in recent years have resulted from reduced survival of juvenile or adult females or from changes in the geographic distribution of females.

Herreman, J. K., Blundell, G. M., & Ben-David, M. (2009). Evidence of Bottom-up Control of Diet Driven by Top-Down Processes in a Declining Harbor Seal Phoca Vitulina Richardsi Population. *Marine Ecology Progress Series, 374*, 287-300. <u>https://doi.org/10.3354/meps07719</u>

Two mechanisms of population control dominate most biological systems: bottom-up and top-down regulation. It is possible, however, that. top-down mediation may lead to bottom-up control of a population if predators simultaneously compete for the same prey. Harbor seal Phoca vitulina richardsi populations in Glacier Bay (GB) and Prince William Sound (PWS), Alaska, have declined drastically since the 1970s, with PWS recently stabilizing and GB continuing to decline. hypotheses for the declines include both bottom-up and top-down processes. We hypothesized that increased competition and predation risk are causing harbor seals in GB to forage on lower quality prey. We combined analyses of prey remains in scat and stable carbon and nitrogen isotope ratios in blood and hair to compare seal diets in these areas. Seal diets in GB and PWS varied spatially and temporally due to changes in resource availability and sexual segregation. Adults showed clear divergence in diet during specific times of the year in both areas. Sexual segregation of diet in GB was most prevalent during sprung and fall, while in PWS segregation was greatest during late summer. Diet of seals in PWS showed annual variation not found in GB, likely following prey cycles. In GB during summer, all seals switched to a diet with a lower fat: content, including more intertidal/demersal species such as rockfish and sculpin. This switch coincided with an increase in competitors and predators entering GB. The change in diet, combined with higher emigration of harbor seals out of GB, suggest that increased competition and risk of predation may contribute to overall population declines.

Holmes, E. E., Fritz, L. W., York, A. E., & Sweeney, K. (2007). Age-Structured Modeling Reveals Long-Term Declines in the Natality of Western Steller Sea Lions. *Ecological Appliations*, *17*(8), 2214-2232. <u>https://doi.org/10.1890/07-0508.1</u> Since the mid-1970s, the western Steller sea lion (Eumetopias jubatus), inhabiting Alaskan waters from Prince William Sound west through the Aleutian Islands, has declined by over 80%. Changing oceanographic conditions, competition from fishing operations, direct human-related mortality, and predators have been suggested as factors driving the decline, but the indirect and interactive nature of their effects on sea lions have made it difficult to attribute changes in abundance to specific factors. In part, this is because only changes in abundance, not changes in vital rates, are known. To determine how vital rates of the western Steller sea lion have changed during its 28-year decline, we first estimated the changes in Steller sea lion age structure using measurements of animals in aerial photographs taken during population surveys since 1985 in the central Gulf of Alaska (CGOA). We then fit an age-structured model with temporally varying vital rates to the age-structure data and to total population and pup counts. The model fits indicate that birth rate in the CGOA steadily declined from 1976 to 2004. Over the same period, survivorship first dropped severely in the early 1980s, when the population collapsed, and then survivorship steadily recovered. The best-fitting model indicates that in 2004, the birth rate in the central Gulf of Alaska was 36% lower than in the 1970s, while adult and juvenile survivorship were close to or slightly above 1970s levels. These predictions and other model predictions concerning population structure match independent field data from mark-recapture studies and photometric analyses. The dominant eigenvalue for the estimated 2004 Leslie matrix is 1.0014, indicating a stable population. The stability, however, depends on very high adult survival, and the shift in vital rates results in a population that is more sensitive to changes in adult survivorship. Although our modeling analysis focused exclusively on the central Gulf of Alaska, the western Gulf of Alaska and eastern Aleutians show a similar pattern of declining pup fraction with no increase in the juvenile, or pre-breeding, fraction. This suggests that declining birth rate may be a problem for western Steller sea lions across the Gulf of Alaska and into the Aleutian Islands.

Isono, T., Burkanov, V. N., Ueda, N., Hattori, K., & Yamamura, O. (2010). Resightings of Branded Steller Sea Lions at Wintering Haul-out Sites in Hokkaido, Japan 2003–2006. *Marine Mammal Science*, 26(3), 698-706. <u>https://doi.org/10.1111/j.1748-7692.2009.00367.x</u>

The article presents a study concerning the systematic resigning efforts of branded Steller sea lions (SSLs) at Ofuyu Point which was conducted in three winters in Hokkaido, Japan from 2003 to 2006. It presents a chart depicting the variations in the number of SSLs each year from November to May. It states that the study is supported by the Japan Fisheries Agency.

Jemison, L. A. (1992). Abundance and Distribution of Marine Mammals in Northern Bristol Bay. A status report of the 1991 marine mammal monitoring effort at Togiak National Wildlife Refuge. Retrieved from <u>http://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/research_pdfs/marine_mammals_northern_bristol_bay.pdf</u>

The number of walruses hauled out at Cape Peirce was the highest since 1988, with a peak count of 4008 animals on 12 September. Fifteen haulout peaks occurred from June through September, with haulout periods ranging from 6 to 13 days. Opportunistic censuses of walrus haulout beaches at Cape Newenham produced a high count of 870 on 5 July. Fluctuations in haulout numbers at Cape Peirce and Round Island from 1987 through 1991 may be the result of disturbance from of yellow-fin sole vessels in northern Bristol Bay. Walrus carcasses on the beach were counted and mapped during coastal survey

flights in northern Bristol Bay. The highest concentration of carcasses occurred along the southwestern shores of the Nushagak Peninsula. other concentrations occurred along the eastern shores of Hagemeister Island. The maximum number of carcasses observed during a single survey was 49. Nanvak Bay near Cape Peirce continues to be the largest seal haulout in northern Bristol Bay. A peak count of 400 seals in Nanvak Bay was recorded on 3 September. This peak is significantly lower than the peak count of 3100 in 1975. This decline parallels harbor seal population trends throughout the state of Alaska; the causes of the decline are unknown and must be further investigated. Both spotted and harbor seal pups were observed, with a high of 21 pups recorded on 25 June. In cooperation with the National Marine Fisheries Service, six surveys were flown of the northern Bristol Bay harbor seal haulout sites from 23 August through 5 September. The high count for the surveys was 953 seals on 29 August, with a mean count of 750 animals. Cape Newenham continues to be an important haulout for the threatened northern sea lion. Monitoring effort continued in 1991 in cooperation with NMFS. The haulout was surveyed from the air and ground between late April and late October. The peak count of 1295 occurred on 16 May. Approximately 30 sea lions were also observed in December during an unrelated flight. Composition of sea lions at the haulout was variable, with the percent juveniles ranging from 8-23 throughout the season. Eight tagged sea lions were seen during ground observations; numbers were read from three of the tags.

Johnson, D. (2018). Trends of Nonpup Survey Counts of Russian Steller Sea Lions. Memorandum for T. Gelatt and J. Bengtson, June 6, 2018. National Marine Fisheries Service Alaska Region.

[NO ABSTRACT AVAILABLE]

Kastelein, R., & Weltz, F. (1990). Distribution, Abundance, Reproduction and Behaviour of Steller Sea Lions (*Eumetopias Jubatus*) in Prince William Sound, Alaska. *Aquatic Mammals, 15*, 145-157. Retrieved from

https://www.aquaticmammalsjournal.org/share/AquaticMammalsIssueArchives/1990/Aquatic Mammals 15_4/Kastelein_Weltz.pdf

This study is about the distribution, abundance, reproduction and behaviour of Steller sea lions (*Eumetopias jubatus*) on their rookery and haulout areas in Prince William Sound, Alaska in the period June-July 1988.

Kusin, A. E. (2005). Spatial Structure and Age-Sex Composition of Steller Sea Lions on Tuleny Island (Sakhalin Region). *Transactions of the Pacific Research Fisheries Centre*, 143, 97-107. Retrieved from

https://search.proquest.com/asfa/docview/19343196/817A77452A874FDDPQ/1?accountid=28 258

Reproductive group of Steller sea lions on Tyuleny Island is represented by two harem rookeries and two hauling grounds placed on capes of the Island. About 80 % of the sea lions concentrate in harem rookeries in reproductive period, and about 20 % are on bachelors sites. Females prevail on harem sites (> 80 %), but males -- in hauling grounds (> 78 %). The number of bulls on harem sites is twice lower than the number of indifferent bulls on bachelors grounds. Halfbulls are absent on harem sites, and the number of young males and bachelors is insignificant. These age groups of males concentrate on the

capes basically. The age-sex structure of the sea lions is similar on both harem sites. Bulls are 5-6 % (4-5 % harem ones); females 85-88 %; others about 6 % (young sea lions 2-3 %, bachelors 3-4 %). The agesex structure on the capes is more variable: bulls are 7-13 %, halfbulls 11-12 %, others (mainly bachelors) 71-82 %. Generally, the structure of harem rookeries is more ordered then the structure of the whole herd of Steller sea lions because of certain mechanisms of its regulation.

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. <u>https://doi.org/10.1134/s1063074011070054</u>

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 onethird 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 lony 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. (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. <u>https://doi.org/10.1134/s1063074014070037</u>

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.

Loughlin, T. R. (2002). *Steller Sea Lion Pup Counts Bogoslof to Attu Islands 24 June-10 July 2002*. National Marine Fisheries Service Alaska Fisheries Science Center.

The purpose of this ship-based study was to continue to monitor the status and trends of the western stock of Steller sea lions (*Eumetopias jubatus*) by counting and measuring pups at rookeries during the breeding season from Dutch Harbor to the end of the Aleutian Islands chain. Concomitant with this survey, others from the National Marine Mammal Laboratory (NMML) did similar ship-based surveys from Dutch Harbor east to Prince William Sound on the USFWS vessel Tiglax; the Alaska Department of Fish and Game surveyed from Prince William Sound to Forester Island, and conducted brand-resight studies in British Columbian waters. Just prior to the ship-based studies, NMML biologists conducted a 35 mm photographic aerial survey of rookeries and haulout sites in the state in coordination with the NMFS Southwest Fisheries Science Center who conducted medium-format aerial photography of the Alaskan rookeries and haulout sites. Also, the NMML had observers at three sites (Ugamak, Marmot, and Fish islands) and the ADFG had observers at Lowri Island (Forester Is.) to monitor survival of marked animals and to conduct population assessments during June-August. Lastly, the NMML contracted with Calkins Wildlife Consulting and with North Pacific Wildlife Consultants to conduct ship and land-based surveys and to measure sea lion pups in Russian waters. All these studies will provide a basis for assessing the status and trends of Steller sea lion pup production in Alaska and Russia during 2002

Loughlin, T. R., Perlov, A. S., & Vladimirov, V. A. (1992). Range-Wide Survey and Estimation of Total Number of Steller Sea Lions in 1989. *Marine Mammal Science*, 8(3), 220-239. <u>https://doi.org/10.1111/j.1748-7692.1992.tb00406.x</u>

The first range-wide survey of Steller (northern) sea lions (*Eumetopias jubatus*) was completed in 1989 with a total of 68,094 adult and juvenile (nonpup) Steller sea lions counted. This total count includes 10,000 in Russia (15% of the range-wide count), 47,960 in Alaska (70%), 6,109 in British Columbia (9%), 2,261 in Oregon (3%), and 1,764 in California (3%). A range-wide pup count was not obtained. We estimated the 1989 world population based on a calculation for total pups and obtained a range-wide estimate of 116,000 total animals, or about 39–48% of the 240,000-300,000 estimated 30 yr ago.

Loughlin, T. R., Rugh, D. J., & Fiscus, C. H. (1984). Northern Sea Lion Distribution and Abundance: 1956-80. *The Journal of Wildlife Management*, 729-740. <u>https://doi.org/10.2307/3801420</u>

The present distribution and abundance of the northern sea lion (Eumetopias jubatus) was determined from surveys made between 1975 and 1980 and compared to estimates made approximately 20 years earlier. The previous population estimate of 240,000-300,000 is similar to our estimate of 245,000-290,000. Declines appear to have occurred in the eastern Aleutian Islands, Pribilof Islands, and near Kodiak Island in the Gulf of Alaska. Increases may have occurred principally in the western and central Aleutians and west of Kodiak Island. Seasonal movements and indirect and direct effects by humans are considered the likely causes for regional changes in distribution and abundance.

Loughlin, T. R., Vladimirov, V. A., Perlov, A. S., & National Marine Mammal, L. (1990). Survey of Northern Sea Lions (Eumetopias Jubatus) in the Gulf of Alaska and Aleutian Islands During June 1989. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS F/NWC 176. Retrieved from

ftp://ftp.library.noaa.gov/noaa_documents.lib/NMFS/TM_NMFS_FNWC/TM_NMFS_FNWC_176 .pdf

This report summarizes a 1989 aerial survey conducted to determine if the abundance decline is continuing in Alaska.

Maniscalco, J. M. (2018). NOAA/NMFS 5-Year Status Review for Endangered Steller Sea Lions – Comments.

[NO ABSTRACT AVAILABLE]

Maniscalco, J. M., Springer, A. M., & Parker, P. (2010). High Natality Rates of Endangered Steller Sea Lions in Kenai Fjords, Alaska and Perceptions of Population Status in the Gulf of Alaska. *PLoS ONE*, 5(4), 1-9. https://doi.org/10.1371/journal.pone.0010076

Steller sea lions experienced a dramatic population collapse of more than 80% in the late 1970s through the 1990s across their western range in Alaska. One of several competing hypotheses about the cause holds that reduced female reproductive rates (natality) substantively contributed to the decline and continue to limit recovery in the Gulf of Alaska despite the fact that there have been very few attempts to directly measure natality in this species. We conducted a longitudinal study of natality among individual Steller sea lions (n = 151) at a rookery and nearby haulouts in Kenai Fjords, Gulf of Alaska during 2003–2009. Multi-state models were built and tested in Program MARK to estimate survival, resighting, and state transition probabilities dependent on whether or not a female gave birth in the previous year. The models that most closely fit the data suggested that females which gave birth had a higher probability of surviving and giving birth in the following year compared to females that did not give birth, indicating some females are more fit than others. Natality, estimated at 69%, was similar to natality for Steller sea lions in the Gulf of Alaska prior to their decline (67%) and much greater than the published estimate for the 2000s (43%) which was hypothesized from an inferential population dynamic model. Reasons for the disparity are discussed, and could be resolved by additional longitudinal estimates of natality at this and other rookeries over changing ocean climate regimes. Such estimates would provide an appropriate assessment of a key parameter of population dynamics in this endangered species which has heretofore been lacking. Without support for depressed natality as the explanation for a lack of recovery of Steller sea lions in the Gulf of Alaska, alternative hypotheses must be more seriously considered.

Maniscalco, J. M., Springer, A. M., Parker, P., & Adkison, M. D. (2014). A Longitudinal Study of Steller Sea Lion Natality Rates in the Gulf of Alaska with Comparisons to Census Data. *PLoS ONE*, 9(11) <u>https://doi.org/10.1371/journal.pone.0111523</u>

Steller sea lion (*Eumetopias jubatus*) numbers in the Western Distinct Population Segment are beginning to recover following the dramatic decline that began in the 1970s and ended around the turn of the

century. Low female reproductive rates (natality) may have contributed to the decline and remain an issue of concern for this population. During the 2000s we found high natality among Steller sea lions in the Gulf of Alaska indicating a healthy population. This study extends these previous estimates over an additional three years and tests for interannual variations and long-term trends. We further examine the proportions of pups to adult females observed on the rookery and nearby haulouts during the birthing season to assess whether census data can be used to estimate natality. Open robust design multistate models were built and tested using Program MARK to estimate survival, resighting, and state transition probabilities in addition to other parameters dependent on whether or not a female gave birth in the previous year. Natality was estimated at 70% with some evidence of interannual variation but a long-term increasing or decreasing trend was not supported by the data. Bootstrap and regression comparisons of census data are not an appropriate proxy for natality in this species. Longitudinal studies of individual animals are an appropriate method for estimating vital rates in species with variable detection over time such as the Steller sea lion. This work indicates that natality remains high in this region and is consistent with a population in recovery.

Maschner, H. D. G., Trites, A. W., Reedy-Maschner, K. L., & Betts, M. (2014). The Decline of Steller Sea Lions (*Eumetopias Jubatus*) in the North Pacific: Insights from Indigenous People, Ethnohistoric Records and Archaeological Data. *Fish and Fisheries*, 15(4), 634-660. https://doi.org/10.1111/faf.12038

A number of hypotheses have been proposed to explain the most recent decline (1977-2012) of Steller sea lions (SSL; Eumetopias jubatus) in the Gulf of Alaska and Aleutian Islands. We examined hypotheses about fisheries competition, environmental change, predation, anthropogenic effects and disease using observations of modern Aleut and archaeological, ethnohistoric and ethnographic data from the western Gulf of Alaska and Aleutian Islands. These data indicate that Steller sea lion numbers have declined and recovered repeatedly over the past 4500 years and were last at critically low numbers during the 1870s-1930s. Steller sea lions appear to have been more abundant during the cool periods and lower during the warmer periods. Observations by local peoples, explorers, early government surveyors and biologists since the late 1800s suggest that low populations of SSL have been associated with high populations of Gadidae fishes (Pacific cod - Gadus macrocephalus and walleye pollock -Theragra chalcogramma) and are consistent with the ocean climate hypothesis to explain the decline of sea lions. They suggest that removals by people and killer whales (Orcinus orca) did not cause the sea lion declines, but could have compounded the magnitude of the decline as sea lion numbers approached low densities. Archaeological, anthropological and ethnohistorical analyses demonstrate that fluctuations have occurred in the North Pacific over hundreds to thousands of years and provide context for understanding the changes that occur today and the changes that will continue to occur in the future.

Mathews, E. A., Womble, J. N., Pendleton, G. W., Jemison, L. A., Maniscalco, J. M., & Streveler, G. (2011). Population Growth and Colonization of Steller Sea Lions in the Glacier Bay Region of Southeastern Alaska: 1970s-2009. *Marine Mammal Science*, *27*(4), 852-880. <u>https://doi.org/10.1111/j.1748-7692.2010.00455.x</u>

We estimated trends in numbers of Steller sea lions in the Glacier Bay region of the eastern population from the 1970s to 2009. We documented the colonization of several new haul-outs and the transition of

one haul-out (Graves Rocks) to a rookery, assessed seasonal patterns in distribution, and compared counts from different observation platforms. Sea lions increased in the region by 8.2%/yr (95% CI = 6.4%-10.0%), with the most growth at South Marble Island in Glacier Bay (16.6%/yr, 1991-2009) and rapid growth in Cross Sound. Seasonal patterns in the distribution of sea lions were likely influenced by new breeding opportunities and the seasonal availability of prey. Factors that likely contributed to the exceptional growth include availability of new habitat following deglaciation, immigration, redistribution, decreases in mortality, and ecosystem-level changes. The rapid increase in sea lion numbers in this region is of particular interest in light of dramatic declines in the western population and evidence that Steller sea lions from both the eastern and western populations colonized the Graves Rocks rookery. The colonization and rookery development in this dynamic area may signal the reversal of the reproductive isolation of the two populations.

McDermott, S. F., Haist, V., & Rand, K. M. (2016). Evaluating the Efficacy of Trawl Exclusion Zones by Estimating Local Atka Mackerel Abundance and Movement Patterns in the Central and Eastern Aleutian Islands. *Marine and Coastal Fisheries, 8*(1), 334-349. https://doi.org/10.1080/19425120.2015.1135218

Atka Mackerel Pleurogrammus monopterygius is the most abundant commercially exploited groundfish in the Aleutian Islands, Alaska. It is also the predominant prey of the endangered Steller sea lion *Eumetopias jubatus* in the Aleutians Islands range. In 1992, trawl exclusion zones (TEZs) that ranged from 10 to 20 nautical miles were established around rookeries to protect Steller sea lion prey abundance. This study examined the efficacy of the TEZs by estimating the movement and local abundance (10?20 nautical miles) of Atka Mackerel inside and outside of these zones using an integrated tagging model that incorporated independent data for tagging survival, recruitment, and tag reporting rates. Atka Mackerel were tagged, released, and recovered from 2000 to 2006 at four Aleutian Island locales, from both inside and outside of the TEZs. Atka Mackerel local abundance and their movement patterns across these harvest boundaries were estimated for all the study areas inside and outside the TEZs, and local exploitation rate by the fishery was calculated for each area open to fishing outside the TEZ boundary. In areas with high Atka Mackerel abundance and little movement from inside to outside the protection zones (e.g., Seguam Pass and Kiska Island), the TEZs were expected to work well to preserve the prey field for Steller sea lions. In areas of low Atka Mackerel abundance and frequent movement from the inside to the outside of the protection zone (e.g., Amchitka Island), the TEZs were expected to be less effective. Our study indicated that TEZs can be effective for preserving prey fields of Atka Mackerel for Steller sea lions, but each study area needs to be carefully evaluated in order to understand area-specific variations in abundance and movement patterns. Received October 21, 2014; accepted December 16, 2015

McDermott, S. F., Logerwell, E. A., Ortiz, I., & Haist, V. (2009). Fishery Interaction and Availability of Atka Mackerel Prey for Steller Sea Lions: Results from Local Abundance and Movement Study of Atka Mackerel. Retrieved from <u>http://www.ices.dk/sites/pub/CM%20Doccuments/CM-2009/J/J0309.pdf</u>

Atka mackerel (Pleurogrammus monopterygius) are the most abundant commercially exploited groundfish in the Aleutian Islands, Alaska. They display a highly aggregated patchy distribution centered around island passes and areas of high currents which is reflected in the fishery. Atka mackerel are batch spawners with males guarding nests demersally up to 6 months of the year. Females aggregate in large

schools close to the spawning grounds, presumably to feed. Atka mackerel is the predominant prey of the endangered Steller sea lion in the Aleutian Islands. 10- to 20-nautical mile trawl exclusion zones have been established around rookeries to protect prey abundance. This study estimated the movement and local abundance of Atka mackerel with a mark recapture experiment using an integrated tagging model. Atka mackerel were tagged, released, and recovered from 2000 - 2006 in 4 local areas inside and outside of trawl exclusion zones in the Aleutian Islands. Population abundance was examined with respect to Steller sea lion prey energetic requirements within the trawl exclusion zones. Atka mackerel local movement patterns across these harvest boundaries was related to local fishing patterns and the interaction between fishery and prey abundance was examined.

Mello, S. (1994). Status of the Steller Sea Lion, *Eumetopias Jubatus*, in Alaska. *Endangered Species Update*, *11*(12), 1. Retrieved from https://deepblue.lib.umich.edu/handle/2027.42/39317

Endangered species update summarizing the status of the Steller sea lion including reasons for the population declines, management actions, research program, and prospects for the future.

Merrick, R. L. (1997). Current and Historical Roles of Apex Predators in the Bering Sea Ecosystem. *Journal of Northwest Atlantic Fishery Science, 22,* 343-355. Retrieved from https://journal.nafo.int/Portals/0/1997-2/Merrick.pdf

Large population declines (>50%) since the early-1970s of some eastern Bering Sea and Aleutian Island apex predator populations (Steller sea lions, murres, and kittiwakes) suggest that major changes have occurred in the structure of the Bering Sea ecosystem. One cause of the decline in mammalian and avian predator populations may be a decrease in availability or abundance of preferred prey (e.g. capelin, juvenile walleye pollock). However, adult groundfish biomass has generally been at high levels, and periods of high adult groundfish biomass coincide with periods of decline of sea lion and seabird populations. Adult groundfish may, therefore, be out-competing other predators for their common prey (i.e. small schooling fish). Three factors may have led to increases in adult groundfish biomass in the southeastern Bering Sea, changes in environmental conditions, present commercial fishing practices, and predator release resulting from overharvesting of marine mammals and some fishes during 1955– 75. If the decline in whale and fur seal populations during 1955–75 contributed to the current high biomass of groundfish, then marine mammals once (but no longer) exerted a structuring effect on the Bering Sea ecosystem. The current high abundance of piscivorous adult groundfish in the eastern Bering Sea may, therefore, impede the recovery of marine mammal and bird populations to historical levels.

Merrick, R. L., Brown, R., Calkins, D. G., & Loughlin, T. R. (1995). A Comparison of Steller Sea Lion, *Eumetopias-Jubatus*, Pup Masses between Rookeries with Increasing and Decreasing Populations. *Fishery Bulletin*, 93(4), 753-758. Retrieved from <u>https://spo.NMFS.noaa.gov/content/comparison-stellar-sea-lion-eumetopias-jubatus-pup-masses-between-rookeries-increasing-and</u>

The Steller sea lion, *Eumetopias jubatus*, population in Alaska has decreased by 62% since the late 1970's (Merrick et al., 1987; Loughlin et al., 1992; Sease et al., 1993). Declines occurred at all 33 rookeries in the GulfofAlaska and Aleutian Islands, although numbers at five rookeries in Southeast Alaska and Oregon increased. The severity of the declines at affected rookeries led the National Marine

Fisheries Service (NMFS) to list the species as threatened throughout its range under the Endangered Species Act (1990). The proximate cause for the decline appears to be chronically reduced juvenile (ages 0-3 yr) survival. After the early 1980's, juveniles were in far lower abundance on rookeries than in the 1970's (Merrick et al., 1988; NMFSI). During the summers of 1987-88, 424 female pups were marked at the Alaska rookery on Marmot Island. According to the life table constructed for the area from data collected in the 1970's <York, 1994; Calkins and Pitcher2), close to 90 females should have survived to 1994. Biologists returning to the site from 1991 through 1994 have relocated less than 25 animals (NMFSI). York (994) found that changes in the population size and the age structure ofadult females were consistent with a decrease in juvenile survival. Also, the mass of juvenile animals in the 1980's was significantly less than that found in the 1970's (Calkins and Goodwin3).

Merrick, R. L., Calkins, D. G., & McAllister, D. (1992). *Aerial and Ship-Based Surveys of Steller Sea Lions* (*Eumetopias Jubatus*) in Southeast Alaska, the Gulf of Alaska, and Aleutian Islands During June and July 1991. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-1. Retrieved from https://repository.library.noaa.gov/view/noaa/6071

Aerial and ship-based surveys of Steller sea lions (Eumetooias iubatus) were conducted during June and July 1991 from Forrester Island in Southeast Alaska to Attu Island in the Aleutian Islands. A total of 36,459 adult and juvenile sea lions were counted at 103 trend sites in this area; this is 4.4% less than in 1990 (38,154) and represents a 68.8% decrease from 1979 (116,804). In the Kenai to Kiska index area, 21,737 sea lions were counted at trend sites, 4.5% less than in 1990 (22,754), and a 75.7% decrease from the 1970s count (89,364). In the past year, trend site numbers increased in Southeast Alaska (from 7,629 to 7,715), the eastern Aleutian Islands (from 3,801 to 4,231), and the western Aleutian Islands (from 2,327 to 2,411). Numbers decreased in the central Aleutian Islands (from 7,988 to 7,499). Decreases also occurred in the eastern (from 5,444 to 4,596), central (from 7,050 to 6,273), and western (from 3,915 to 3,734) Gulf of Alaska. Statistically significant declining trends in Alaskan adult and juvenile numbers have occurred since the late 1970s, except in the eastern Gulf of Alaska and Southeast Alaska, since 1985 in all of the Kenai to Kiska area except the eastern Aleutian Islands, and since 1989 in the central and eastern Gulf of Alaska. Differences between 1990 and 1991 were not statistically significant. From 1990 to 1991, pup numbers declined 13.1% at seven Kenai to Kiska rookeries (from 4,258 to 4,821).

Merrick, R. L., Ferm, L. M., Everitt, R. D., Ream, R. R., & Lessard, L. A. (1991). Aerial and Ship-Based Surveys of Northern Sea Lions (Eumetopias Jubatus) in the Gulf of Alaska and Aleutian Islands During June and July 1990. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS F/NWC 196. Retrieved from https://repository.library.noaa.gov/view/noaa/5984

Aerial and ship-based surveys of northern sea lions (*Eumetopias jubatus*) conducted during June and July 1990 from the Kenai Peninsula to Kiska Island in the Aleutian Islands, reconfirm findings of the 1989 survey that the area's population has declined significantly since 1956. Declines occurred at all regions and sites during the 1956-89 period. The total number of sea lions counted in the Kenai to Kiska study area, however, did not change significantly either in the study area or in any region between 1989 and 1990. Adults and juveniles counted at 77 trend sites decreased from 105,289 in 1956-59 to 55,824 in 1985 and then to 23,064 and 22,754 in 1989 and 1990, respectively. Between 1989 and 1990 the counts of adults and juveniles increased in the eastern Aleutian Islands (from 3,032 to 3,801) and central Aleutian Islands (from 7,572 to 7,988). The total count of sea lions in the western Gulf of Alaska

remained essentially unchanged from 3,908 in 1989 to 3,915 in 1990. Sea lion numbers decreased in the central Gulf of Alaska between 1989 and 1990, from 8,552 in 1989 to 7,050 in 1990. Numbers of live pups counted at 19 major rookeries located from Chirikof Island to Kiska Island decreased between 1985 (21,391) and 1990 (6,871). However, at the only three rookeries counted in 1989, pup numbers increased by 29% between 1989 and 1990 at Bogoslof and Seguam Islands, while decreasing by 25% at Kiska Island.

Merrick, R. L., Loughlin, T. R., & Calkins, D. G. (1987). Decline in Abundance of the Northern Sea Lion, *Eumetopias-Jubatus*, in Alaska, 1956-86. *Fishery Bulletin, 85*(2), 351-365. Retrieved from <u>https://spo.NMFS.noaa.gov/content/decline-abundance-northern-sea-lion-eumetopias-jubatus-alaska-1956-86</u>

Aerial, ship, and onshore surveys were conducted to assess the abundance of northern sea lions, Eumatopias jubatus, in southwestern Alaska. from the central Gulf of Alaska through the central Aleutian Islands, during June-July of 1984-86. Counts of northern sea lions from these surveys were compared with counts made in 1956-62 and 1975-79. These data indicated that the number of adults and juveniles onshore declined 52% from 140,000 animals in 1956-60 to 68,000 in 1985-an annual rate of decline of at least 2.7%. Numbers have declined throughout the region, with the greatest declines in the eastern Aleutian Islands (79%) and the least in the central Aleutian Islands (8%). This was not due to emigration because significant increases have not been noted elsewhere. Between the 1960s and mid-1970s, there were large decreases in the eastern Aleutian Islands and western Gulf of Alaska, and a major increase in the central Aleutian Islands. Beginning in the late 1970s declines occurred in all areas. The causes of the declines are unknown, but they may be associated with disease, prey availability or quality, or a combined effect of these and other factors. Factors which may contribute to the declines include the pre-1973 commercial harvests, entanglement of juveniles in marine debris, incidental takes in fisheries, and killing by fishermen.

Merrick, R. L., Maminov, M. K., Baker, J. D., & Makhnyr, A. G. (1990). *Results of U.S.-U.S.S.R. Joint Marine Mammal Research Cruise in the Kuril and Aleutian Islands 6 June-24 July 1989*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS F/NWC 177. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/5918</u>

As part of the U.S. -U.S.S.R. Agreement on Cooperation in the Field of Environmental Protection, U.S. and Soviet biologists conducted surveys for northern sea lions (*Eumetopias jubatus*) and other species of marine mammals and birds in the Kuril and Aleutian Islands from 6 June to 24 July 1989. These surveys indicated that previously established declines in sea lion abundance have continued in both areas. Kuril Island pup numbers have declined by 26% since 1983, while pup numbers at Seguam and Bogoslof Islands have declined 79 and 66%, respectively, since 1985. Twelve of the Kuril Islands were surveyed for northern sea lions and 3,215 adults and juveniles and 1,479 pups were seen on land. In addition, 692 sea otters (Enhydra lutris, including 149 pups), 360 harbor seals (Phoca vitulina, 16 pups), and 78 spotted seals (Phoca largha) were seen. Surveys in the Aleutian Islands at Kiska, Seguam, and Bogoslof Islands found 3,467 adult and juvenile sea lions and 1,497 pups. Also seen were 130 harbor seals (13 pups), 442 otters (89 pups), and 719 northern fur seals (99 pups). Northern sea lion pups (739) were flipper tagged and branded in the Kuril Islands. Ten adult female northern sea lions were anesthetized, with radio tags applied to five. Tissue samples were collected for disease and contaminant studies from 18 animals (7 sea otters, 8 sea lions, 1 northern fur seal, 1 harbor seal, 1 spotted seal).

Milette, L. L. (1998). *Reproductive Life History, Survival and Site Fidelity of Steller Sea Lions (Eumetopias Jubatus) in Alaska*. University of British Columbia Fisheries Center. Alaska Department of Fish and Game, Wildlife Conservation Division.

Steller sea lions (*Eumetopias jubatus*) were classified as threatened under the U.S. Endangered Species Act in 1990 after the world population dropped from about 300,000 in 1980 (Loughlin et al., 1992) to under 100,000. In 1997, the western stock of Steller sea lions, west of Cape Suckling (144° west longitude), was reclassified as endangered because of the continuing population decline in that region (U.S. Federal Register: 62:24345-243.55). Although the eastern stock is not declining, it conservatively retains a threatened status. Food limitation continues to be a leading hypothesis to explain the Steller sea lion decline. Nutritional stress caused by either a change in the quantity or quality of available prey can cause mortality or reproductive failure (Loughlin and Merrick, 1989 cited in Merrick, 1995). During the 1983 El Niño event, many pinniped populations exhibited these responses (e.g. Trillmich and Dillinger, 1991; Francis and Heath, 1991). Moreover, evidence suggests that all female mammals in poor condition suppress reproduction (Wasser and Barash, 1983). Therefore, we might expect females in the area of decline to have more reproductive failures if they are undernourished whereas severe food limitations could additionally cause higher mortality rates if individuals are not meeting their metabolic requirements.

Miller, A. J. (2006). The Climate-Ocean Regime Shift Hypothesis of the Steller Sea Lion Decline in Alaska. PICES 15 Annual Meeting. Retrieved from https://meetings.pices.int/publications/presentations/PICES 15/Ann15 W8/W8 Miller.pdf

Declines of Steller sea lion populations in the Aleutian Islands and Gulf of Alaska could be a consequence of physical oceanographic changes associated with the 1976-77 climate regime shift. Changes in ocean climate are hypothesized to have affected the quantity, quality and accessibility of prey, which in turn may have affected the rates of birth and death of sea lions. Recent studies of the spatial and temporal variations in the ocean climate system of the North Pacific support this hypothesis. Ocean climate changes appear to have created adaptive opportunities for various species that are preyed upon by Steller sea lions at mid-trophic levels. The east-west asymmetry of the oceanic response to climate forcing after 1976-77 is consistent with both the temporal aspect (populations decreased after the late 1970's) and the spatial aspect of the decline (western, but not eastern, sea lion populations decreased). Shifts in ocean climate are the most parsimonious underlying explanation for the broad suite of ecosystem changes that have been observed in the North Pacific Ocean in recent decades.

Mueter, F. J., & Norcross, B. L. (2000). Species Composition and Abundance of Juvenile Groundfishes around Steller Sea Lion *Eumetopias Jubatus* Rookeries in the Gulf of Alaska. *Alaska Fishery Research Bulletin, 7*, 33-43. Retrieved from <u>https://www.cf.adfg.state.ak.us/FedAidPDFs/AFRB.07.033-043.pdf</u>

We conducted bottom trawl surveys to determine species composition and abundance of juvenile groundfish communities around 6 Steller sea lion rookeries in the western Gulf of Alaska from 1994 to 1996. Overall, the most abundant species in our collections were rock sole Pleuronectes bilineatus, walleye pollock Theragra chalcogramma, Pacific halibut Hippoglossus stenolepis, northern sculpin

Icelinus borealis, Triglops spp., Gymnocanthus spp., Pacific cod Gadus macrocephalus, slim sculpin Radulinus asprellus, and arrowtooth flounder Atheresthes stomias. Our results showed significant differences in species composition among rookeries within each of 3 depth strata and a greater abundance of juvenile groundfishes in the western part of the study area. Gadid and flatfish species were more abundant and had a higher probability of occurrence in the vicinity of sea lion rookeries on Akun, Ugamak, Atkins, and Chowiet Islands, compared to rookeries on Marmot and Sugarloaf Islands. The observed differences in species composition coincided with differences in topography, substrate composition, temperature, and salinity. A potential relationship between the abundance of juvenile groundfishes and sea lion survival is discussed.

Muto, 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. <u>https://doi.org/10.7289/V5/TM-AFSC-355</u>

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

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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.

National Marine Fisheries Service Alaska Fisheries Science Center. (1995). Status Review of the United States Steller Sea Lion (Eumetopias Jubatus) Population.

[NO ABSTRACT AVAILABLE]

National Marine Fisheries Service Alaska Fisheries Science Center. (2011). *Results of Steller Sea Lion Surveys in Alaska June-July 2011*. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/17326</u>

An aerial survey to assess Steller sea lion (*Eumetopias jubatus*) pup production in the range of the western distinct population segment (DPS) in Alaska was conducted by the Alaska Fisheries Science Center (AFSC) from 27 June to 16 July 2011 (Figure 1). A secondary objective was to survey adult and juvenile (non-pup) sea lions in areas missed during the 2010 survey, particularly in the central and western Aleutian Islands. We successfully surveyed 135 of the 179 targeted terrestrial rookeries and haul-outs in 2011. All 73 sites in the eastern, central, and western Gulf of Alaska and in the eastern Aleutian Islands between 144°-170°W were successfully surveyed, as were all 52 sites in the eastern half of the central Aleutian Islands between 170°-178°W and 10 of 13 sites in the western Aleutian Islands between 172°-177°E. However, we were unable to survey any of the 40 sites (including 7 rookeries) in the western half of the central Aleutian Islands, and 1 site (a small rookery on Walrus Island in the Pribilof Islands, eastern Bering Sea) because of persistent fog and bad weather. In addition, we could not survey 2 haul-outs (Alaid and Nizki) in the western Aleutian Islands due to airspace restrictions near Shemya Island.

National Marine Fisheries Service Alaska Fisheries Science Center. (2011). *Review and Determination of Discreteness and Significance of the Steller Sea Lion Eastern Distinct Population Segment. Appendix 1b of National Marine Fisheries Service. 2013. Status Review of the Eastern Distinct Population Segment of Steller Sea Lion (Eumetopias Jubatus).* Retrieved from <u>https://repository.library.noaa.gov/view/noaa/16214</u>

On June 29, 2010, the National Marine Fisheries Service (NMFS) provided notice it was initiating the first 5-year status review of the eastern Distinct Population Segment (DPS) of Steller sea lion, listed as "threatened" under the Endangered Species Act (ESA), and opened a public comment period (75 FR 37385, June 29, 2010; 75 FR 38979, July 7, 2010). A 5–year status review is a periodic process conducted to ensure that the listing classification of a species is accurate and is based on the best available scientific and commercial data. During the ensuing comment period, NMFS received two petitions to delist this DPS: from the States of Washington and Oregon; and from the State of Alaska. NMFS released a Draft Status Review of the eastern DPS on April 18, 2012. Concurrently, NMFS published a proposed rule to remove this DPS from the List of Endangered and Threatened Wildlife (77 FR 23209). NMFS requested public comment on these documents. Further, NMFS obtained peer review on the draft Status Review. The public comment and peer review ended on June 18, 2012. This status review has

been revised in response to those comments. This Status Review considers the biological (demographic) criterion and the threats-based ESA listing factor criteria set forth in the 2008 Recovery Plan for the Steller Sea Lion, Eastern and Western Distinct Population Segments (Recovery Plan) (NMFS 2008), as well as the five listing factors included in section 4(a) of the ESA, which NMFS must consider when making a determination whether a species should be removed from the list of threatened species (16 U.S.C. 1533(c)(2)(B)).

National Marine Fisheries Service Alaska Fisheries Science Center. (2016). AFSC/MML/Alaska Ecosystem Program. Counts of Alaska Steller Sea Lion Adult and Juvenile (Non-Pup) Conducted on Rookeries and Haul-Outs in Alaska Aleutian Islands, Bering Sea, and Others from 1904-01-01 to 2015-08-01. https://doi.org/10.7289/V54F1NP1

This database contains counts of adult and juvenile (non-pup) Steller sea lions on rookeries and haulouts in Alaska made between 1904 and 2015. Non-pup counts have been conducted throughout the year. Breeding season (June-mid July) non-pup counts are used for population trend analysis, while counts at other times are used for analyses of distribution and for other purposes. Non-pups are counted from the ground (by walking along the rookery), from cliff-side overlooks, and from aerial imagery (oblique and vertical orientation). Non-pup counts represent only a fraction of the total number of animals that may use a site. Sea lions haulout less frequently in winter than in summer; thus, winter counts represent a smaller fraction of the total population than summer counts.

National Marine Fisheries Service Alaska Region. (2013). *Status Review of the Eastern Distinct Population* Segment of Steller Sea Lion (Eumetopias Jubatus). Retrieved from https://repository.library.noaa.gov/view/noaa/16214

This Status Review considers the biological (demographic) criterion and the threats-based ESA listingfactor criteria set forth in the 2008 Recovery Plan for the Steller Sea Lion, Eastern and Western Distinct Population Segments (Recovery Plan) (NMFS 2008), as well as the five listing factors included in section 4(a) of the ESA, which NMFS must consider when making a determination whether a species should be removed from the list of threatened species (16 U.S.C. 1533(c)(2)(B)).

Pascual, M. A., & Adkison, M. D. (1994). The Decline of the Steller Sea Lion in the Northeast Pacific -Demography, Harvest or Environment. *Ecological Applications*, 4(2), 393-403. <u>https://doi.org/10.2307/1941942</u>

When apparent declines in population numbers are observed, biologists are confronted with the challenge of determining if such behavior conforms to the expected dynamics of the population or if, on the contrary, the decline reflects some pathological change in the environment that requires management actions. Experimental investigations are often impractical for large free-ranging populations such as fish or large mammals. Consequently, biologists need to get the best possible answer from the limited data available. In this paper we combine deterministic and stochastic modeling, together with statistical estimation techniques, to explore the likelihood of various hypotheses for the decline of Steller sea lions in the North Pacific. Our results show that deterministic transient population behavior, historical pup harvesting, and short-term environmental stochasticity are unlikely causes for

the decline. The elimination of these alternatives leads us to agree with previous authors, who suggest that some long-term change in the environment or a novel catastrophe is responsible for the decline.

Perlov, A. S. (1991). Present Abundance of Steller Sea Lions (Eumetopias Jubatus) in the U.S.S.R. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from https://repository.library.noaa.gov/view/noaa/12022

In the Soviet Union, Steller sea lions (*Eumetopias jubatus*) are found in the Okhotsk Sea, Bering Sea, and north into the Chukchi Sea (Krasheninnikov 1949; Nikulin L937; Tikhornirov 1964; Perlov 1983). The largest group of these sea lions is concentrated on five of the Kuril Islands; a smaller grouping occurs near eastern Kamchatka and north along the Koriak coast. Small sea lion rookeries occur on the Commander Islands, and on Iony and lamskie Islands in the okhotsk Sea. Haul-out sites occur near Hokkaido at LaPerouse Strait (Opasnosti Rock) and on Tyuteniy Island (Robben Island) near Sakhalin. During the history of sea lion research in the Soviet Union, there has never been an estimate of the total population abundance for any given year. All abundance estimates are rough approximations and based on estimates obtained during different years. Also, the historical data were sometimes incomplete. In 1966, nearly 35,000 sea lions were estimated to inhabit the Kuril Islands, Commander Islands, Iony Island, and Kamchatka area (Marakov L9661. Subsequent analysis of published information and inquiries to loca1 authorities led me to reduce this estimate to 26,000 Steller sea lions, including animals in the Bering Sea (Pertov L975). Part of the reduction was based on the consideration that Marakov's estimate was too high (Perlov 1977) since the amount of information available for the Kamchatka Coast was minimal.

Perlov, A. S. (1996). Steller Sea Lion Catch as One of the Main Reasons for the Decline in Their Abundance. *Transactions of the Pacific Research Fisheries Centre*, *121*, 143-149.

[NO ABSTRACT AVAILABLE]

Permyakov, P. A., Ryazanov, S. D., Trukhin, A. M., Mamaev, E. G., & Burkanov, V. N. (2014). The Reproductive Success of the Steller Sea Lion *Eumetopias Jubatus* (Schreber, 1776) on Brat Chirpoev and Medny Islands in 2001–2011. *Russian Journal of Marine Biology, 40*(6), 440-446. <u>https://doi.org/10.1134/s1063074014060182</u>

The reproductive success of the Steller sea lion was estimated based on monitoring the breeding performance of known-age branded females on Brat Chirpoev and Medny islands in 2001–2011. First pup birth occurred at 4 years of age, but the majority of females gave birth to their first pup at the age of 5 years on both islands. The period of the highest realization of female initial reproductive capacity on Medny Island was 4–5 years shorter compared to Brat Chirpoev Island. The differences were caused by a lower number of middle-aged females and a higher proportion of non-pregnant females on Medny Island. The low reproductive success of females is probably the main reason for the depression of the Steller sea lion population on Medny Island.

Pitcher, K., Olesiuk, P., Brown, R., Lowry, M., Jeffries, S., Sease, J., . . . Lowry, L. (2003). *Status and Trends* of the Eastern Steller Sea Lion Population. Manuscript.

[NO ABSTRACT AVAILABLE]

Pitcher, K. W., Burkanov, V. N., Calkins, D. G., Le Boeuf, B. J., Mamaev, E. G., Merrick, R. L., & Pendleton, G. W. (2001). Spatial and Temporal Variation in the Timing of Births of Steller Sea Lions. *Journal* of Mammalogy, 82(4), 1047-1053. <u>https://doi.org/10.1644/1545-1542(2001)082<1047:Satvit>2.0.Co;2</u>

Throughout the range of the Steller sea lion (*Eumetopias jubatus*), nearly all births of fullterm pups observed from 1968 to 1998 occurred between 15 May and 15 July. We found significant differences in timing of births between rookeries with the earliest mean date of birth (4 June) at Forrester Island, Alaska, and the latest (21 June) at Ano Nuevo Island, California. Mean date of birth becomes progressively later both north and south of Forrester Island. Births at individual rookeries were synchronous, with 90% of pups born within a 25-day period. We hypothesize that timing of births at rookeries is determined through selection for time periods when weather conditions are generally favorable for pup survival and when adequate prey items are predictably available near rookeries for lactating females. Temporal differences also were found in mean date of birth at 4 rookeries, with a maximum difference between earliest and latest mean date of birth of 10.2 days at Ano Nuevo Island. The most likely explanation for temporal variability at individual rookeries is variable nutritional status of reproductive females.

Pitcher, K. W., Calkins, D. G., & Pendleton, G. W. (1998). Reproductive Performance of Female Steller Sea Lions: An Energetics-Based Reproductive Strategy? *Canadian Journal of Zoology-Revue Canadienne De Zoologie, 76*(11), 2075-2083. <u>https://doi.org/10.1139/cjz-76-11-2075</u>

We examined the reproductive performance of female Steller sea lions (*Eumetopias jubatus*) in order to evaluate the hypothesis that low pup production was associated with nutritional stress and to assess whether reduced birth rates could have been a factor in a recent large-scale decline in numbers. Nearly all (97%) sexually mature females were pregnant during early gestation. However, by late gestation, pregnancy rates had declined to 67 and 55% in the 1970s and 1980s, respectively, owing to reproductive failures. We found that body condition, as depicted by mass index and blubber index, had a positive effect on the probability that a female would be pregnant during late gestation. Age, age(2), and lactation were also associated with pregnancy status during late gestation. These findings support the hypotheses that reproductive failures were associated with lowered nutritional status and that the resulting low birth rates were a proximate factor in the decline. We speculate that abortion is a part of the reproductive strategy of the female Steller sea lion that enhances overall reproductive performance during times of suboptimal nutrition. A major shift in oceanic regime occurred in the Gulf of Alaska during the late 1970s that resulted in a reduction of about 50% in the overall biomass of fishes and a shift in species composition. Prey resources may not have been adequate to successfully support the Steller sea lions' "energetically expensive" reproductive/foraging strategy during the period of our study.

Pitcher, K. W., Olesiuk, P. F., Brown, R. F., Lowry, M. S., Jeffries, S. J., Sease, J. L., . . . Lowry, L. F. (2007).
Abundance and Distribution of the Eastern North Pacific Steller Sea Lion (*Eumetopias Jubatus*)
Population. *Fishery Bulletin*, 105(1), 102-115. Retrieved from

https://spo.NMFS.noaa.gov/content/abundance-and-distribution-eastern-north-pacific-stellersea-lion-eumetopias-jubatus

The eastern Steller sea lion (*Eumetopias jubatus*) population comprises animals that breed along the west coast of North America between California and southeastern Alaska. There are currently 13 major rookeries (>50 pups): five in southeastern Alaska, three in British Columbia, two in Oregon, and three in California. Overall abundance has increased at an average annual rate of 3.1% since the 1970s. These increases can largely be attributed to population recovery from predator-control kills and commercial harvests, and abundance is now probably as high as it has been in the last century. The number of rookeries has remained fairly constant (n=11 to 13) over the past 80 years, but there has been a northward shift in distribution of both rookeries and numbers of animals. Based on the number of pups counted in a population-wide survey in 2002, total pup production was estimated to be about 11,000 (82% in southeastern Alaska and British Columbia), representing a total population size as approximately 46,000–58,000

Ryazanov, S. D., Belonovich, O. A., Mamaev, E. G., Nikulin, V. S., Fomin, S. V., & Burkanov, V. N. (2014). Establishing of Local Population, Population Dynamics and Current Abundance of Steller Sea Lion (*Eumetopias Jubatus*) in the Commander Islands. *Transactions of the Pacific Research Fisheries Centre, 176*, 100-114. Retrieved from <u>https://cyberleninka.ru/article/n/obrazovanie-lokalnoy-</u> <u>populyatsii-dinamika-i-sovremennoe-sostoyanie-chislennosti-sivucha-eumetopias-jubatus-nakomandorskih-ostrovah</u>

The time course of the establishment of a local population of Steller sea lions in the Commander Islands, population dynamics and current abundance were studied using literature published since the 1930s and the author's observations conducted during breeding seasons 2008-2011. The local population of Steller sea lions started formation in the early 1960s, when mature females first began to populate the islands and the population was fully established in the early 1990s. The whole process of development the Commander Islands Steller sea lion sub-population took about three decades. Abundance of adult and juvenile sea lions fluctuated highly in 1991-2011 without any statistically significant trend, but numbers of pups had a pronounced negative slope mostly due to three sharp declines in pup production in 2000, 2009, and 2011. A total of about 700 animals of age 1+ inhabit the islands during the breeding season and about 200 pups are born annually at the present time. This total number of Steller sea lions is close to the mean value for the period after 1990s. Nevertheless, occasional sharp declines in pup production cause some anxiety, so far as they could lead to extinction of the Steller sea lion sub-population in this area as had occurred in the middle of the 19th century.

Sampson, D. B., & Brown, R. F. (2001). Progress and Final Technical Report to the University of British Columbia North Pacific Universities Marine Mammal Research Consortium: Population Trends and Dynamics of Steller Sea Lions in Oregon. Oregon State University University of British Columbia/North Pacific Universities Marine Mammal Research Consortium

During the past few decades there have been significant declines in the Alaskan populations of Steller sea lions (Eumetopia jubatus) in the region of the Aleutian Islands, which historically were the center of the range for this species. Although the rate of population decline has lessened in recent years, the Alaskan populations have continued to diminish. In contrast, the breeding colonies of Steller sea lions off the U.S. West Coast have been increasing during the past two decades. The two regions are broadly

similar in terms of oceanographic conditions and the ecological communities that reside there. Many of the demersal and pelagic fish species that form the food base for Steller sea lions are found in both regions. Large stocks of semi-pelagic gadids provide a significant component of the Steller sea lion diet, walleye pollock (Theragra chalcogramma) in Alaska versus Pacific hake (Merluccius productus) off the U.S. West Coast. In both cases these dominant fish stocks are harvested by industrial-scale fisheries, primarily using mid-water trawls. In the Aleutian Islands, where Steller sea lion colonies have suffered the greatest declines, the stocks of walleye pollock are considered to be in healthy condition, with estimates of recent biomass being close to the maximum historic levels for the Eastern Bering Sea and Aleutian Islands (Ianelli et al. 2001). In the Gulf of Alaska, where the sea lions have declined more moderately, the pollock stocks are considerably below the peak levels estimated for the early 1980s (Dorn et al. 2001). Off the U.S. West Coast, where the Steller sea lion colonies have been increasing, the stock of Pacific hake has been declining steadily since 1987 as the exceptionally large 1980 and 1984 year classes have been replaced by weaker ones (Dorn et al. 1999). The goal of this study is to provide information that will permit comparisons between conditions in the Aleutian Islands versus conditions off the U.S. West Coast, where there is a relatively small but healthy population of Steller sea lions. Such comparisons could provide clues regarding the causes of the declines in the Aleutian Islands populations and human actions that might reverse the trend. The study, which was conducted jointly by researchers from Oregon State University (OSU) and the Oregon Department of Fish and Wildlife (ODFW), consisted of three main components: (1) analysis of distribution, abundance, and trend data for the Steller sea lion population in Oregon: 1976-2000; (2) examination and description of the food habits of Steller sea lions in Oregon; and (3) development of an ecosystem model for Steller sea lions in Oregon.

Scordino, J. (2006). Steller Sea Lions (Eumetopias Jubatus) of Oregon and Northern California: Seasonal Haulout Abundance Patterns, Movements of Marked Juveniles, and Effects of Hot-Iron Branding on Apparent Survival of Pups at Rogue Reef. (Master of Science), Oregon State University, Retrieved from https://ir.library.oregonstate.edu/concern/graduate thesis or dissertations/n870zw20m

Sea lions belong to the Order Carnivora, Suborder Pinnipedia, Family Otariidae, and Subfamily Otariinae. Steller sea lions (*Eumetopias jubatus*) are the largest member of the family otariidae and show marked sexual dimorphism of size. The average length of adult males is 282 cm and 228 cm for adult females (maximum of about 325 cm and 290 cm, respectively); weight of males averages 566 kg and females 263 kg (maximum of about 1,120 kg and 350 kg) (Calkins and Pitcher 1982; Loughlin and Nelson 1986). Females sexually mature between 3 – 6 years of age, and males sexually mature at 3 – 7 years of age but cannot hold a breeding territory until 8 – 12 years of age (Pitcher and Calkins 1981). Steller sea lions congregate at breeding rookeries from late April through August where females have one pup. Pups are born between late May and early July and have a thick chocolate brown coat at birth which molts to a lighter brown at six-months of age (Daniel 2003). Juveniles have a similar light brown coat that appears to lighten with age. Adult females have a tawny to silver colored pelt (Mate 1973). Males are characterized by dark, dense fur around the neck that appears like a mane and light tawny coloring to the rest of their body. Steller sea lions prey on a variety of fish and invertebrate species. Many of the fish species Steller sea lion consume are also targeted by human fisheries.

Sease, J., Strick, J., Merrick, R., & Lewis, J. (1999). *Aerial and Land-Based Surveys of Steller Sea Lions* (*Eumetopias Jubatus*) in Alaska, June and July 1996. National Marine Fisheries Service Alaska

Fisheries Science Center. NMFS-AFSC-99. Retrieved from https://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-99.pdf

The National Marine Fisheries Service and the Alaska Department of Fish and Game conducted aerial and land-based surveys of Steller sea lions (Eumetopias jubatus) during June and July 1996 from Southeast Alaska to the western Aleutian Islands. We counted a total of 41,529 adult and juvenile (nonpup) sea lions at 280 rookery and haul-out sites. Of these sea lions, 30,454 (73.3%) were at 95 trend sites (rookeries and haulouts) and 22,562 (54.3%) were at 33 trend rookeries. The 1996 count at the 95 trend sites was a decline of 18.0% since 1991, 12.6% since 1992, and 7.6% since 1994. Overall declines were slightly less for all surveyed sites. The average annual rate of decline from 1991 to 1996 was about 3.7% for trend sites and trend rookeries and 2.1% for all surveyed sites. The western stock of Steller sea lions in Alaska includes animals from the eastern Gulf of Alaska through the western Aleutian Islands. In 1996 we counted 30,622 non-pups at 222 surveyed sites. Of these, 22,223 (72.6%) were on 82 trend sites and 16,358 (53.4%) were on 30 trend rookeries. For the 82 trend sites, the 1996 count represented declines of 27.2% from 1990, 24.5% from 1991, 18.6% from 1992, and 7.9% from 1994. The annual rates of decline were about 5.5% for trend sites and trend rookeries (1990 to 1996) and 3.8% for all surveyed sites (1991 to 1996). In the Kenai Peninsula to Kiska Island index area, a sub-area within the Alaska portion of the western stock, we counted 24,625 non-pup sea lions at 189 surveyed sites. Of these, 17,900 (72.7%) were at 69 trend sites, and 13,905 (56.5%) were at 26 trend rookeries. The 1996 count for the 69 trend sites was a decline of 21.3% from 1990, 17.7% from 1991, 13.4% from 1992, and 4.3% from 1994. The estimated annual rates of decline were 4-5% for trend sites and trend rookeries (1990 to 1996) and 2% for all surveyed sites (1991 to 1996).

Sease, J. L., Lewis, J., McAllister, D., Menick, R., & Mello, S. (1993). Aerial and Ship-Based Surveys of Steller Sea Lions (Eumetopias Jubatus) in Southeast Alaska, the Gulf of Alaska, and Aleutian Islands During June and July 1992. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-17. Retrieved from https://www.st.NMFS.noaa.gov/tm/afsc/afsc017.pdf

Aerial and ship-based surveys of Steller sea lions (Eumetopias jubatus) were conducted during June and July 1992 from Forrester Island in Southeast Alaska to Attu Island in the western Aleutian Islands. A total of 34,844 adult and juvenile sea lions were counted at 95 "trend sites" (sites surveyed. consistently since the 1970s and are thus appropriate for monitoring trends). The 1992 count represents a decline of 70.2% from 1979 (116,804) and a decline of 4.4% (P = 0.043) from 1991 (36,459). The annual rate of decline from 1979 to 1992, based on linear regression, was 9.6% (P = 0.0026). Of the 95 trend sites, 32 are rookeries. Estimated annual rates of decline for these rookeries were 10.2% (P < 0.001) for 1979-92 and 5.4% (P = 0.06) for 1989-92. Sixty-nine of the trend sites are located between the Kenai Peninsula and Kiska Island. At these sites, we counted 20,679 adult and juvenile sea lions, which represents declines of 76.9% from the 1975-79 counts (89,364) and 4.9% (P = 0.034) from 1991 (21,737). Estimated annual rates of decline, based on linear regression, were 10.0% (P = 0.002) for 1975-79 to 1992 and 3.7% (P = 0.026) for 1989 to 1992. For 26 trend rookeries in the Kenai to Kiska area, estimated annual rates of decline were 9.8% (P < 0.001) for 1975-79 and 4.4% (P = 0.067) for 1989-92. During the past year, numbers of sea lions counted at trend sites increased only in the eastern Aleutian Islands (from 4,231 in 1991 to 4,839 in 1992) and the western Aleutian Islands (from 2,411 to 2,869). Counts at trend sites declined in Southeast Alaska (from 7,715 in 1991 to 7,558 in 1992), in the eastern Gulf of Alaska (from 4,596 to 3,738), in the central Gulf of Alaska (from 6,273 to 5,721), and in the central Aleutian Islands (from 7,499 to 6,399). Counts of sea lions in the western Gulf of Alaska in 1991 and 1992 remained essentially unchanged (3,734 and 3,720, respectively). We counted 2,951 live pups at six rookeries in
1992. The number of pups increased at three of the four rookeries last surveyed in 1990: Akutan-Cape Morgan (+25.8%), Chernabura (+8.8%), and Chowiet (+9.1%) and declined sharply at Sugarloaf Island (-46.6%). Regionally, numbers of pups increased in Southeast Alaska (+24.2%), in the eastern (+16.9%) and western Gulf of Alaska (+13.9%), and in the eastern Aleutian Islands (+9.3%), but declined in the central Gulf of Alaska (-29.3%) from 1989-90 to 1991-92. Overall the number of pups declined by 4.4%, the same rate that the number of adult and juvenile sea lions declined from 1991 to 1992.

Sease, J. L., Taylor, W., Loughlin, T., & Pitcher, K. (2001). Aerial and Land-Based Surveys of Steller Sea Lions (Eumetopias Jubatus) in Alaska, June and July 1999 and 2000. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC 122. Retrieved from <u>https://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-122.pdf</u>

The National Marine Fisheries Service (NMFS) and the Alaska Department of Fish and Game (ADF&G) conducted aerial and land-based surveys of Steller sea lions (Eumetopias jubatus) in Alaska during July 1999 and June 2000. The 1999 aerial survey was restricted to the eastern Gulf of Alaska, where we counted 2,072 non-pup Steller sea lions on 23 rookery and haul-out sites. In June 2000, we counted a total of 37,801 non-pups on 289 rookery and haul-out sites from Southeast Alaska through the western Aleutian Islands. Of these non-pups Alaska-wide, 28,187 were on the 94 trend rookery and haul-out sites, which was a decline of 3.2% from 1998 and 26.1% from 1990. The 33 trend rookeries Alaska-wide included 20,298 non-pups, indicating declines of 3.8% from the 1998 count and 26.4% from 1990. Estimated average annual rates of decline from 1990 to 2000 were 3.2% (P < 0.001: 95% C.I. 2.5% to 3.9%) for all trend sites and 3.3% (P < 0.001: 95% C.I. 2.7% to 3.9%) for the 33 trend rookeries. Most of the sites surveyed in 2000 (264 of 289: 91%) are part of the western stock, which includes animals from the eastern Gulf of Alaska (144° W long.) through the western Aleutian Islands. The June 2000 count of 25,384 non-pups at all 264 sites in the western-stock indicated declines of 13.9% from 1998 and 31.7% from 1991, with an estimated annual decline of 4.0% (P < 0.001: 95% C.I. 3.1% to 4.9%). At 82 rookery and haul-out trend sites in the western stock, the June 2000 count of 18,325 represented declines of 10.3% from 1998 and 40.0% from 1990. The 13,402 nonpups at the 30 western-stock trend rookeries indicated declines of 18.5% from 1998 and 39.9% from 1990. The estimated average annual decline from 1990 to 2000 was 5.1% for all western-stock trend sites (P < 0.001: 95% C.I. 4.7% to 5.6%), as well as for western-stock trend rookeries (P < 0.001: 95% C.I. 4.3% to 5.8%).

Shima, M., Hollowed, A. B., & VanBlaricom, G. R. (2010). Response of Pinniped Populations to Directed Harvest, Climate Variability, and Commercial Fishery Activity: A Comparative Analysis. *Reviews in Fisheries Science*, 8(2), 89-124. <u>https://doi.org/10.1080/10641260091129189</u>

Hypotheses concerning the decline of Steller sea lions in the Gulf of Alaska (GOA) were evaluated based on comparison of data to three other ecosystems that had similar environmental and commercial fishery characteristics. We focus on examining the effects of commercial pinniped harvest, commercial fisheries, and environmental changes. Of the four pinniped species included in this study, only the Steller sea lion population has exhibited a sharp decline in population number. Comparative analysis indicated that the Gulf of Alaska pinniped population has not experienced any unique large-scale perturbations compared to the other ecosystems. Commercial pinniped harvest occurred in all four ecosystems. The history of harvest was shortest for GOA Steller sea lions and the numbers taken were lower than in the Barents Sea and Benguela Current ecosystems. Exploitation rates, though only calculated for years when both harvest numbers and total population size were available, also indicated that the Steller sea lions have experienced very little commercial harvest pressure compared to the other pinniped populations in the three other ecosystems. The age group of animals killed was comparable throughout all ecosystems. Large-scale variability in water temperature was common to all four ecosystems. Although the periodicity of the changes varied among ecosystems, they all appeared to be driven by low pressure systems. The variability of the oscillations in water temperature was lowest for the eastern Pacific ocean (i.e., the GOA and California Current ecosystems) and highest in the Benguela Current. Commercial fisheries played a major part in all four ecosystems. The main species in pinniped diets were often the target of commercial fishing activity leading to potential conflicts between the 2 types of predators (i.e., pinnipeds and commercial fisheries). Exploitation rates in the GOA were comparable to or less than rates in the other ecosystems while the rates were highest in the Barents Sea. Statistical analysis showed that GOA pollock exploitation rates were significantly different from the rates of most other species. Healthy pinniped populations were present in all the ecosystems in this study except for the GOA despite the presence of much commercial fisheries in the GOA ecosystem and the management actions taken to alleviate its effects.

Springer, A. M., Estes, J., Van Vliet, G. B., Williams, T., Doak, D., Danner, E., . . . 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), 12223-12228. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC218740/pdf/10012223.pdf

Populations of seals, sea lions, and sea otters have sequentially collapsed over large areas of the northern North Pacific Ocean and southern Bering Sea during the last several decades. A bottom-up nutritional limitation mechanism induced by physical oceanographic change or competition with fisheries was long thought to be largely responsible for these declines. The current weight of evidence is more consistent with top-down forcing. Increased predation by killer whales probably drove the sea otter collapse and may have been responsible for the earlier pinniped declines as well. We propose that decimation of the great whales by postWorld War II industrial whaling caused the great whales' foremost natural predators, killer whales, to begin feeding more intensively on the smaller marine mammals, thus "fishing-down" this element of the marine food web. The timing of these events, information on the abundance, diet, and foraging behavior of both predators and prey, and feasibility analyses based on demographic and energetic modeling are all consistent with this hypothesis.

Strick, J. M., Fritz, L. W., & Lewis, J. (1997). Aerial and Ship-Based Surveys of Steller Sea Lions (Eumetopias Jubatus) in Southeast Alaska, the Gulf of Alaska, and Aleutian Islands During June and July 1994. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-71. Retrieved from <u>https://www.afsc.noaa.gov/publications/AFSC-TM/NOAA-TM-AFSC-71.pdf</u>

Aerial and ship-based surveys of Steller sea lions (*Eumetopias jubatus*) were conducted during June and July 1994 from Forrester Island in Southeast Alaska to Attu Island in the western Aleutian Islands. A total of 32,945 adults and juvenile Steller sea lions were counted at 95 trend rookery and haulout sites. This represents decreases of 5.5% from 1992 counts (34,844) and 13.7% from 1990 (38,154). Annual rates of change, as estimated by linear regression, were -2.8% from 1992 to 1994 (P < 0.05) and -3.7% from 1990 to 1994 (P = 0.008). In 1994, 23,452 adult and juvenile sea lions were counted on trend rookery sites throughout Alaska. This represents a decrease of 14.9% from 1990 counts (27,563) and a 9.3% decrease from 1992 counts (25,849). Estimated annual rates of change for 32 trend rookeries throughout Alaska

were -3.9% (P = 0.017) for 1990-94 and -4.9% (P < 0.005) for 1992-94. The area between the Kenai Peninsula and Kiska Island includes 69 trend rookery and haulout sites. Since 1990, adult Steller sea lions decreased 17.8% on these trend sites. Between 1992 and 1994, the number of adult Steller sea lions on trend sites decreased 9.5%. Annual rates of change of adult Steller sea lions on trend sites have been - 4.9% (P < 0.001) for 1990-94, and -5.0% (P < 0.001) for 1992-94.

Sweeney, K., L. Fritz, R. Towell, & T. Gelatt. (2017). Results of Steller Sea Lion Surveys in Alaska, June-July 2017. Memorandum to the Record, December 5, 2017. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from https://www.afsc.noaa.gov/NMML/PDF/SSL Aerial Survey 2017.pdf

The Marine Mammal Laboratory (MML) conducted aerial-, ship-, and land-based surveys to count Steller sea lion (*Eumetopias jubatus*) pups (~1 mo old) and non-pups (adults and juveniles ≥ 1 year old) on terrestrial rookery and haulout sites in Alaska in June-July 2017. The occupied aircraft survey team conducted their survey from 27 June to 5 July from southeast Alaska (Dixon Entrance, 132°W) to the Shumagin Islands in the western Gulf of Alaska (161°W). The ship-based survey team, which included the use of an unoccupied aircraft system (UAS), conducted their survey from 22 June to 7 July in the Aleutian Islands between 172°E and 166°W. In addition, the Alaska Department of Fish and Game (ADFG) counted Steller sea lions from land on Round Island in Bristol Bay (eastern Bering Sea). The stock boundary between the eastern and western DPSs of the Steller sea lion is 144°W longitude. The MML's survey in southeast Alaska was part of a range-wide survey of the eastern distinct population segment (DPS) of Steller sea lions (California through southeast Alaska) conducted in 2017 by Department of Fisheries and Oceans Canada, Washington and Oregon Departments of Fish and Wildlife, and NOAA Fisheries (including the SW Fisheries Science Center).

Sweeney, K. M., Fritz, L. W., Towell, R. G., & Gelatt, T. S. (2016). Results of Steller Sea Lion Surveys in Alaska, June-July 2016. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/19544</u>

Aerial, ship, and land-based surveys to count Steller sea lion (*Eumetopias jubatus*) pups (~1 mo old) and non-pups (adults and juveniles ≥ 1 year old) on terrestrial rookery and haul-out sites in Alaska were conducted by the MML in June-July 2016. The manned aerial survey was conducted from 23 June to 11 July from the western Gulf of Alaska (158°W) to the Delarof Islands in the central Aleutian Islands (179°W). The ship-based survey, which included the use of an unmanned aircraft system (UAS), was conducted from 23 June to 6 July in the Aleutian Islands between 172°E and 166°W. In addition, Steller sea lions were counted from land on Round Island in Bristol Bay by Alaska Department of Fish and Game (ADFG) and on Ugamak Island in the eastern Aleutian Islands by MML.

Sweeney, K. M., Fritz, L. W., Towell, R. G., & Gelatt, T. S. (2017). *Results of Steller Sea Lion Surveys in Alaska, June-July 2017*. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/18790</u>

The Marine Mammal Laboratory (MML) conducted aerial-, ship-, and land-based surveys to count Steller sea lion (*Eumetopias jubatus*) pups (~1 mo old) and non-pups (adults and juveniles \geq 1 year old) on terrestrial rookery and haulout sites in Alaska in June-July 2017. The occupied aircraft survey team

conducted their survey from 27 June to 5 July from southeast Alaska (Dixon Entrance, 132°W) to the Shumagin Islands in the western Gulf of Alaska (161°W). The ship-based survey team, which included the use of an unoccupied aircraft system (UAS), conducted their survey from 22 June to 7 July in the Aleutian Islands between 172°E and 166°W. In addition, the Alaska Department of Fish and Game (ADFG) counted Steller sea lions from land on Round Island in Bristol Bay (eastern Bering Sea).

Trites, A. W. (1998). Steller Sea Lions (Eumetopias Jubatus): Causes for Their Decline and Factors Limiting Their Restoration: University of British Columbia Marine Mammal Research Unit, Fisheries Centre. Retrieved from <u>http://www.marinemammal.org/wp-content/pdfs/Trites1998-</u> restoration.pdf

Most researchers believe that food shortages are the most likely cause of the decline of Steller sea lions (ASG 1993 – "Is it Food? Conference"). Poor nutrition caused by a lack of abundance, availability or appropriateness of prey can reduce birth rates and increase mortality through disease, predation and starvation. Major changes in the quantity and quality of Steller sea lion prey appear to have been affected by natural changes in the ecosystem, not by fishing activities. Recent results from ecosystem models of the eastern Bering Sea, comparisons of sea lion diets across time and space, and environmental and biological time series are analyzed.

Trites, A. W., & Larkin, P. A. (1996). Changes in the Abundance of Steller Sea Lions(*Eumetopias Jubatus*) in Alaska from 1956 to 1992: How Many Were There? *Aquatic Mammals, 22*(3), 153-166. Retrieved from <u>https://www.aquaticmammalsjournal.org/share/AquaticMammalsIssueArchives/1996/Aquatic Mammals_22-03/22-03_Trites.pdf</u>

The size of Steller sea lion populations in the Gulf of Alaska and Aleutian Islands was estimated by applying life table statistics to counts of pups and adults (non-pups) at rookery sites. Total population size was 5.10 times the number of pups counted or 3.43 times the number of adults counted. Only 55% of the adult population return to rookeries during the summer. Data compiled from published and unpublished sources for all 39 major rookeries in Alaska suggest that the total number of Steller sea lions (including pups) rose from 250 000 to 282 000 between the mid 1950s and the mid 1970s. Since 1980 it has decreased by over 70% (roughly 5% per year) to about 76 000 animals in 1992. Most of the decline took place in the Aleutian Islands and Kodiak region. However since 1989, the population decline appears to have slowed or stopped within two subareas of these large regions—the eastern Aleutians and western Gulf of Alaska. Increases have been occurring in the smaller populations of southeast Alaska. It is not known why these changes have occurred.

Trites, A. W., Livingston, P. A., Mackinson, S., Vasconcellos, M., Springer, A. M., & Pauly, D. (1999).
Ecosystem Change and the Decline of Marine Mammals in the Eastern Bering Sea: Testing the Ecosystem Shift and Commercial Whaling Hypotheses. In Fisheries Centre Research Reports, Vol.
7. Retrieved from http://www.marinemammal.org/wp-content/pdfs/Trites_1999.pdf

Some species in the Bering Sea underwent large changes between the 1950s and the 1980s. Among the best documented are the declines of Steller sea lions and northern fur seals, and the possible increase and dominance of ground fish – pollock and large flatfish. A frequently proposed explanation is that

human exploitation of top predators and/or a shift in the physical oceanography altered the structure of the eastern Bering Sea ecosystem. We employed two inter-related software packages (Ecopath and Ecosim) to describe quantitatively the eastern Bering Sea ecosystem during the 1950s, before large-scale commercial fisheries were underway, and during the 1980s, after many marine mammal populations had declined. We grouped the hundreds of species that make up the Bering Sea ecosystem into 25 functional groups. Our mass-balance ecosystem models showed that most of the top predators (trophic level IV) declined from the 1950s to the 1980s. They included Steller sea lions, seals, sperm whales, deep-water fish and other demersal fishes. The only top predators to increase were large flatfish such as arrowtooth flounder. At the mid-trophic level (III), baleen whales and pelagic fishes declined, while small flatfish, pollock, and walrus and bearded seals increased. Based on our model assumptions, pollock contributed over 50% of the total flow of energy at the mid trophic levels during the 1980s compared to only 10% in the 1950s model. In contrast, pelagic fishes contributed nearly 50% of the flow in the 1950s. At trophic level IV, no one species dominated the flow of energy during the 1950s. However, large flatfish contributed over 60% of the total energy flow in the 1980s model. Large flatfish and adult pollock that dominate the Bering Sea in the 1980s appear to be significant competitors of seals. Large flatfish are also competitors of Steller sea lions and there are large overlaps in the diets of pollock and baleen whales.

Westlake, R. L., Perryman, W. L., & Ono, K. A. (1997). Comparison of Vertical Aerial Photographic and Ground Censuses of Steller Sea Lions at Ano Nuevo Island, July 1990-1993. *Marine Mammal Science*, *13*(2), 207-218. <u>https://doi.org/10.1111/j.1748-7692.1997.tb00628.x</u>

Counts of Steller sea lion (*Eumetopias jubatus*) PUPS and non-pups (adults and juveniles) from aerial photographs of rookeries at Ano Nuevo Island between 1990 and 1993 were significantly higher than those made on the ground. Based on regression of natural logs of photographic counts versus year, the number of pups declined at a rate of -0.099/yr while non-pup numbers declined at -0.315/yr. Examination of ground count data for the same period revealed a significant decline in non-pups (-0.139/yr), but no trend was detected in the ground counts of pups. The regression coefficients from photographic and ground counts of non-pups did not differ significantly. Power analyses using the program TRENDS indicated that detectable rates of change in abundance from four annual surveys were much lower for counts of pups than counts of non-pups where sampling precision was based on fits to linear models.

 Wilson, C. A. (1996). Abundance and Distribution of Marine Mammals in Northern Bristol Bay and Southern Kuskokwim Bay: a status report of the 1996 marine mammal monitoring effort at Togiak National Wildlife Refuge. US Fish and Wildlife Service. Retrieved from <u>http://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/research_pdfs/abundance_distri</u> <u>bution_marine_mammals_northern_bristol_bay_southern_kuskokwim_bay_1996.pdf</u>

Togiak National Wildlife Refuge's (TNWR) 1996 marine mammal program focusing on monitoring the abmtdance and distribution of walruses, seals and sea lions in northern Bristol Bay and southern Kuskokwim Bay. For the frrst time since 1993, funding permitted regular monitoring of Cape Newenham walrus and sea lion haulouts from early Jmte to mid-August Gromtd counts of walruses at Cape Peirce, Cape Newenham and Romtd Island produced peak numbers of3, 105 on 6 October, 1,280 on 13 July, and 6,331 on 25 July, respectively. The peak COWit at Cape Peirce in 1996 occurred later than usual and was lower than the peaks of the last three years. The greatest number counted on any one day during

1996 in northern Bristol Bay-southern Kuskokwim Bay was 6,691 on 15 July. Other high total comtts of the area occurred on 25 July with 6,614 walruses, and on 23 July with 6,388 walruses, comtted at all three haulouts.

Wilson, K., Fritz, L., Kunisch, E., Chumbley, K., & Johnson, D. (2012). Effects of Research Disturbance on the Behavior and Abundance of Steller Sea Lions (*Eumetopias Jubatus*) at Two Rookeries in Alaska. *Marine Mammal Science, 28*(1), E58-E74. <u>https://doi.org/10.1111/j.1748-7692.2011.00485.x</u>

We examined the effects of research disturbance on the behavior and abundance of Steller sea lions (*Eumetopias jubatus*) at rookeries on Marmot and Ugamak Islands in Alaska. During 3 of 6 yr, researchers intentionally drove all adult and juvenile sea lions off at least part of the beach in order to permanently mark and measure sea lion pups. The research disturbance occurred after the majority of females had bred and when most pups were 1 mo old. We used generalized linear models to determine the relationship between research disturbance and sea lion behavior or abundance. Research disturbance was related to changes in the proportion of sea lions exhibiting two to three of nine behavior metrics: agonistic and resting females and active males at Marmot, and active and resting males and females at Ugamak. Model results indicated that changes lasted between 3 and 20 d depending on the sex, behavior, and rookery. Inclusion of research disturbance into Marmot abundance models did not improve the fit to the data, if variability between years was permitted. Optimally timed, low-frequency research disturbance did not appear to have long-term effects on sea lion behavior or abundance and was largely associated with changes that were similar to natural variation.

Wolf, N., & Mangel, M. (2008). Multiple Hypothesis Testing and the Declining-Population Paradigm in Steller Sea Lions. *Ecological Applications*, 18(8), 1932-1955. <u>https://doi.org/10.1890/07-1254.1</u>

We describe a novel spatially and temporally detailed approach for determining the cause or causes of a population decline, using the western Alaskan population of Steller sea lions (Eumetopias jubatus) as an example. Existing methods are mostly based on regression, which limits their utility when there are multiple hypotheses to consider and the data are sparse and noisy. Our likelihood-based approach is unbiased with regard to sample size, and its posterior probability landscape allows for the separate consideration of magnitude and certainty for multiple factors simultaneously. As applied to Steller sea lions, the approach uses a stochastic population model in which the vital rates (fecundity, pup survival, non-pup survival) at a particular rookery in each year are functions of one or more local conditions (total prey availability, species composition of available prey, fisheries activity, predation risk indices). Three vital rates and four scaling functions produce twelve nonexclusive hypotheses, of which we considered 10; we assumed a priori that fecundity would not be affected by fishery activities or predation. The likelihood of all the rookery- and year-specific census data was calculated by averaging across sample paths, using backward iteration and a beta-binomial structure for observation error. We computed the joint maximum likelihood estimates (MLE) of parameters associated with each hypothesis and constructed marginal likelihood curves to examine the support for each effect. We found strong support for a positive effect of total prey availability on pup recruitment, negative effects of prey species composition (pollock fraction) on fecundity and pup survival, and a positive effect of harbor seal density (our inverse proxy for predation risk) on non-pup survival. These results suggest a natural framework for adaptive management; for example, the areas around some of the rookeries could be designated as experimental zones where fishery quotas are contingent upon the results of pre-fishing season survey

trawls. We contrast our results with those of previous studies, demonstrating the importance of testing multiple hypotheses simultaneously and quantitatively when investigating the causes of a population decline.

Wright, B. E., Brown, R. F., DeLong, R. L., Gearin, P. J., Riemer, S. D., Laake, J. L., & Scordino, J. J. (2017). Survival Rates of Steller Sea Lions from Oregon and California. *Journal of Mammalogy*, 98(3), 885-894. <u>https://doi.org/10.1093/jmammal/gyx033</u>

Due to significant population declines in the 1970s and 1980s, Steller sea lions (*Eumetopias jubatus*) were listed as threatened under the U.S. Endangered Species Act in 1990, and subsequently partitioned in 1997 into an endangered western stock and a threatened eastern stock. We estimated survival rates from a mark-recapture study of 7 eastern stock cohorts marked as pups in California and Oregon from 2001 to 2009 (n = 1,154 pups) and resighted range-wide from 2002 to 2013. First-year survival rates were among the lowest found for Steller sea lions thus far, averaging 0.46 (range 0.21-0.72) for females and 0.44 (0.21-0.68) for males; yearling survival rates, however, were among the highest, averaging 0.85 for females and 0.81 for males. Low pup and high yearling rates offset each other, however, so that cumulative survival rates to age 4, averaging 0.33 for females and 0.27 for males, were similar to those found in studies from Alaska and Russia. While range-limit effects and environmental variation may be related to the low and variable pup survival rates we found, populations in Oregon and California nonetheless continued to grow, which contributed to delisting of the eastern stock in 2013. Continued monitoring and incorporation of new information on vital rates into regional population models will help inform post-delisting monitoring for the eastern stock of Steller sea lions.

York, A. E. (1994). The Population Dynamics of Northern Sea Lions, 1975-1985. *Marine Mammal Science*, 10(1), 38-51. <u>https://doi.org/10.1111/j.1748-7692.1994.tb00388.x</u>

Abstract: Populations of northern sea lions (Eumetopias jubatus) in the vicinity of Marmot Island, Alaska declined during 1975–1985 at about 5% per year (Merrick et al. 1987). The cause of this decline is not known. A life table for the northern sea lion was calculated assuming that life spans follow a Weibull distribution. Samples of northern sea lions taken in the vicinity of Marmot Island, Alaska during 1975-1978 and 1985–1986 indicate that the average age of females older than 3 yr increased about 1.55 yr (SD = 0.35 yr) while the population was declining at about 5% per year. Fecundity rates decreased by 10% over the same period, but the decrease was not statistically significant (Calkins and Goodwin 1988). Possible causes of the population decline and the change in age structure were examined by writing the Leslie matrix population equation in terms of changes in juvenile and adult survival rates and fecundity, and examining the short-term behavior of the trajectories of the average age of adult females, total number of females, and total number of pups with respect to those changes in the vital parameters. From the observed rate of declines of adults and the changes in average age of adult females and fecundity, estimates of the changes in adult and juvenile survival were calculated; estimates of the standard deviations of these changes were estimated via a bootstrap procedure. One purpose of this exercise is to aid in setting priorities for research for determining the cause of the decline. An explanation for the observed declines in numbers of adult sea lions consistent with the observed fecundity rates, a rate of decrease of 5% in the number of adults, and the corresponding increase in average age (of females age 3 yr and older) was a 10%–20% decrease in the survival of juveniles (age 0-3 yr) coupled with an insignificant change in adult survival (0.03%, SD = 1%).

 York, A. E., Merrick, R. L., & Loughlin, T. R. (1996). An Analysis of the Steller Sea Lion Metapopulation in Alaska. In *Metapopulations and Wildlife Conservation*. D. R. McCullough (Ed.), (pp. 259-292).
Washington: Island Press. Retrieved from <u>https://islandpress.org/books/metapopulations-and-wildlife-conservation</u>

Book chapter on the population of the Steller sea lion in Alaska and its decline.

Zadalskii, S. V. (1997). Spatial Structure and Size of the Sea Lion (*Eumetopias Jubatus* Schreb, 1776) Population on the Yam Islands. *Russian Journal of Ecology, 28*(6), 420-422. Retrieved from <u>http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch_&qid=5&SID=8AKBSJ5RixL6hagr5Wp&page=1&doc=1</u>

[NO ABSTRACT AVAILABLE]

Zador, S., & Yasumiishi, E. (2017). 2017 Status of Alaska Marine Ecosystems Considerations - Gulf of Alaska. National Marine Fisheries Service North Pacific Fisheries Management Council. Retrieved from <u>https://www.fisheries.noaa.gov/resource/data/2017-status-alaska-marine-</u> ecosystems-considerations-gulf-alaska

The goals of the Ecosystem Considerations report are to (1) provide stronger links between ecosystem research and fishery management and to (2) spur new understanding of the connections between ecosystem components by bringing together the results of diverse research efforts into one document. Beginning in 2016, we split the report into four separate documents, one for the Gulf of Alaska, Aleutian Islands, eastern Bering Sea, and the Arctic1. This year, we present updated reports for the Gulf of Alaska and eastern Bering Sea. Each report contains four main sections: Report Card(s) ^ Executive Summary ^ Ecosystem Assessment ^ Ecosystem Status Indicators and Fishing and Human Dimensions Indicators.

Zerbini, A. N., Waite, J. M., Durban, J. W., LeDuc, R., Dahlheim, M. E., & Wade, P. R. (2007). Estimating Abundance of Killer Whales in the Nearshore Waters of the Gulf of Alaska and Aleutian Islands Using Line-Transect Sampling. *Marine Biology*, *150*(5), 1033-1045. https://doi.org/10.1007/s00227-006-0347-8

Killer whale (Orcinus orca Linnaeus, 1758) abundance in the North Pacific is known only for a few populations for which extensive longitudinal data are available, with little quantitative data from more remote regions. Line-transect ship surveys were conducted in July and August of 2001–2003 in coastal waters of the western Gulf of Alaska and the Aleutian Islands. Conventional and Multiple Covariate Distance Sampling methods were used to estimate the abundance of different killer whale ecotypes, which were distinguished based upon morphological and genetic data. Abundance was calculated separately for two data sets that differed in the method by which killer whale group size data were obtained. Initial group size (IGS) data corresponded to estimates of group size at the time of first sighting, and post-encounter group size (PEGS) corresponded to estimates made after closely approaching sighted groups. 'Resident'-type (fish-eating) killer whales were more abundant than the 'transient'-type (mammal-eating). Abundance estimates of resident killer whales (991 [95% CI = 379– 2,585] [IGS] and 1,587 [95% CI = 608–4,140] [PEGS]), were at least four times greater than those of the

transient killer whales (200 [95% CI = 81–488] [IGS] and 251 [95% CI = 97–644] whales [PEGS]). The IGS estimate of abundance is preferred for resident killer whales because the estimate based on PEGS data may show an upward bias. The PEGS estimate of abundance is likely more accurate for transients. Residents were most abundant near Kodiak Island in the northern Gulf of Alaska, around Umnak and Unalaska Islands in the eastern Aleutians, and in Seguam Pass in the central Aleutians. This ecotype was not observed between 156 and 164°W, south of the Alaska Peninsula. In contrast, transient killer whale sightings were found at higher densities south of the Alaska Peninsula between the Shumagin Islands and the eastern Aleutians. Only two sightings of 'offshore'-type killer whales were recorded during the surveys, one northeast of Unalaska Island and the other south of Kodiak Island. These are the first estimates of abundance of killer whale ecotypes in the Aleutian Islands and Alaska Peninsula area and provide a baseline for quantifying the role of these top predators in their ecosystem.

Section II: Behavior

Burkanov, V., Gurarie, E., Altukhov, A., Mamaev, E., Permyakov, P., Trukhin, A., . . . Gelatt, T. (2011). Environmental and Biological Factors Influencing Maternal Attendance Patterns of Steller Sea Lions (*Eumetopias Jubatus*) in Russia. *Journal of Mammalogy*, 92(2), 352-366. <u>https://doi.org/10.1644/10-MAMM-A-194.1</u>

Maternal attendance patterns in free-ranging wildlife can provide insight into basic biology, foraging behavior, and population dynamics. We collected detailed visual observations of attendance patterns by adult lactating Steller sea lions (Eumetopias jubatus) from 2005 to 2007 on 6 major rookeries in the Russian Far East, including those with an increasing population trend (Sea of Okhotsk), severely depleted populations that were recovering (Kuril Islands), or those that were stable (Commander Islands). Individually identifiable females were observed during the postpartum period, with special attention paid to presence and absence during the day and to departure and arrival times. Within Russia females on several Kuril Islands rookeries exhibited extremely short foraging trip durations (median 6.5–8.0 h) and spent higher proportions of time on the rookery (75–82%), whereas females in the Sea of Okhotsk population had the longest trips (median 19.8 h) and spent the least amount of time on the rookery (60%). Most indices of attendance pattern were more favorable (longer peripartum period, higher proportion of time spent on rookery, shorter trips, and longer visits) than those reported in Alaska and much more so than those in California during El Niño years, where the proportion of time spent on the rookery was nearly half that in Russia. Females >6 years of age had shorter trips and longer visit durations than the youngest females (4–5 years), and older mothers exhibited significantly longer periods of nursing before taking their 1st trip, suggesting greater physical condition for older females. Although trip durations remained constant throughout the season, visit durations shortened significantly as the pups aged, suggesting that increasing nutritional demands of pups are met by more frequent, rather than longer, trips. No apparent relationships between attendance patterns and population status were observed; however, many of the differences in attendance patterns throughout the range of the Steller sea lion could be related to local variation in bathymetry and diet patterns.

Byrnes, P. E., & Hood, W. R. (1994). First Account of Steller Sea Lion (*Eumetopias Jubatus*) Predation on a California Sea Lion (Zalophus Californianus). *Marine Mammal Science*, 10(3), 381-383. https://doi.org/10.1111/j.1748-7692.1994.tb00494.x On 12 July 1992 we observed a territorial male Steller sea lion (*Eumetopias jubatus*) attack and eat a small California sea lion (Zalophus californianus) at Ano Nuevo Island, California.

Campbell, G. S., Gisiner, R. C., Helweg, D. A., & Milette, L. L. (2002). Acoustic Identification of Female Steller Sea Lions (*Eumetopias Jubatus*). *Journal of the Acoustical Society of America*, 111(6), 2920-2928. <u>https://doi.org/10.1121/1.1474443</u>

Steller sea lion (*Eumetopias jubatus*) mothers and pups establish and maintain contact with individually distinctive vocalizations. Our objective was to develop a robust neural network to classify females based on their mother-pup contact calls. We catalogued 573 contact calls from 25 females in 1998 and 1323 calls from 46 females in 1999. From this database, a subset of 26 females with sufficient samples of calls was selected for further study. Each female was identified visually by marking patterns, which provided the verification for acoustic identification, Average logarithmic spectra were extracted for each call, and standardized training and generalization datasets created for the neural network classifier. A family of backpropagation networks was generated to assess relative contribution of spectral input bandwidth, frequency resolution, and network architectural variables to classification accuracy. The network with best overall generalization accuracy (71%) used an input representation of 0-3 kHz of bandwidth at 10.77 Hz/bin frequency resolution, and a 2:1 hidden:output layer neural ratio. The network was analyzed to reveal which portions of the call spectra were most influential for identification of each female. Acoustical identification of distinctive female acoustic signatures has several potentially important conservation applications for this endangered species, such as rapid survey of females present on a rookery.

Cappozzo, H. L., Túnez, J. I., & Cassini, M. H. (2008). Sexual Harassment and Female Gregariousness in the South American Sea Lion, *Otaria Flavescens*. *Naturwissenschaften*, *95*(7), 625-630. Retrieved from <u>https://link.springer.com/article/10.1007%2Fs00114-008-0363-2</u>

Most colonial pinnipeds form extreme clusters of breeding females that cannot be entirely explained by the distribution of sites for reproduction. Avoidance of male harassment has been postulated as an important determinant of reproductive aggregation in this group of mammals. Female gregariousness can reduce harassment by resident males by two mechanisms; directly by the 'dilution effect' or indirectly because resident males that defend large female groups are less harassing. In order to investigate the relationship between male harassment and female gregariousness in relation to the size of breeding groups, we analysed the behaviour of dominant males and their females in a breeding colony of Otaria flavescens. Females in large breeding groups received less harassment by resident males due to dilution effects and because males that defended a large group interacted less frequently with females than males with small groups.

Chilvers, B. L., Robertson, B. C., Wilkinson, I. S., Duignan, P. J., & Gemmell, N. J. (2005). Male Harassment of Female New Zealand Sea Lions, Phocarctos Hookeri: Mortality, Injury, and Harassment Avoidance. *Canadian Journal of Zoology*, *83*(5), 642-648. <u>https://doi.org/10.1139/z05-048</u>

Sexual aggression by male pinnipeds during breeding can lead to female injury and death, affecting reproductive success, fecundity, and increasing the cost of mating for females. Thus, females that

employ strategies to minimize the probability of being injured will be at an advantage. Here we investigate the extent of injuries and the number of deaths attributed to male harassment, and test the hypothesis of whether the arrival and departure behaviour of female New Zealand sea lions (Phocarctos hookeri (Gray, 1844); NZSL) at Sandy Bay, Enderby Island, the Auckland Islands, is adapted to reduce the chance of injury or death from encounters with male NZSLs. During the breeding season, harassment by non-territorial male NZSLs causes mortality in adult female NZSLs, approximately 5 in every 1000 females breeding each year. Permanent scars from male bites are observed on 84% of adult females. This mortality and visible injury rate only represents the direct impacts on female NZSL from male harassment. Indirect impacts, such as the time and energy cost of avoidance behaviour, pup separation, and pup injury and death, can have as significant long-term effects on individuals and the population. We find that male harassment can influence the behaviour of individuals in NZSL breeding harems.

Davis, R. W., Brandon, E. A. A., Calkins, D. G., & Loughlin, T. R. (2006). Female Attendance and Neonatal Pup Growth in Steller Sea Lions (Eumetopias Jubatus). In Sea Lions of the World. A.W. Trites, S.K. Atkinson, D.P. DeMaster, L.W. Fritz, T.S. Gelatt, L.D. Rea, and K.M. Wynne (Eds.) Sea Grant Alaska. <u>https://doi.org/10.4027/slw.2006.02</u>

We studied attendance behavior of lactating Steller sea lions (SSL) and the growth rates of pups in Southeast Alaska, the Gulf of Alaska, and the Aleutian Islands from 1990 to 1997. These rookeries included one (Lowrie Island in Southeast Alaska) in an area of stable population and three (Chirikof and Marmot islands in the Gulf of Alaska and Seguam and Yunaska islands in the Aleutian Islands) in areas where the population of SSL has declined significantly over the past 30 years. Radio transmitters were glued to the fur of lactating SSL and their presence on the rookeries monitored for the first four to six weeks postpartum. Newborn pups were weighed and measured every two weeks over the same period. The time spent onshore (22.5 h +/- 8.26 SD) by females did not differ significantly among rookeries. Average foraging trip duration was significantly different among rookeries and ranged from 25.6 h +/-11.64 SD in the area of stable population to 9.4 h +/- 3.32 SD in the area of declining population. The average percentage of time spent at sea was significantly different among rookeries and ranged from 51% +/- 8.9 SD in the area of stable population to 31% +/- 9.99 SD in the area of declining population. Male pups (22.6 kg +/- 2.21 SD) were significantly heavier than female pups (19.6 kg +/- 1.80 SD) at 1-5 days of age, but there were no significant differences among rookeries at that age. Male and female pups on the same rookery grew at the same rate during the first four to six weeks. Body mass and standard length increased at a faster rate for pups in the Aleutian Islands and the western Gulf of Alaska (0.45-0.48 kg day(-1) and 0.47-0.53 cm day(-1), respectively) than in Southeast Alaska (0.23 kg day(-1))and 0.20 cm day(-1)). Overall, average foraging trip duration among rookeries decreased and pup growth rate increased in an east-to-west direction from the area of stable to declining population. There was no evidence that female sea lions and pups were nutritionally stressed during the first six weeks postpartum in the area of population decline.

Frid, A., Burns, J., Baker, G. G., & Thorne, R. E. (2008). Predicting Synergistic Effects of Resources and Predators on Foraging Decisions by Juvenile Steller Sea Lions. *Oecologia*, *158*(4), 775-786. <u>https://doi.org/10.1007/s00442-008-1189-5</u>

Many theoretical and experimental studies suggest that synergistic interactions between resources and predators influence foraging decisions and their fitness consequences. This framework, however, has been ignored almost completely by hypotheses on causes of the population decline of Steller sea lions

(SSLs) (*Eumetopias jubatus*) in western Alaska. By comparing predictions from a dynamic state variable model to empirical data on the behaviour of individuals instrumented with satellite-linked time-at-depth recorders, we develop and find preliminary support for the hypothesis that, during winter in Prince William Sound, juvenile SSLs (a) underutilise walleye pollock, a predictable resource in deep strata, due to predation risk from Pacific sleeper sharks, and (b) underutilise the potential energy bonanza of inshore aggregations of Pacific herring due to risk from either killer whales, larger conspecifics, or both. Further, under conditions of resource scarcity—induced by overfishing, long-term oceanographic cycles, or their combination—trade-offs between mortality risk and energy gain may influence demographic parameters. Accordingly, computer simulations illustrated the theoretical plausibility that a decline of Pacific herring in shallow strata would greatly increase the number of deep foraging dives, thereby increasing exposure to sleeper sharks and mortality rates. These results suggest that hypotheses on the decline of SSLs should consider synergistic effects of predators and resources on behaviour and mortality rates. Empirical support for our model, however, is limited and we outline tasks for empirical research that emerge from these limitations. More generally, in the context of today's conservation crises, our work illustrates that the greater the dearth of system-specific data, the greater the need to apply principles of behavioural ecology toward the understanding and management of large-scale marine systems.

Gende, S. M., Womble, J. N., Willson, M. F., & Marston, B. H. (2001). Cooperative Foraging by Steller Sea Lions, *Eumetopias Jubatus. Canadian Field-Naturalist*, *115*(2), 355-356. Retrieved from <u>https://biodiversitylibrary.org/page/34995429</u>

Steller Sea Lions were observed cooperatively foraging for Eulachon (Thaleichthyes pacificus) and possibly Herring (Clupea pallasi) in Berners Bay, southeast Alaska in spring, 1996-1999.

Gentry, R. L. (1970). Social Behavior of the Steller Sea Lion. University of California, Santa Cruz; 1970.

[NO ABSTRACT AVAILABLE]

Gisiner, R. C. (1985). *Male Territoriality and Reproductive Behavior in the Steller Sea Lion, Eumetopias Jubatus*: University of California, Santa Cruz.

[NO ABSTRACT AVAILABLE]

Higgins, L. V. (1984). *Maternal Behavior and Attendance Patterns of the Stellar Sea Lion in California.* University of California, Santa Cruz.

[NO ABSTRACT AVAILABLE]

Higgins, L. V., Costa, D. P., Huntley, A. C., & Leboeuf, B. J. (1988). Behavioral and Physiological Measurements of Maternal Investment in the Steller Sea Lion, Eumetopias-Jubatus. *Marine Mammal Science*, 4(1), 44-58. <u>https://doi.org/10.1111/j.1748-7692.1988.tb00181.x</u> The onshore and at-sea cycles of females, suckling behavior of pups and their milk intake were studied in Steller sea lions (*Eumetopias jubatus*) during 1983 at Año Nuevo Island, California. Females averaged approximately 2 1 h ashore and 36 h at sea. The trips to sea lengthened as pups aged, resulting in an overall decline in female time ashore to 30% by the sixth week foliowing parturition. Activity budgets of pups showed no significant differences among suckling time, age and sex. Milk intake, estimated using labeled water studies, revealed that heavier pups consumed more milk than lighter ones (milk ingestion in ml/d = 4.26 + 0.0687 x [Pup Mass in kg]). Mean milk intake was 1.78 ± 0.33 liters/d. Mean pup growth rate was 0.38 ± 0.1 kg/d. The results suggest that female attendance patterns are shaped by the increasing nutritional demands of growing pups and their increasing efficiency at suckling.

 Hood, W. R., & Ono, K. A. (1997). Variation in Maternal Attendance Patterns and Pup Behaviour in a Declining Population of Steller Sea Lions (*Eumetopias Jubatus*). *Canadian Journal of Zoology*, 75(8), 1241-1246. <u>https://doi.org/10.1139/z97-146</u>

Maternal attendance patterns of lactating female Steller sea lions (*Eumetopias jubatus*) and the activity budgets of pups on Ano Nuevo Island, California, were compared between the 1973 and 1992 breeding seasons to investigate temporal changes in behaviour that may be associated with population decline. Females were absent from the breeding area longer in 1992, which may reflect increased foraging effort. Pups also spent significantly less time sucking and more time swimming in 1992. Suckling time is correlated with milk intake in some otariid species, thus the decreased amount of time 1992 pups spent sucking could reflect a reduction in the total volume of milk produced by females. Pups in 1992 are likely to have spent more time swimming than pups in 1973 because high tide covered a greater proportion of the study site in 1992 than in 1973. An increase in time females spent at sea and a decrease in time pups spent sucking are consistent with behavioural changes associated with reduced prey availability.

Iida, K., Park, T. G., Mukai, T., & Kotani, S. (2006). Avoidance of Artificial Stimuli by the Steller Sea Lion. In Sea Lions of the World. A.W. Trites, S.K. Atkinson, D.P. DeMaster, L.W. Fritz, T.S. Gelatt, L.D. Rea, and K.M. Wynne (Eds.) Sea Grant Alaska. <u>https://doi.org/10.4027/slw.2006.33</u>

Every winter, hundreds of Steller sea lions (*Eumetopias jubatus*) visit the coast of Hokkaido, northern Japan. Their foraging behavior destroys fishing gear, which is a serious problem. In order to find a solution that allows the coexistence of both Steller sea lions and fishing activities, attempts have been made to control their behavior using acoustical and optical stimuli. This study examined methods of repelling Steller sea lions from fishery gear using aerial and underwater sounds and flashing lights. In this study, we (1) observed and analyzed the relationship between the calls and the behavior of Steller sea lions; (2) searched for effective stimuli for repelling Steller sea lions; (3) developed a displacing system that generates artificial stimuli to repel Steller sea lions using sounds and lights; and (4) tested the displacing system. Experiments were conducted at a Steller sea lion haul-out located on the west coast of Hokkaido, on the Sea of Japan. Steller sea lions were exposed to acoustical and optical stimuli consisting of repeated intermittent sounds with or without flashing lights. This system was controlled from the edge of a cliff, and the reactions of Steller sea lions were monitored using a video camera and microphone. Most of the Steller sea lions responded to the stimuli for repelling Steller sea lions were aerial sounds, underwater sounds, and flashing lights in that order.

Kucey, L. (2005). Human Disturbance and the Hauling out Behaviour of Steller Sea Lions (Eumetopias Jubatus). (Master of Science), University of British Columbia, Retrieved from http://www.marinemammal.org/wp-content/pdfs/kucey_2005.pdf

There is considerable interest in assessing and mitigating disruptive effects of humans on the behaviour of marine mammals, especially for species with uncertain or decreasing population trends. Steller sea lions (*Eumetopias jubatus*) have been under intensive study throughout their range over the past few decades in an attempt to identify the causes of a large population decline in the Gulf of Alaska and Aleutian Islands. Consequently, disturbance due to scientific research has also increased at rookeries and haulouts. The purpose of my study was to determine if there were measurable short-term effects of human disturbance on the numbers of Steller sea lions using terrestrial sites. Numbers and composition of sea lions were documented for 2 ñ 3 week periods in southeast Alaska and British Columbia during summer (n = 8 sites) and winter / spring (n = 6 sites). They revealed considerable daily variation in numbers of sea lions hauled out within and among study sites that was related in part to prevailing environmental conditions. However, counts could not be corrected to account for environmental influences on the total numbers of sea lions using haulouts.

Kucey, L., & Trites, A. W. (2004). The Effects of Disturbance on Sea Lions: Assessing Response and Recovery. University of British Columbia Marine Mammal Research Unit. <u>https://doi.org/10.14288/1.0074874</u>

There is considerable interest in assessing and mitigating disruptive effects of humans on the behaviour of marine mammals, especially for species with uncertain or decreasing population trends. Steller sea lions (Eumetopias jubatus) have been under intensive study throughout their range over the past few decades in an attempt to identify the causes of a large population decline in the Gulf of Alaska and Aleutian Islands. Consequently, disturbance due to scientific research has also increased at rookeries and haulouts. The purpose of my study was to determine if there were measurable short-term effects of human disturbance on the numbers of Steller sea lions using terrestrial sites. Numbers and composition of sea lions were documented for 2 - 3 week periods in southeast Alaska and British Columbia during summer (n = 8 sites) and winter / spring (n = 6 sites). They revealed considerable daily variation in numbers of sea lions hauled out within and among study sites that was related in part to prevailing environmental conditions. However, counts could not be corrected to account for environmental influences on the total numbers of sea lions using haulouts. Hauling out trends were examined for preand post-disturbance periods across multiple sites over two seasons. Predetermined research disturbances occurred to collect scats at the haulouts, and to brand pups at the rookery. Three methods were explored to assess local population recovery that addressed both quantitative and temporal aspects of sea lions returning to the study locations. Disturbances resulted in significantly fewer sea lions using haulouts during the post-disturbance period. Variation in the numbers of animals using the haulouts increased following the disturbance, but rates of change in daily numbers did not differ significantly between periods. Six of ten disturbed sites reached full recovery (100% of the predisturbance mean) on average 4.3 days after the research disturbance. To determine if individual behaviour was affected by disturbance, sea lions arriving on shore were followed to determine normal patterns of interactions and behaviour. Significant differences were noted in hauling out behaviour between animals that remained on land and those that returned to the water. Sea lions that returned to the water exhibited higher rates of behaviour and interactions with other animals during the week that

followed the disturbance. Seasonal differences were also noted in the rates of behaviour and interactions that may be indicative of certain times of the year when sea lions are more sensitive to human presence and disturbance. Increasing levels of human-sea lion contact are expected as more and more people visit the remote coastal habitat of Steller sea lions. Future studies are needed to assess the influence of disturbance on sea lion redistribution within a critical recovery period, as well as to determine the physiological effects that sea lions experience with repeated human disturbance. Disturbance studies are an important aspect of conservation initiatives because they can help guide policies and establish restrictions to protect wild populations from human intrusion.

Kucey, L., & Trites, A. W. (2006). A Review of the Potential Effects of Disturbance on Sea Lions: Assessing Response and Recovery. <u>https://doi.org/10.4027/slw.2006.36</u>

Human intrusion within areas of sea lion habitat is increasing worldwide, leading to concerns about disruption of distribution and daily activities of sea lions. Sea lion responses to disturbance can be quantified by recording changes in behavioral patterns, documenting numbers of animals on shore before, during, and after the disturbance, or by measuring physiological stress of individual animals. However, assessing recovery is not so straightforward, as highlighted by an example from a study of the short-term effects of disturbance on Steller sea lions. Recovery is generally recognized as a return to an original state or normal condition, but is often operationally defined as a percent-return to pre-disturbance numbers or behaviors. Simple interpretation of disturbance effects can be easily confounded by concurrent natural seasonal changes in behaviors or haul-out patterns, or by daily variability in numbers of animals present that can be attributed to weather, tidal cycle stage, and other factors. Overall, a range of recovery criteria needs to be simultaneously applied when assessing the effects of human disturbance on sea lion populations. Insights gained from research on the effects of disturbance on Steller sea lions may help guide the development of studies undertaken on other species of sea lions.

Kuhn, C. E., Chumbley, K., Fritz, L., & Johnson, D. (2017). Estimating Dispersal Rates of Steller Sea Lion (*Eumetopias Jubatus*) Mother-Pup Pairs from a Natal Rookery Using Mark-Resight Data. *PLoS* ONE, 12(12) <u>https://doi.org/10.1371/journal.pone.0189061</u>

To monitor population trends of Steller sea lions (*Eumetopias jubatus*) in Alaska, newborn pups are counted during aerial surveys. These surveys are scheduled to occur after the majority of pups are born, but before pups begin to spend significant time in the water. Some studies have reported dispersal of mother-pup pairs away from breeding beaches during the pupping season (July), which may influence survey results. Using a multistate mark-recapture model with state uncertainty, we estimated the amount of dispersal during the pupping season based on observations of permanently marked sea lions. Research was conducted at land-based observation sites on Marmot Island, Alaska, between 2000 and 2013. Both marked adult females with dependent pups and marked pups were observed at two rookery beaches from May to July. Cumulative dispersal rates were minimal (< 1%) prior to the planned start of the aerial survey (23 June) and increased to 11.2% by the planned survey completion date (10 July). The increased cumulative dispersal rate during the remainder of the observation period (end of July) suggests potential bias in surveys that occur beyond 10 July, however surveys past this date are rare (< 10% between 1973 and 2016). As a result, movements of mother-pup pairs during the pupping season are not likely to influence aerial survey estimates.

Kuhn, C. E., Chumbley, K., Johnson, D., & Fritz, L. (2017). A Re-Examination of the Timing of Pupping for Steller Sea Lions *Eumetopias Jubatus* Breeding on Two Islands in Alaska. *Endangered Species Research*, 32, 213-222. <u>https://doi.org/10.3354/esr00796</u>

Steller sea lions are distributed from Japan to the California coast, USA, and population demographics vary spatially, with populations in some regions increasing while others are declining. To assess changes in population size, aerial surveys are conducted annually to quantify pup production. The timing of these surveys is critical for accurate population estimates, and survey windows were determined based on historical estimates of mean pupping date. We re assessed the timing of pupping for Steller sea lions at 2 breeding islands in the central Gulf of Alaska, USA (Marmot Island) and the eastern Aleutian Islands (Ugamak Island) for evidence of temporal shift. Using land-based counts of pups, we quantified mean pupping date and the duration of the pupping season between 2003 and 2013 and compared these data to historical mean pupping dates between 1977 and 1999. The mean pupping date of 9 June on Marmot Island was not significantly different than the mean pupping date on Ugamak Island, 8 June. On Marmot Island, mean pupping date differed by 3.7 +/- 0.9 d between beaches; however, mean pupping date did not differ between beaches on Ugamak Island. On Ugamak Island, mean pupping date was significantly earlier than previously reported by 2.5 d, but this may be an artifact of the limited number of years available for comparison. On Marmot Island mean pupping date was not different from historical dates. On both islands, 94.2 +/- 1.6% of the pups were born prior to the planned start of aerial surveys in Alaska (23 June). Our results demonstrate that although mean pupping date was variable and may have shifted earlier relative to historical data at Ugamak Island, the current timing of the aerial survey is suitable for obtaining peak pup counts for Steller sea lions in these regions.

Kulinchenko, A. B., Rogers, E. O., Kopylova, Y., Olsen, E., Andrews, J., Sirnpson, P. K., Jones, M. (2004). *Steller Watch - Time-Lapse Photography System for Remote Steller Sea Lion Sites*. Paper presented at the 2004 IEEE International Geoscience and Remote Sensing Symposium. <u>https://doi.org/10.1109/IGARSS.2004.1368692</u>

The ultimate goal of the Steller Watch system is a tool that will provide comprehensive imagery data from remote locations for analyzing Steller Sea Lion behavior and a rich data set for scientific analyses. This project directly addresses three of the thirteen funding priorities for Steller Sea Lions: (1) Predation by other mammals; (2) Juvenile and pup survival rates; and (3) population counts.

Lynn, B. L., Reichmuth, C., Schusterman, R. J., & Gulland, F. M. D. (2010). Filial Imprinting in a Steller Sea Lion (*Eumetopias Jubatus*). *Aquatic Mammals, 36*(1), 79-83. <u>https://doi.org/10.1578/AM.36.1.2010.79</u>

The Marine Mammal Center hand reared a male Steller sea lion (*Eumetopias jubatus*) after it was found abandoned as a neonate in June 2006. Following release in April 2007, the animal repeatedly approached humans on the shore, necessitating long-term captive placement. To evaluate the extent of this preference for human contact, we conducted three behavioral assessments: (1) a stationary preference test, (2) a following test, and (3) a vocal playback test. This sea lion demonstrated an overall penchant for human interaction and a strong preference for the voice of one of his early caretakers. Filial imprinting, a developmental phenomenon extensively studied in birds but less so in mammals, is suggested as the cause of this aberrant social behavior. The long-term effects of imprinting in mammals,

including impacts on reproductive success, remain poorly understood. This observation with a Steller sea lion is the first documented case of probable imprinting in this species.

Mamaev, E. G. (1997). Time Budget and Activities of *Eumetopias Jubatus* (Pinnipedia, Otariidae) Bulls in Reproduction. *Zoologichesky Zhurnal*, *76*(4), 494-500. Retrieved from https://elibrary.ru/item.asp?id=14941179

Data on time budgets and activities of northern sea lion bulls are represented. Duration of rest ranges within 30-90% a day. In the reproduction period the average duration of rest covers 64.4% of light day but is related considerably to the social status of an individiual. In the post-reproduction period the duration of rest increases, The bulls inhabiting the tidal area spend on average 23% of the time in water due not only to thermoregulative, but also to territorial behaviour. Time costs for the competitive behaviour cover up to 0.16% of the total time budget. Harem bulls are characterized by the highest activity and the least duration of rest.

Mamaev, E. G. (2001). Territoriality of the Steller's Sea Lion, *Eumetopias Jubatus* (Pinnipedia, Otariidae), Bulls: Longevity and Dynamics of Using Individual Territories. *Zoologichesky Zhurnal*, *80*(4), 477-483. Retrieved from

http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch &qid=9&SID=8AKBSJ5RixL6hagr5Wp&page=1&doc=1

Some aspects of territoriality in Steller's sea lion bulls was studied on a reproductive rookery in Mednyi Island (the Commander Islands) in 1995-1997. In the rookery, from 1.5 to 15% of bulls do not form individual territoires for the reproductive and post-reproductive periods. The maximum longevity of residence of bulls in these areas is 68 days. At least 8.5% of bulls have their individual territories for more than 40 days. Sixty percent of individual territories are formed by mid-June. In the post-reproductive period, some bulls leave the rookery, but 38% of individuals come back. The maximum duration bull are absent is 53 days. In the post-reproductive period, bulls leave their territories for a short time.

Maniscalco, J., Atkinson, S., & Armato, P. (2002). Early Maternal Care and Pup Survival in Steller Sea Lions: A Remote Video Monitoring Project in the Northern Gulf of Alaska. *Arctic Research of the United States, 16*, 36-36. Retrieved from <u>https://nsf.gov/pubs/2003/nsf03021/nsf03021_6.pdf</u>

The endangered western population of Steller sea lions that occurs within and adjacent to several of Alaska's National Parks (Anaikchak National Monument and Preserve, Katmai National Park and Preserve, Kenai Fjords National Park, and Lake Clark National Park and Preserve) has undergone a major population decline over the last several decades. In an effort to understand the mechanics of the decline, the Alaska SeaLife Center, in cooperation with National Fish and Wildlife Foundation, the National Marine Fisheries Service, and the Ocean Alaska Science and Learning Center, is studying, through the application of remote cameras and field research, the behavioral ecology of this species throughout its range. One component of the study is investigating the importance of early maternal care to young Steller sea lions.

Maniscalco, J. M., Harris, K. R., Atkinson, S., & Parker, P. (2007). Alloparenting in Steller Sea Lions (*Eumetopias Jubatus*): Correlations with Misdirected Care and Other Observations. *Journal of Ethology, 25*(2), 125-131. <u>https://doi.org/10.1007/s10164-006-0001-4</u>

Alloparental care is rarely observed in Steller sea lions (*Eumetopias jubatus*) where maternal care is extended to a single pup for up to 1 year or more. However, we observed 28 allonursing events and one case of adoption at a small breeding rookery in the western Gulf of Alaska between the years 2001 and 2005. Multiparous and primiparous females were observed nursing nonfilial individuals with equal frequency, but primiparous females spent significantly more time nursing nonfilial individuals. Multiparous females allowed allonursing only while sleeping and unaware while most primiparous females were allonursing. These results are consistent with the misdirected-care hypothesis suggesting that primiparous (presumably younger) females nurse nonfilial pups due to inexperience, whereas multiparous (presumably older) females are victims of milk stealing during times of inattentiveness. Nonfilial pups were aggressively tossed most often during the pupping season and only by multiparous females, while allonursing events occurred more frequently after the pupping season. Starveling pups were not cared for by any female, but two were attended by a single bull during separate autumn seasons.

Maniscalco, J. M., & Parker, P. (2009). A Case of Twinning and the Care of Two Offspring of Different Age in Steller Sea Lions. *Marine Mammal Science*, 25(1), 206-213. <u>https://doi.org/10.1111/j.1748-7692.2008.00247.x</u>

The article presents a study on twinning and caring for twin Steller sea lions or the *Eumetopias jubatus* in the U.S. It discusses the case of three female sea lions which gave birth in Chisell Island. Results on the comparison of perinatal periods of foraging trips of females nursing a yearling and a pup, weight of the pups, and the weight regressions are provided. Results further indicate that breastfeeding of more than one pup is uncommon for sea lions and concludes that suckling of pups and yearling is difficult for female sea lions until they are fully weaned.

Maniscalco, J. M., Parker, P., & Atkinson, S. (2006). Interseasonal and Interannual Measures of Maternal Care among Individual Steller Sea Lions (*Eumetopias Jubatus*). *Journal of Mammalogy, 87*(2), 304-311. <u>https://doi.org/10.1644/05-mamm-a-163r2.1</u>

We studied maternal care in Steller sea lions (*Eumetopias jubatus*) at a small rookery in the northern Gulf of Alaska over the course of 4 summers, 2001-2004 and 3 autumn seasons, 2002-2004, using remotely operated video cameras. Perinatal periods were long (>= 10.0 days); although varied between years. Timing of parturition was earlier and perinatal periods longer for multiparous females compared to females considered to be primiparous. Summer foraging trip durations were short ((X) over bar = 16.5 h), increased during August, then did not change significantly over the course of the autumn ((X) over bar = 55.7 h). Individual lactating females spent a greater proportion of their time on shore during the summer and a greater proportion of their time at sea during the autumn. The amount of time that females nursed their pups also increased significantly from the summer to autumn. Long perinatal periods and short foraging trips during summer indicate that sea lions are likely finding sufficient food nearby. Our data also suggest that Steller sea lions reach an upper plateau in duration of foraging cycles as early as mid-August and large increases above that plateau may indicate difficulty finding sufficient food during the winter months.

Milette, L. L., & Trites, A. W. (2003). Maternal Attendance Patterns of Steller Sea Lions (*Eumetopias Jubatus*) from Stable and Declining Populations in Alaska. *Canadian Journal of Zoology-Revue Canadienne De Zoologie*, *81*(2), 340-348. <u>https://doi.org/10.1139/z03-008</u>

Maternal attendance patterns of Alaskan Steller sea lions (Eumetopias jubatus) were compared during the summer breeding seasons in 1994 and 1995 at Sugarloaf Island (a declining population) and Lowrie Island (a stable population). Our goal was to determine whether there were differences in maternal attendance between the two populations that were consistent with the hypothesis that lactating Steller sea lions in the area of decline were food-limited during summer. Our a priori expectations were based on well-documented behavioural responses of otariids to reduced prey availability. We found that foraging trips were significantly shorter in the area of population decline, counter to initial predictions. The mean length of foraging trips in the declining area was 19.5 h compared with 24.9 h in the stable area. In contrast, the mean perinatal period (time between parturition and first feeding trip) was significantly longer in the area of decline (9.9 versus 7.9 days), again countering initial predictions. The mean length of shore visits for the declining population was also significantly longer (27.0 h compared with 22.6 h where the population was stable). For both populations, the mean time that mothers foraged increased as pups grew older, whereas the time that they spent on shore with their pups became shorter. Behavioural observations of maternal attendance patterns are inconsistent with the hypothesis that lactating Steller sea lions from the declining population had difficulty obtaining prev during summer.

Parker, P., & Maniscalco, J. M. (2014). A Long-Term Study Reveals Multiple Reproductive Behavior Strategies among Territorial Adult Male Steller Sea Lions (*Eumetopias Jubatus*). Canadian Journal of Zoology, 92(5), 405-415. <u>https://doi.org/10.1139/cjz-2013-0099</u>

We conducted a long-term study to assess how tenure and territorial behaviors influence reproductive success among male Steller sea lions (*Eumetopias jubatus* (Schreber, 1776)). Copulations by males (n = 44) that maintained territories on a rookery in the Gulf of Alaska from 2001 to 2009 were observed using a remote video system. Approximately half of postpartum females copulated with a male in a different territory from where they gave birth. Nearly two-thirds of territorial males with known tenure were unsuccessful in copulating during their first year. Number of copulations for territorial males increased from acquisition year to year 2 with no change in subsequent years. Cluster analysis of tenure and territorial tactic variables for 15 males with observed lifetime reproductive success was used to describe multiple reproductive strategies. Characteristics of the two most successful strategies were the following: (i) males typically copulated in their first year, retained the same territories for 3-5 years, and occupied centrally located coastal territories where the highest percentage of females gave birth and (ii) males did not copulate until at least their third year and occupied peripheral territories with fewer births for a longer tenure of 7-8 years. Results indicated that lifetime reproductive success was not achieved solely by time on the breeding area; rather, it was achieved from a combination of tenure and territorial tactics.

Porter, B. T., & Trites, A. W. (2004). Suckling Attempts During Winter by Two Non-Filial Steller Sea Lion Pups (*Eumetopias Jubatus*). *Mammalia, 68*(1), 23-26. <u>https://doi.org/10.1515/mamm.2004.003</u> Milk stealing and fostering care is rare among mammals (Packer et al. 1992). Such behaviour can benefit neonates and possibly the nursing foster mother (Roulin 2002, 2003). However, it also likely comes at a cost to the fostering mother and her dependent young. Neonates may increase their chances of survival by sneak-suckling unrelated females, or by obtaining milk with the consent of mothers of other neonates. However, chances are greater that females protective of their limited milk resources will aggressively prevent unrelated young from suckling. Risks of being bitten, attacked or killed by adult females presumably outweigh the potential benefits that might be achieved by sneak-suckling.

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. <u>https://doi.org/10.1111/mms.12437</u>

The article analysis the spread of infanticide and cannibalism in *Eumetopias jubatus*. Topics discussed include sexual behavior of subadult males; observations on the breeding of Steller sea lions conducted at the Yugo-Vostochny rookery of Medny Island; and use of photographs for obtaining natural marks on the same.

 Schakner, Z. A., Petelle, M. B., Tennis, M. J., Van der Leeuw, B. K., Stansell, R. T., & Blumstein, D. T.
(2017). Social Associations between California Sea Lions Influence the Use of a Novel Foraging Ground. *Royal Society Open Science*, 4(5), 160820. <u>https://doi.org/10.1098/rsos.160820</u>

Social relationships define an individual's position in its social network, which can influence the acquisition and spread of information and behavioural variants through the population. Thus, when nuisance behaviours spread through wildlife populations, identifying central individuals may provide valuable insights for problem-species management. We studied the effects of network position on California sea lion (Zalophus californianus) discovery and foraging success at a novel foraging ground— the salmonids that aggregate at the Bonneville Dam tail-race, 235 km up the Columbia River. We found that an individual's centrality in their social network influenced discovery of the Bonneville Dam and whether they returned the next year. Foraging success once at the dam was independent of network position. Extensive lethal and non-lethal removal efforts have been implemented at Bonneville Dam and focused on reducing the number of individual sea lions at the dam. Since social relationships forged at the opening of the Columbia River influence both the discovery and return to the Bonneville Dam, efforts to increase salmon recovery may be enhanced by breaking apart social networks at the opening of the river.

Shuert, C. R., & Mellish, J. E. (2016). Size, Mass, and Occurrence of Gastroliths in Juvenile Steller Sea Lions (*Eumetopias Jubatus*). *Journal of Mammalogy*, *97*(2), 639-643. <u>https://doi.org/10.1093/jmammal/gyv211</u>

Gastroliths, or stones found in the digestive tract of some pinnipeds, were gathered (n = 128) from temporarily captive juvenile Steller sea lions (n = 23, *Eumetopias jubatus*) at the Alaska SeaLife Center and characterized by their size and mass. Blubber depth and season were significant predictors of gastrolith mass and also positively associated with larger animals. From this, we conclude that they are likely actively ingested for a functional use rather than incidental.

Trites, A. W., Porter, B. P., Deecke, V. B., Coombs, A. P., Marcotte, M. L., & Rosen, D. A. (2006). Insights into the Timing of Weaning and the Attendance Patterns of Lactating Steller Sea Lions (*Eumetopias Jubatus*) in Alaska During Winter, Spring, and Summer. *Aquatic Mammals, 32*(1), 85. <u>https://doi.org/10.1578/AM.32.1.2006.85</u>

Behavioral observations of lactating Steller sea lions (Eumetopias jubatus) and their offspring were recorded at four haulout sites in Alaska to determine (1) whether sea lions wean during winter while they are 7 to 9 mo old and (2) whether sea lions using sites in the Gulf of Alaska (the declining endangered population) made longer foraging trips than sea lions in southeast Alaska (where the population appeared larger and healthier). Longer foraging trips are commonly thought to be an indicator of nutritional stress. Eight sets of behavioral observations were made using focal and scansampling techniques at haulouts from 1995 to 1998 during three seasons (winter, spring, and summer). Counter to expectations, we found no significant differences between haulout populations in the time that lactating Steller sea lions spent at sea or on shore. This suggests that lactating sea lions did not have more difficulty capturing prey from winter through summer in the area of decline compared to where sea lion numbers increased. Lactating Steller sea lions in both regions did make longer foraging trips in winter than they did in spring and summer. These changes in foraging patterns among seasons were consistent among all years and sites. The proportion of time that immature Steller sea lions suckled declined through the spring to early summer, suggesting that sea lions began supplementing their milk diet with solid food in the spring. We did not observe any sea lions weaning during winter; rather, most appeared to wean at the start of the breeding season when they were 1 or 2 y old. Sea lions observed in southeast Alaska during the late 1990s while population growth was slowing suggest that most males weaned at 2 y and that about 50% of females weaned at 1 y and the remainder at 2 y.

Trites, A. W., & Porter, B. T. (2002). Attendance Patterns of Steller Sea Lions (*Eumetopias Jubatus*) and Their Young During Winter. *Journal of Zoology, 256*, 547-556. https://doi.org/10.1017/s0952836902000596

Winter attendance patterns of lactating Steller sea lions *Eumetopias jubatus* and their offspring were recorded during the late stages of nursing when the young were expected to move from milk to independent foraging. Trip duration and nursing visits to shore by 24 mothers with pups (7-9 months old) and six mothers with yearlings (19-21 months old) were noted during 600 h of observations (from 22 January to I April 1996) at a non-breeding haulout site in south-eastern Alaska. Pups and yearlings tended to stay on or near the haulout while their mothers were away and showed no signs of weaning during winter. Their average trips to sea were 43% shorter in duration than those of lactating females, suggesting that pups and yearlings make independent trips away from the haulout while their mothers forage. The winter attendance cycle of lactating females (consisting of one trip to sea and one visit on land) averaged about 3 days, with the mothers Of Pups spending an average of 15 h of this time onshore with their offspring. The winter attendance cycle of pups and yearlings averaged just over 22 days, with the immature sea lions spending an average of 22h on shore. Foraging trips by mothers of yearlings were significantly longer than those by mothers of pups. However, there was no significant difference in the foraging times of mothers of male and female pups. Lactating females spent more time at sea during winter than during summer. The probability of sighting an individual on the v inter haulout during daylight hours was 15% for lactating females and 40% for immature animals.

Trukhin, A. M. (2008). Daily Time Budget of Lactating Steller Seal Lion (*Eumetopias Jubatus*) Females and Their Pups at the Early Stage of the Postnatal Ontogenesis. *Vestnik Dal'nevostochnogo* otdeleniya RAN, 4, 110-116. Retrieved from <u>https://search.proquest.com/asfa/docview/20164726/83E1E69BAECB4803PQ/1?accountid=282</u> 58

The results of visual observation over two couples of the Steller sea lions (mother-cub) on the reproductive rookery of the Raykoke Island (Kuril Islands) are analyzed. The basic part of the day time budget of a lactating female at the periphery of the rookery consisted of sleep, and the time budget, spent for wakefulness, is almost twice less than that of a female, which gave the birth to a puppy in the center of the rookery. The quantity of 'sleep-activity' cycles per time unit for the female in the center of the rookery is almost twice more, than that for the female at the periphery. In the process of puppies growth time budget of their mothers undergoes certain changes. Within the first one and a half weeks after delivery, passive condition prevailed over the active one for the both females, but later on duration of their activity increased. Activity of females is affected by many factors, but the main one has proved to be the neighbor animal behavior. No appreciable differences in the character of daily activity of puppies in the center and at the periphery of a rookery were revealed, that, probably, could testify to the equivalence of the central and peripheral sites for successful crop development.

Womble, J. N., & Conlon, S. (2010). Observation of Steller Sea Lion (*Eumetopias Jubatus*) Predation on a Harbor Seal (Phoca Vitulina Richardii) in the Glacier Bay Region of Southeastern Alaska. *Aquatic Mammals*, 36(2), 129-137. <u>https://doi.org/10.1578/am.36.2.2010.129</u>

Pinnipeds prey primarily on fish and invertebrates; however, several species are known to prey upon other pinniped species. Herein, we document an observation of a Steller sea lion (*Eumetopias jubatus*) attacking and partially consuming a juvenile harbor seal (Phoca vitulina richardii) in Johns Hopkins Inlet in Glacier Bay National Park, Alaska. Population trends for Steller sea lions and harbor seals contrast dramatically in the Glacier Bay region. Although other marine predators are known to attack harbor seals, it is possible that Steller sea lions could potentially have both a direct and indirect influence on harbor seals in the Glacier Bay region.

Section III: Bibliographies and Encyclopedia Articles

Bowen, W., Beck, C., & Austin, D. (2009). Pinniped Ecology. In *Encyclopedia of Marine Mammals (Second Edition)*. (pp. 852-861): Elsevier <u>https://doi.org/10.1016/B978-0-12-373553-9.00198-X</u>

Ecology is the study of the interactions between individuals and their environment. In this context, environment is taken broadly to include other organisms and the physical characteristics of habitat. These interactions take place at various spatial and temporal scales, and influence both the abundance and distribution of individuals. However, ecology is also a historical science in that the patterns we see today reflect past events and phylogenetic relationships. Thus, processes acting on both evolutionary and ecological time-scales have undoubtedly influenced many of the characteristics of pinniped ecology we see today. Pinnipeds are large, long-lived, aquatic mammals exhibiting delayed sexual maturity and reduced litter size; a single precocial offspring is the norm. As such, they share many of the demographic features of other large mammals. The reproductive ecology of pinniped species share features that reflect their common ancestry as terrestrial carnivores, and their subsequent adaptation to a predominantly aquatic lifestyle. Within the order Pinnipedia, mating systems range from extreme polygyny to sequential defense by males of individual females. Mating systems are closely associated with the dimensionality and stability of the habitat used, and distribution of females at parturition. Male pinnipeds do not participate in the care of the offspring. Thus, parental care is the exclusive responsibility of the female. Female care involves the transfer of energy-rich milk to the pup and protection from conspecifics and terrestrial predators. Knowledge of the at-sea movements of pinnipeds is important because spatial patterns can fundamentally affect the nature and dynamics of species interactions. These interactions largely determine the distribution of foraging. The relative mobility, range, and body size of an animal affects the resolution at which it recognizes environmental heterogeneity.

Hunter, A. M. J., & Trites, A. W. (2001). An Annotated Bibliography of Scientific Literature (1751-2000) Pertaining to Steller Sea Lions (Eumetopias Jubatus) in Alaska. Vancouver: University of British Columbia Fisheries Centre. https://doi.org/10.14288/1.0348128

We compiled an annotated bibliography of Steller sea lion literature that identifies the areas of research that have been undertaken to date, and whether or not they address the leading hypotheses proposed to explain the population decline in Alaska. We identified 263 scientific papers with a primary research focus on Steller sea lions. Of these, 110 articles were peer-reviewed publications in scientific journals, and 153 were other forms of publication (e.g., technical reports, unpublished reports, dissertations, etc.). The total number of Steller sea lion articles published per decade has risen exponentially from 4 in the 1940s to 120 in the 1990s. The bulk of scientific studies have focused on population dynamics, population distribution, ecology, census data, nutrition and behavior. Subject areas that have received low research attention include predation on Steller sea lions, captive studies, metabolism and parasitology. Only 56 of the 263 scientific articles contained information relative to testing one of the 12 hypothesized causes of the Steller sea lion decline. The most frequently addressed hypothesis mortality (24 papers). concerned juvenile This was followed by competition with fisheries, starvation and regime shifts. Only 1 of the 263 articles addressed the role that killer whale predation may be playing in the decline of Steller sea lions. To date, over 9,149 pages pertaining to Steller sea lions have been printed (1,145 pages of primary publications and 8,004 pages of other publications). The relative number of articles that address or provide significant information to assess hypothesized causes of the population decline are few (< 35% of the sea lion literature per decade).

Loughlin, T. R. (2009). Steller Sea Lion: *Eumetopias Jubatus*. In *Encyclopedia of Marine Mammals (Second Edition)*. W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), (pp. 1107-1110). London: Academic Press <u>https://doi.org/10.1016/B978-0-12-373553-9.00253-4</u>

Publisher Summary The Steller sea lion, *Eumetopias jubatus*, is the largest otariid pinniped and one of the more aesthetically appealing sea lions. It exhibits significant sexual dimorphism with males larger. The average standard length of males is 282 cm and of females 228 cm. Estimated average weight of males is 566 kg and of females 263 kg. The upper postcanine number 5 is double rooted, with the crown directed backward, and does not occlude with lower postcanine 5; all other postcanines are single rooted, slant somewhat forward, and have irregular conical pointed crowns. Steller sea lions occur throughout the North Pacific Ocean rim from Japan to southern California. They abound on numerous

breeding sites (rookeries) in the Russian Far East, Alaska, and British Columbia, with lower numbers in Oregon and California. Steller sea lions eat a variety of fishes and invertebrates. The variety of the sea lion diet has been correlated with population dynamics. A cacophony of noise engulfs rookeries and haul-out sites, with animals of both sexes and all ages vocalizing throughout the day and night. Territorial males use low-frequency roars to signal threats to other males and to court females. Females vocalize frequently, calling to their pups and squabbling with other sea lions of all ages. Observations at sea suggest that large groups usually consist of females of all ages and subadult males; adult males sometimes occur in those groups but are usually found individually. On land, all ages and both sexes occur in large aggregations during the nonbreeding season. Breeding season aggregations are segregated by sexual/territorial status. Steller sea lions are rarely seen in aquaria because of their large size and pugnacious nature. The species is an important subsistence resource for Alaskan natives, who hunt sea lions for food and other uses. Two hundred or more may be taken a year in Alaska.

Loughlin, T. R., & Gelatt, T. S. (2018). Steller Sea Lion: *Eumetopias Jubatus*. In *Encyclopedia of Marine Mammals (Third Edition)*. B. Würsig, J. G. M. Thewissen, & K. M. Kovacs (Eds.), (pp. 931-935): London: Academic Press. <u>https://doi.org/10.1016/B978-0-12-804327-1.00245-4</u>

Summary Steller sea lions are the largest otariid pinniped. They occur throughout the North Pacific Ocean rim from Japan to southern California. Two subspecies are recognized, with the separation boundary between them occurring near Prince William Sound, Alaska. The eastern subspecies (*Eumetopias jubatus* monteriensis) was recently removed from the IUCN List of Threatened Species; the western subspecies (E. jubatus) remains listed as Endangered and is declining in some areas. This sea lion eats a variety of fishes and invertebrates across its range. Steller sea lions are shallow divers, with only a few dives recorded to depths greater than 250m. The species is an important subsistence resource for Alaskan natives. Steller sea lions can be negatively affected by commercial fishing directly through incidental catch in nets, by entanglement in derelict debris, by shooting, or indirectly through competition for prey, disturbance, or disruption of prey schools.

Loughlin, T. R., & Tagart, J. V. (2006). *Compendium of Steller Sea Lion Related Research, 2000-2006*. TRL Wildlife Consulting Tagart Consulting. National Marine Fisheries Service North Pacific Fishery Management Council.

On November 29, 2005, Chris Oliver, on behalf of the North Pacific Fishery Management Council, entered into a contract with Thomas R. Loughlin, TRL Wildlife Consulting, and Jack V. Tagart, Tagart Consulting, for the purpose of constructing a compendium of Steller sea lion (SSL) related research in the North Pacific. The objectives of the project were to: 1) identify all relevant SSL related research conducted from the year 2000 to 2006, including gray literature; 2) compile brief (one to two page) summaries of each research project; and 3) synthesize these various research findings into major (thematic) categories with attendant summary results.

Section IV: Fisheries Interaction and Deterrents

Adams, C. F., Foy, R. J., Johnson, D. S., & Coyle, K. O. (2008). Seasonal Changes in Pelagic Fish Biomass around the Chiswell Island Steller Sea Lion Rookery in 2003. *Fisheries Research*, 93(1-2), 179-185. <u>https://doi.org/10.1016/j.fishres.2008.04.003</u>

Fisheries acoustics surveys were conducted around the Chiswell Island rookery in the northern Gulf of Alaska at night in April and August 2003 to assess seasonal changes in prey available to Steller sea lions (*Eumetopias jubatus*) foraging around the rookery. Adult walleye pollock (Theragra chalcogramma)>= 28 cm fork length was the dominant biomass in the upper 50 m of the water column in both months. increasing from 122.8 kg/nmj(2) in April to 457.9 kg/nmi(2) in August. A similar pattern was observed for Pacific herring (Clapeo pallasii), which averaged 2.8 and 65.6 kg/nmi(2) in April and August, respectively. Incidental trawl catch suggested the appearance of age-0 pollock and juvenile salmonids (Oncorhynchus spp.) around the rookery in August as well. The increased biomass of these key prey species is linked to increased foraging trip durations by lactating sea lions from Chiswell Island, and Supports the general view that sea lions in the northern Gulf of Alaska are not food limited during summer months.

Alverson, D. L. (1992). A Review of Commercial Fisheries and the Steller Sea Lion (Eumetopias-Jubatus) the Conflict Arena. *Reviews in Aquatic Sciences, 6*(3-4), 203-256. Retrieved from <u>http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch_&qid=11&SID=8AKBSJ5RixL6hagr5Wp&page=1&doc=1</u>

World War II, which concluded in the Pacific in August 1945, gave birth to an array of new technologies that rapidly galvanized fishery development and greatly altered the character of fisheries throughout the world, including those off Alaska. From the early 1950s to the present. Alaska fisheries have been subjected to an unparalleled series of foreign and domestic developments. In a matter of 4 decades, the fleets of small coastal catcher boats targeting salmon, halibut, and/or herring were transformed into diverse high-tech fleets of small and large vessels fishing a complex of demersal, pelagic. and anadromous fish and shellfish species inhabiting the continental shelf and slope to depths of 1000 m, as well as extensive high seas areas well beyond the topographic influences of the continents. The post-World War II era constituted a period of massive intrusion of human activity into a region previously, except for whaling, almost the exclusive domain of marine invertebrates, fishes, seabirds, and marine mammals. The 1950 to 1990 period, which witnessed explosive growth and changes in the fisheries, also saw a marked decline in Steller sea lion populations off Alaska. Major new fishing activity over this time period included the Japanese driftnet fishery for salmon and herring, Soviet and Japanese tanglenet fisheries for crab, the U.S. crab pot fisheries, the U.S. trawl shrimp fishery, foreign and U.S. trawl fisheries for bottomfish, and U.S. and foreign line fisheries for sablefish, cod, and other bottomfish. Each of these fisheries, along with the well-established U.S. salmon, halibut, and herring fisheries were well entrenched long before World War II), at times and in certain areas introduced potential interactions with sea lions inhabiting the region. These interactions may have included competition for food sources, bycatch mortalities, interruption of normal feeding patterns, shooting in defense of gear, and shooting of an indiscriminate character. Studies of population trends provide evidence that large-scale shifts occurred in the abundance of major elements of the pelagic and demersal fish communities during thc 30-year decline of Steller sea lions. Some of the changes are considered to have been fishery induced while others may have been associated with environmental factors. Regardless of the underlying cause and effect, it is evident that significant adjustments within the ecosystem have occurred and current community structures of the nekton of the region are significantly different from that which prevailed in the early 1960s. Various hypotheses have emerged regarding factors that have brought about the collapse of the Steller sea lion. The author concludes that no single factor can at this time be identified

as the sole or major factor responsible for the Steller sea lion decline and that the responsible factors are likely to have changed over time. Primary causes that may have contributed to the decline include (1) nutritional deficiencies, (2) indiscriminate shooting, (3) bycatch in fishing gear and shootings in defense of gear, and (4) authorized commercial harvests.

Artukhin, Y., Burkanov, V., & Nikulin, V. (2010). Accidental by-Catch of Marine Birds and Mammals in the Salmon Gillnet Fishery in the Northwestern Pacific Ocean. Retrieved from <u>https://wwf.ru/en/resources/publications/booklets/accidental-by-catch-of-marine-birds-and-mammals-in-the-salmon-gillnet-fishery-in-the-northwestern-pa/</u>

The origins and development of the salmon driftnet fishery in the northwest Pacific are described. The scope of the modern gillnet fishery in the Russian Exclusive Economic Zone (EEZ), as well as its research and monitoring programs. Gillnet fishery methods in the Russian EEZ and the monitoring effort by commercial Japanese and scientific Russian fleets are described. Marine bird and mammal by-catch data collected during the large scale salmon fishery from the 1990s through the early 2000s are summarized in detail. Species composition and seasonal, interannual and geographic variation in by-catch mortality are analyzed. Estimates of bird and mammal mortality in gillnets are presented and the potential effect of the fishery on populations is discussed. Global measures to mitigate gillnet by-catch are presented, as is the potential of implementing some of these measures in Russian waters.

 Balsiger, J. W. (2003). Corrections to the Final Rule Implementing Steller Sea Lion Protection Measures for the Bering Sea and Aleutian Islands Management Area (Bsai) and the Gulf of Alaska (Goa) Groundfish Fisheries -Categorical Exclusion. National Marine Fisheries Service Alaska Region. Retrieved from https://repository.library.noaa.gov/view/noaa/19376

The final rule implementing Steller sea lion protection measures was published in the Federal Register on January 2, 2003 (68 FR 204). Corrections are needed to the regulatory text and tables to implement Pollock, Pacific cod, and Atka mackerel fishing restrictions around certain haul outs and rookeries and to ensure consistency with the American Fisheries Act (AFA) regulations implementing Amendments 61/61/13/8 (67 FR 79692, December 30, 2002). The corrections are considered noncontroversial. This action is necessary to minimize confusion and ensure effective implementation of the Steller sea lion protection measures.

Balsiger, J. W. (2014). Endangered Species Act Section 7 Consultation Biological Opinion for Authorization of the Alaska Goundfish Fisheries under the Proposed Revised Steller Sea Lion Protection Measures. National Marine Fisheries Service Alaska Region. Retrieved from <u>https://alaskafisheries.noaa.gov/sites/default/files/final0414.pdf</u>

Section 7(a)(2) of the Endangered Species Act (ESA) (16 U.S.C. 1531 et seq.) requires that each federal agency insure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of such species. If a federal action "may affect" a listed species or critical habitat, section 7 of the ESA requires that the agency consult with NOAA's National Marine Fisheries Service (NMFS) and/or the U.S. Fish and Wildlife Service, depending upon the listed resources that may be affected. This ESA section 7 consultation considers the action proposed by the NMFS Alaska

Region Sustainable Fisheries Division (SFD) to modify the federal groundfish fisheries and State of Alaska parallel groundfish fisheries for Atka mackerel, Pacific cod, and pollock primarily in the Aleutian Islands subarea. This consultation also considers proposed research to better understand the potential effects of these fisheries on Steller sea lions and on the efficacy of conserving prey in areas closed to fishing.

 Balsiger, J. W., & Muse, B. (2003). Final Regulatory Flexibility Analysis for a Proposed Amendment to Regulations Implementing the Fishery Management Plan for Groundfish of the Gulf of Alaska Proposed Steller Sea Lion Amendments to Exempt Pacific Cod Vessels Using Pot Gear from Two Haulout Protection Areas in the Gulf of Alaska. National Marine Fisheries Service Alaska Region. Retrieved from https://repository.library.noaa.gov/view/noaa/18229

This Final Regulatory Flexibility Analysis (FRFA) evaluates a proposed action to permit Pacific cod pot fishing at two Steller sea lion haulouts in the Gulf of Alaska. This FRFA meets the requirements of the Regulatory Flexibility Act at 5 U.S.C. 604(a).

Barbeaux, S., Aydin, K., Fissel, B., Holsman, K., Palsson, W., Shotwell, K., . . . Zador, S. (2017). Assessment of the Pacific Cod Stock in the Gulf of Alaska. November 2017 Council Draft. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from https://www.afsc.noaa.gov/refm/stocks/plan_team/2017/GOApcod.pdf

Pacific cod (Gadus macrocephalus) is a transoceanic species, occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about 34° N latitude, with a northern limit of about 63° N latitude. Pacific cod is distributed widely over Gulf of Alaska (GOA), as well as the eastern Bering Sea (EBS) and the Aleutian Islands (AI) area. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and GOA. Recent research indicates the existence of discrete stocks in the EBS and AI (Canino et al. 2005, Cunningham et al. 2009, Canino et al. 2010, Spies 2012). Pacific cod is not known to exhibit any special life history characteristics that would require it to be assessed or managed differently from other groundfish stocks in the GOA and the Pacific cod stock in the GOA is managed as a single stock.

Barbeaux, S. J., Fraser, D. E., Fritz, L. W., & Logerwell, E. A. (2017). Cooperative Multispecies Acoustic Surveys in the Aleutian Islands. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC 347. <u>https://doi.org/10.7289/V5/TM-AFSC-347</u>

In Alaska, commercial fisheries have been implicated in the slow recovery of the endangered Western stock of Steller sea lions (*Eumetopias jubatus*; hereafter, W-SSL). To address this issue the Aleutian Islands walleye pollock (Gadus chalcogrammus; hereafter, pollock) fishery was closed in 1999. Although the fishery was reopened in 2005 to accommodate development of an economically struggling Aleutian Islands community, W-SSL critical habitat in the Aleutian Islands remained closed to pollock fishing. From 2006 through 2008, fishery biologists with the Alaska Fisheries Science Center (AFSC) in conjunction with an Alaska Native regional corporation, fish processors, and fishers explored the technical feasibility of conducting small-scale multispecies cooperative acoustic surveys in the Aleutian Islands. The surveys were meant to provide spatially and temporally relevant estimates of groundfish biomass to set acceptable biological catch levels for a pollock fishery within one day's transit from the community, including areas inside W-SSL critical habitat. This was intended as a means to open W-SSL

critical habitat to the developing pollock fishery while reducing the probability of adverse interactions between the fishery and W-SSL stock. The surveys were designed by AFSC biologists but conducted by fishers on board commercial fishing vessels using scientifically calibrated echosounders. Biological data collected from the concurrent fishery were used to characterize acoustic backscatter. This report discusses the development of these surveys, the technical feasibility of conducting scientific grade surveys on board fishing vessels, the use of fishery data to supplement the acoustic surveys, and evaluates the uncertainty around estimates obtained in this manner.

Bowen, W., Harwood, J., Goodman, D., & Swartzman, G. (2001). *Review of the November 2000 Biological Opinion and Incidental Take Statement with Respect to the Western Stock of the Steller Sea Lion, with Comments on the Draft August 2001 Biological Opinion. Final Report Prepared for North Pacific Fishery Management Council.* National Marine Fisheries Service North Pacific Fishery Management Council. Retrieved from <u>https://www.npfmc.org/wp-</u> content/PDFdocuments/conservation_issues/SSL/SSLFinalReport.pdf

The November 30, 2000 Biological Opinion (Nov 2000 BiOp) prepared by the National Marine Fisheries Service (NMFS) resulted in a finding of jeopardy to the Endangered western stock of Steller sea lions (SSL; *Eumetopias jubatus*) relative to fisheries for pollock, Atka mackerel, and Pacific cod under management jurisdiction of the North Pacific Fisheries Management Council (Council). The Nov 2000 BiOp set forth a set of management measures (termed reasonable and prudent alternatives or RPAs) intended to alleviate jeopardy if implemented in the 2001 fishing season. There is continuing scientific debate about the evidence regarding food competition between SSL and these commercial fisheries, and the role of other factors that might be limiting the recovery of SSL, and the implications of this evidence for the conclusions of the Nov 2000 BiOp.

Bowen, W., & Plains, H. (2012). *Center for Independent Experts Independent Peer Review of the November 2010 North Pacific Groundfish Fishery Biological Opinion.* Center for Independent Experts N. M. F. Service Retrieved from

https://web.archive.org/web/20121224211116/http://www.fakr.noaa.gov/protectedresources/ stellers/esa/biop/final/cie/reports/bowen0912.pdf

In November 2010, the National Marine Fishery Service (NMFS) released a Biological Opinion (BiOp), prepared in compliance with section 7 of the Federal Endangered Species Act (ESA). The BiOp documents the consultation on the effects of the authorization of groundfish fisheries in the Bering Sea and Aleutian Islands region (BSAI) and in the Gulf of Alaska (GOA), including parallel groundfish fisheries in Alaska state waters on both the western and the eastern distinct population segments of Steller sea lions (SSL, Eumetopias jubatus). The objective of this formal consultation was to determine if the groundfish fisheries in the BSAI, GOA and the State of Alaska are likely to jeopardize the continued existence of SSL and are likely to destroy or adversely modify designated critical habitat. This report constitutes my scientific review of the findings and conclusions contained in the November 2010 BiOp for the Center of Independent Experts. Chapter 1 reports my findings from a desktop review of the BiOp and Chapter 2 incorporates new information gather during a panel review meeting that I attended in Seattle, WA in August 2012.

 Brodeur, R. D. (1996). Ecology of Juvenile Walleye Pollock, Theragra Chalcogramma : Papers from the Workshop "the Importance of Prerecruit Walleye Pollock to the Bering Sea and North Pacific Ecosystems," Seattle, Washington, 28-30 October 1993. National Marine Fisheries Service. NMFS 126. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/2996</u>

The Alaska Fisheries Science Center (AFSC), National Marine Fisheries Service (NMFS), hosted an international workshop, "The Importance of Prerecruit Walleye Pollock to the Bering Sea and North Pacific Ecosystems," from 28 to 30 October 1993. This workshop was held in conjunction with the annual International North Pacific Marine Science Organization (PICES) meeting held in Seattle. Nearly 100 representatives from government agencies, universities, and the fishing industry in Canada, Japan, the People's Republic ofChina, Russia, and the United States took part in the workshop to review and discuss current knowledge on juvenile pollock from the postlarval period to the time they recruit to the fisheries. In addition to its importance to humans as a major commercial species, pollock also serves as a major forage species for many marine fishes, birds, and mammals in the North Pacific region.

Burkanov, V., O. Belonovich, S. Fomin, & Usatov, I. (2017). *Evaluation of Steller Sea Lion Mortality in Groundfish Fisheries in Russian Waters of the Far Western Bering Sea.* North Pacific Wildlife Consulting, National Marine Fisheries Service Alaska Region

[NO ABSTRACT AVAILABLE]

Byrd, G. V., Merrick, R. L., Piatt, J. F., & Norcross, B. L. (1997). *Seabird, Marine Mammal, and Oceanography Coordinated Investigations (Smmoci) near Unimak Pass, Alaska.* Paper presented at the International Symposium on the Role of Forage Fishes in Marine Ecosystems. Retrieved from <u>https://seagrant.uaf.edu/bookstore/pubs/AK-SG-97-01.html</u>

Forage fishes comprise the primary prey base for several species of marine birds and mammals that have been monitored in Alaska over the past 20 years. Knowledge of the marine ecosystem is important for understanding causes of changes. Our organizations (U.S. Fish and Wildlife Service, National Marine Fisheries Service, U.S. Geological Survey, and University of Alaska Fairbanks) have agreed to cooperate in an effort to characterize foraging habitat for seabirds and Steller sea lions (*Eumetopias jubatus*) at six locations in the Gulf of Alaska and Bering Sea where background monitoring data are available. We began the nearshore marine habitat characterization in 1995 at Unimak Pass in the eastern Aleutian Islands where seabirds and sea lions have been monitored on two nearby islands: Aiktak and Ugamak. Hydroacoustic data were collected along a series of transects within a 50-km radius of the islands to describe the distribution and biomass of potential prey. Midwater and bottom trawls were conducted to support the hydroacoustic surveys, and longline sets were made to help characterize the bottom fish fauna.

Castellini, M. A. (2003). *The Biopolitics of Steller Sea Lions and Alaska Fisheries*. Paper presented at Arctic Science Conference, American Association for the Advancement of Science. Retrieved from https://search.proquest.com/asfa/docview/17556662/E32C84B5B8FF483EPQ/1?accountid=28258

The Steller sea lion is the largest of all the sea lions and lives along the Pacific Coast of the North America, through the Alaskan coastline and into Russian waters. The population has been in serious decline for over 20 yrs and reached critical levels in the early 1990s. Using genetic information, the population was split into an ESA Threatened Eastern Stock and an Endangered Stock in the mid 1990s. The demarcation line is longitude 144 west, which is approximately through the middle of the Gulf of Alaska. There are no clear reasons for the significant decline of this species. There have not been massive die-offs as seen in other pinniped groups, and the animals are not taken in significant numbers by fishery interactions or subsistence hunting. However, their decline is co-incident with the strong growth of the Alaskan fishery for pollock and this has lead to the hypothesis that a food-based problem is responsible for the population declines. Because the ESA is very strict about interactions between human activities and endangered species, this has led to multiple court actions to restrict the pollock fishery. The National Marine Fisheries Service has been sued several times for better protection of the sea lions and simultaneously, the fishery has claimed that restrictions will impose severe financial losses on the State. Several national level studies by the National Academy of Sciences and the ESA Recovery Team have conducted studies and produced reports on this issue. This talk will cover the basic biology of the Steller sea lion and how the animals interact with fisheries. It will follow the theory that there should be a predictable series of events and physiological patterns seen in food-deprived populations and implications to fisheries management.

Cornick, L. A., Neill, W., & Grant, W. E. (2006). Assessing Competition between Steller Sea Lions and the Commercial Groundfishery in Alaska: A Bioenergetics Modelling Approach. *Ecological Modelling*, 199(1), 107-114. <u>https://doi.org/10.1016/j.ecolmodel.2006.07.003</u>

In the last three decades the western stock of the Steller sea lion (*Eumetopias jubatus*) has declined by more than 85%. Nutritional stress resulting in increased juvenile mortality is one of the leading hypotheses to account for this decline. Competition between Steller sea lions and the commercial groundfishery for walleye pollock (Theragra chalcogramma) has been proposed as a mechanism underlying the nutritional stress. In order to examine the competition component of the nutritional stress hypothesis, we developed a bioenergetics-based model to project the population trends of Steller sea lions under various scenarios of continued groundfish harvest. Annual energy budgets were calculated for the Gulf of Alaska population of Steller sea lions, and compared with projected available energy from walleye pollock under a variety of harvest scenarios. Model simulations produced 50-year Steller sea lion population projections consistent with current trends, as well as with published projections for stable and increasing populations from stable age distribution life table models. Model simulations were unable to produce energy deficits sufficient to account for the decline in Steller sea lions, but do suggest areas where existing data need supplementing.

Dillingham, P. W., Skalski, J. R., & Ryding, K. E. (2006). Fine-Scale Geographic Interactions between Steller Sea Lion (*Eumetopias Jubatus*) Trends and Local Fisheries. *Canadian Journal of Fisheries* and Aquatic Sciences, 63(1), 107-119. <u>https://doi.org/10.1139/f05-208</u>

Fine-scale geographic interactions between Steller sea lion (*Eumetopias jubatus*) abundance trends and the abundance of local fisheries and commercial fishing efforts from Southeast Alaska to the Aleutian Islands were assessed. Census counts of Steller sea lions from 1976 to 2002 at 53 different trend sites and rookeries were grouped into 33 locales with similar population trends. Localized estimates of commercial groundfish biomass densities for walleye pollock (Theragra chalcogramma), Pacific cod

(Gadus macrocephalus), arrowtooth flounder (Atheresthes stomias), and Atka mackerel (Pleurogrammus monopterygius) from 1983 to 2002 and localized estimates of commercial fishing effort from 1990 to 2002 were matched to the 33 locales. Generalized estimating equations methods found a negative relationship between Steller sea lion abundance trends and walleye pollock density (P < 0.10). However, the 4.8-fold change in walleye pollock density between 1984 and 2001 was estimated to change the rate of population change (lambda) by only 0.029. The analysis estimated that elimination of all trawl fishing effort would increase lambda by as little as 0.0056. Neither commercial groundfish abundance nor commercial fishing effort could explain the large historical declines in the rate of Steller sea lion population change observed.

Fomin, S., Belonovich, O., & Burkanov, V. (2014). The First Estimation of Steller Sea Lion Bycatch in the Western Bering Sea. Paper presented at the Lowell Wakefield Fisheries Symposium Series. Retrieved from <u>https://seagrant.uaf.edu/events/2014/wakefield-bycatch/posters/fominestimation-sea-lion.pdf</u>

The Western Steller sea lion (*Eumetopias jubatus*, SSL) population declined by 80% during the last 30-40 years. Bycatch in the groundfish fishery is hypothesized as one of plausible causes. We used personal interviews with fishermen to evaluate the role of bycatch in the SSL population decline. The major difficulty in our research was an absence of regular observations of bycatch in the western Bering Sea and the patchy data regarding fishing effort in the region. Estimation of SSL bycatch per single fishing effort was calculated based on fisherman interviews and few direct measurements in the 1990s and 2000s. Data on fishing effort were derived from several unrelated sources including fishery reports, archives, and published literature. Fishermen confirmed that SSL bycatch have occurred and continue to occur in the trawl and seine net fisheries. The bycatch level varied from 2-3 individual SSLs per 3-4 month fishing trip up to more than 20 per single tow. Although the population of SSLs in the Russian part of western Bering Sea is about 40 times less than in the 1980s, bycatch still occurs there. Considering past and present SSL bycatch, fishing effort, and SSL long distance seasonal migrations we concluded that bycatch in the western Bering Sea could contribute to the Western population decline. The greatest obstacle in assessing the level of bycatch, and developing recommendations on reduction, is the absence of independent observations from fishing vessels and the unwillingness of fishing companies to recognize this problem.

Fritz, L. W., Armistead, C., & Williamson, N. J. (1995). Effects of the Catcher Vessel Operation Area on Walleye Pollock Fisheries and Marine Mammals in the Eastern Bering Sea, 1990-94. National Marine Fisheries Service Alaska Fisheries Science Center. AFSC Processed Report 95-04. Retrieved from https://www.afsc.noaa.gov/Publications/ProcRpt/PR1995-04.pdf

This report contains data and discussion of the distribution (size and spatial) of walleye pollock in the eastern Bering Sea, the distribution (temporal and spatial) of the pollock fishery, and the impact that the Catcher Vessel Operation Area (CVOA) has had and may continue to have on the fishery and other members of the eastern Bering Sea ecosystem (marine mammals). From 1990-94, the exploitable (30+ cm in length) pollock population in the eastern Bering Sea changed from one composed of several strong year-classes (spawned in 1978, 1982 and 1984) to one dominated by a single year-class (1989). Furthermore, there has been a shift in exploitable pollock biomass (and the fishery) to the southeast (toward the CVOA), due to the distribution of the 1989 year-class. While surveys in the last 5 years continue to show that commercial-sized pollock are widely distributed throughout the southeastern

Bering Sea, both inside and outside of the CVOA, the distribution of exploitable pollock during the summer can change from year to year, which may cause the distribution of the fishery and areal CPUEs to change. The f,rshery harvests pollock disproportionately to its areal biomass distribution. During the 1990-94 Bseasons, harvest rates of exploitable pollock in the CVOA ranged from22-50o/o,rates which were much higher than in Areas 51 and 52 outside of the CVOA (combined ranges o11-I4%). Furthermore, A-season pollock removals have also been concentrated in the CVOA.

Fritz, L. W., & Brown, E. S. (2005). Survey- and Fishery-Derived Estimates of Pacific Cod (Godus Macrocephalus) Biomass: Implications for Strategies to Reduce Interactions between Groundfish Fisheries and Steller Sea Lions (*Eumetopias Jubatus*). *Fishery Bulletin*, 103(3), 501-515. Retrieved from <u>https://spo.NMFS.noaa.gov/content/survey-and-fishery-derived-estimates-pacific-codgadus-macrocephalus-biomass-implications</u>

Survey- and fishery-derived biomass estimates have indicated that the harvest indices for Pacific cod (Gadus macrocephalus) within a portion of Steller sea lion (*Eumetopias jubatus*) critical habitat in February and March 2001 were five to 16 times greater than the annual rate for the entire Bering Sea-Aleutian Islands stock. A bottom trawl survey yielded a cod biomass estimate of 49,032 metric tons (t) for the entire area surveyed, of which less than half (23,329 t) was located within the area used primarily by the commercial fishery, which caught 11,631 t of Pacific cod. Leslie depletion analyses of fishery data yielded biomass estimates of approximately 14,500 t (95% confidence intervals of approximately 9,000-25,000 t), which are within the 95% confidence interval on the fished area survey estimate (12,846-33,812 t). These data indicate that Leslie analyses may be useful in estimating local fish biomass and harvest indices for certain marine fisheries that are well constrained spatially and relatively short in duration (weeks). In addition, fishery effects on prey availability within the time and space scales relevant to foraging sea lions may be much greater than the effects indicated by annual harvest rates estimated from stock assessments averaged across the range of the target species.

Fritz, L. W., & Ferrero, R. C. (1998). Options in Steller Sea Lion Recovery and Groundfish Fishery Management. *Biosphere conservation: for nature, wildlife, and humans, 1*(1), 7-19. <u>https://doi.org/10.20798/biospherecons.1.1_7</u>

Recovery of the Steller sea lion (*Eumetopias jubatus*) population in Alaska constitutes a significant challenge to resource managers since the cause (s) of the decline remain a mystery. However, a principal symptom of the population, increased juvenile sea lion mortality, appears to be related to changes in food availability. Such changes may be due to natural shifts in fish community composition, anthropogenic factors, or both. Commercial groundfish fishing is the primary annually-occurring human activity in this region that has a high potential for competitive interactions with sea lions. Consequently, it has received considerable management attention in efforts to recover the Steller sea lion population. In 1991-93, trawl exclusion zones were created around sea lion rookeries and some groundfish catch quotas were allocated spatially and temporally to minimize the likelihood of localized depletions of sea lion prey. These initial measures partitioned some fishing effort away from sea lion habitats, but the conservation benefits remain uncertain. In this paper, we explore the various options available to managers for further reducing sea lion-fishery interactions using traditional fisheries management tools. Recent trends in groundfish fishery distribution and information on sea lion distributions and foraging ranges suggest several areas of overlap which could be addressed through modified fishing practices. These could include changes in trawl gear size and reductions in total catches of certain groundfish

species, as well as spatial and temporal distribution of groundfish catch tuned to seasonal changes in sea lion distribution and foraging range. These measures, in combination, offer mechanisms to more completely incorporate the results of the past decade's research efforts on Steller sea lions in the existing fisheries management framework.

Gende, S. M., & Sugler, M. I. (2006). *Predictability of Prey Available to Steller Sea Lions in Southeastern Alaska*. Retrieved from <u>https://seagrant.uaf.edu/bookstore/pubs/item.php?id=11172</u>

The ability to predict the distribution of prey in space and time can influence foraging efficiency for marine vertebrates: search efforts can be concentrated in a specific area at a specific time of year, reducing energy expended randomly searching for prey. We examined the predictability of pelagic fish distributions during 24 months of surveys in Lynn Canal, Southeast Alaska. The spatial distribution of available prey (measured as energy density) during a given month was examined to determine if it was an accurate indicator of prey distribution during the following month (monthly time scale) or during the same month the following year (annual time scale). We also examined how predictability varied among seasons and across several spatial scales. Pacific herring (Clupea pallasii) dominated the prey energy available to Steller sea lions (Eumetopias jubatus), often occurring at densities several orders of magnitude greater than walleye pollock (Theragra chalcogramma), particularly during the winter months. Prey distribution in one month was a good indicator of prey distribution the same month the following year, but mostly during the winter months. This was due to the formation of large schools of herring in consistent locations during both winters. The distribution of prey in one winter month was also a good indicator of the distribution of prey the following month. However, significant month-tomonth correlations were less frequent than at annual time scales due to a southerly movement of herring aggregations as the winter progressed. High densities and predictable distributions of highenergy prey, such as herring, at relatively small spatial scales may facilitate efficient foraging by Steller sea lions and play a central role in the nutritional health of the stable or increasing populations in this area.

Hattori, K., Isono, T., & Yamamura, O. (2011). Fisheries Damages by Steller Sea Lions and the Countermeasures. Nihon Suisan Gakkai Shi, 77(1). Retrieved from <u>https://search.proquest.com/asfa/docview/1475240421/F60FBF7934F5468FPQ/1?accountid=2</u> 8258

[NO ABSTRACT AVAILABLE]

Hennen, D. R. (2005). *The Steller Sea Lion (Eumetopias Jubatus) Decline and the Gulf of Alaska/Bering Sea Commercial Fishery (Alaska)*: Montana State University. Retrieved from <u>https://scholarworks.montana.edu/xmlui/bitstream/handle/1/1460/HennenD1204.pdf;jsessioni</u> <u>d=0DCE5EC2C83B3DF5A452CB3B666AAE4E?sequence=1</u>

The Steller sea lion (SSL) population in Alaska was listed as threatened under the Endangered Species Act in 1991. Several procedural restrictions were placed on the commercial fisheries of the region at that time in an effort to reduce the potential for human induced mortality on sea lions. Several years have elapsed since these restrictions were put into place and questions about their efficacy abound. In an effort to determine whether or not fisheries interventions have helped the SSL population to recover, estimates of the fishing activity of the Bering Seal Gulf of Alaska commercial fisheries in the vicinity of individual Steller sea lion rookeries and SSL population trends at those rookeries were made using data from the National Marine Fisheries Service (NMFS) Fisheries Observer Program and Steller Sea Lion Adult Count Database. Fisheries data from 1976-2000 were analyzed in relation to SSL population counts from 1956-2001, at 32 rookeries from the endangered Western Stock. Linear regression on the principal components of the fisheries data show that a positive correlation exists between several metrics of historical fishing activity and SSL population decline. The relationship is less consistent after 1991, supporting a hypothesis that fishing closures around some of the rookeries have been effective in moderating the localized effects of fishing activity on SSL.

Hogarth, W. T. (2005). Environmental Assessment of Changes to the Gulf of Alaska Steller Sea Lion Protection Measures. National Marine Fisheries Service. Retrieved from https://repository.library.noaa.gov/view/noaa/19188

This Environmental Assessment/Regulatory Impact Review (EA/RIR) examines a suite of measures to change Steller Sea Lion (SSL) protection measures in the Gulf of Alaska (GOA) that could provide economic relief to GOA groundfish fisheries and local fishery-dependent communities without being likely to adversely affect the endangered western distinct population segment of SSLs or its designated critical habitat. These changes include revising the closure areas around four SSL haulouts in the GOA, revising procedures for pollock total allowable catch rollover, and eliminating certain stand-down periods between seasons in the pollock fishery.

Hui, T. C. Y., Gryba, R., Gregr, E. J., & Trites, A. W. (2015). Assessment of Competition between Fisheries and Steller Sea Lions in Alaska Based on Estimated Prey Biomass, Fisheries Removals and Predator Foraging Behaviour. *PLoS ONE, 10*(5), e0123786. https://doi.org/10.1371/journal.pone.0123786

A leading hypothesis to explain the dramatic decline of Steller sea lions (*Eumetopias jubatus*) in western Alaska during the latter part of the 20th century is a change in prey availability due to commercial fisheries. We tested this hypothesis by exploring the relationships between sea lion population trends, fishery catches, and the prey biomass accessible to sea lions around 33 rookeries between 2000 and 2008. We focused on three commercially important species that have dominated the sea lion diet during the population decline: walleye pollock, Pacific cod and Atka mackerel. We estimated available prey biomass by removing fishery catches from predicted prey biomass distributions in the Aleutian Islands, Bering Sea and Gulf of Alaska; and modelled the likelihood of sea lions foraging at different distances from rookeries (accessibility) using satellite telemetry locations of tracked animals. We combined this accessibility model with the prey distributions to estimate the prey biomass accessible to sea lions by rookery. For each rookery, we compared sea lion population change to accessible prey biomass. Of 304 comparisons, we found 3 statistically significant relationships, all suggesting that sea lion populations increased with increasing prey accessibility. Given that the majority of comparisons showed no significant effect, it seems unlikely that the availability of pollock, cod or Atka mackerel was limiting sea lion populations in the 2000s. Isono, T., Kimura, K., Hattori, K., & Yamamura, O. (2013). Development of Reinforced Bottom Gillnets for Mitigation of Damages from Steller Sea Lion *Eumetopias Jubatus*. *Journal of Fisheries Technology* (Yokohama), 6(1), 17-26. Retrieved from <u>https://agriknowledge.affrc.go.jp/RN/2010870173.pdf</u>

On the western coast of Hokkaido (Japan), bottom gillnets have been damaged due to Steller sea lions (SSL). The destruction of nets and depredation of catches have amounted to more than 1 billion JPY per year since the early 1990s. As mitigation measures, endeavors have been made to develop reinforced bottom gillnets (RBGs). The RBGs are comprised of three layers: a panel of standard netting, sandwiched by a pair of outer nets made of strong fibers. Dyneema, Tetoron and Vectran have been tested as the strengthening fibers. RGBs are required to be operable, catchable, and reasonably priced as well as being defensive against SSL damage. However, none of the three materials completely met these requirements yet. In this paper, the developments of RBG's in the period of 2001-2006 is reviewed. Of the three fibers tested, Dyneema was concluded to be the most promising, although the price is still too expensive to be acceptable to fishermen.

Kruse, G., F Funk, H Geiger, K Mabry, H Savikko, S Siddeek. (2000). Overview of State-Managed Marine Fisheries in the Central and Western Gulf of Alaska, Aleutian Islands, and Southeastern Bering Sea, with Reference to Steller Sea Lions. Alaska Department of Fish and Game Division of Commercial Fisheries. Regional Information Report 5J00-10. Retrieved from https://www.arlis.org/docs/vol1/46653703.pdf

The purpose of this report is to provide information to the National Marine Fisheries Service (NMFS) on fisheries managed by the State of Alaska for consideration in their analysis of the potential cumulative impacts of all fisheries on the endangered status of the western population of Steller sea lion. Specifically, we attempted to answer the following 11 questions that were posed to us: (1) what fisheries occur?; (2) when does each fishery occur?; (3) where does each fishery occur?; (4) what are the status and trends of the fished stock?; (5) what is the biomass available?; (6) what are the stock assessment methods?; (7) what is the catch?; (8) what methods are used to monitor and assess catch?; (9) what is the harvest rate?; (10) what gear types are used?; and (11) what interactions occur with Steller sea lions? In an attempt to answer these questions to the best of our ability within a very limited time frame specified in the request, we queried the state's electronic database of fish tickets (records of landings). To make the project manageable, we established a number of sideboards including confining our consideration to fisheries in the central and western Gulf of Alaska west of 1440 W longitude and in the southeastern Bering Sea that delimits the primary region of NMFS concern about Steller sea lions. Using 1999 as the baseline for analysis, landings data were summarized by fishery, gear type, month and by individual statistical areas within the larger management areas. Detailed maps were made in a Geographic Information System using ArcView. Species were categorized into four groups for analysis: herring, salmon, invertebrates and groundfish. Borrowing from published annual management reports and the expertise of regional fishery management staff, we compiled a history of each fishery, attributes of contemporary fisheries, and readily available information on interactions between the fisheries and Steller sea lions.

Livingston, P. A. (1993). Importance of Predation by Groundfish, Marine Mammals and Birds on Walleye Pollock Theragra-Chalcogramma and Pacific Herring Clupea-Pallasi in the Eastern Bering Sea. *Marine Ecology Progress Series*, 102(3), 205-215. <u>https://doi.org/10.3354/meps102205</u> Consumption of walleye pollock Theragra chalcogramma and Pacific herring Clupea pallasi by groundfish predators in the eastern Bering Sea was quantified and described using data obtained in 1985-88. Groundfish predators considered here include walleye pollock Theragra chalcogramma; Pacific cod Gadus macrocephalus; yellowfin sole Pleuronectes asper; flathead sole Hippoglossoides elassodon; rock sole Pleuronectes bilineatus; Alaska plaice Pleuronectes quadrituberculatus; arrowtooth flounder Atheresthes stomias; and Greenland turbot Reinhardtius hippoglossoides. Marine mammal and bird consumption of pollock and herring was estimated for 1985 and compared with groundfish consumption. Groundfish predation on pollock during this time period was dominated by cannibalism on age-0 pollock by adult pollock. The highest predation rate occurred in 1985 when the largest pollock year class, as assessed at age 1, during the Lime period was produced. Predation mortality estimates by age on the 1985 year class were higher than adjacent year classes. Apparently, predators responded to the increased abundance of the 1985 pollock year class by switching to predation on that year class. The impact of this predation appeared to dampen the size of the 1985 year class at age 3 relative to other adjacent year classes. Marine mammal and bird predation on pollock was small relative to pollock cannibalism. However, marine mammal predation on older pollock was more important, almost doubling the estimated predation mortality rate of age-2 fish. Herring consumption by groundfish predators tended to be sporadic in time and space and may have depended on encounter rates of herring schools rather than overall biomass. Pacific cod was the most consistent groundfish predator on herring. There was no apparent relationship between biomass of herring consumed by groundfish predators and cohort analysis estimates of herring biomass in a given year, suggesting no densitydependent predator response. Marine mammal and bird predation on herring was approximately the same as that by groundfish in terms of weight and about half in terms of numbers. Total predation removals of herring were not large relative to exploitable stock size, indicating that predation of juvenile herring, at least during summer periods typically sampled, was not an important source of herring mortality.

Logerwell, E. A., Hollowed, A. B., Wilson, C. D., Walline, P., Munro, P., Conners, M. E., . . . Rand, K. (2005). *Fish Movement Plays a Key Role in Understanding the Potential for Commercial Fishing to Impact Prey Fields of Endangered Steller Sea Lions*. Slides presented at PICES 14 Annual Meeting. Retrieved from

https://meetings.pices.int/publications/presentations/PICES 14/S1/S1 Logerwell.pdf

The Fishery Interaction Team (FIT) at the Alaska Fisheries Science Center (National Marine Fisheries Service, USA) was formed in 2000 to investigate the potential ecosystem effects of commercial fishing. FIT researchers are presently interested in interactions between commercial fisheries and endangered Steller sea lions. The objectives of our current research projects are to: 1) test the hypothesis that commercial fishing results in localized depletion or disruption of sea lion prey fields, and 2) evaluate the efficacy of trawl exclusion zones designed to mitigate competition between commercial fishing and sea lions. The research activities of FIT currently focus on three commercially fished groundfish species in Alaska: Pacific cod, Atka mackerel and walleye pollock. To investigate whether fishing impacts prey fields, we conducted at-sea experiments that used a before-after, treatment-control type design to compare the change in fish abundance within heavily-trawled areas during the fishing season to the change within adjacent no-trawl zones. These studies focused on Pacific cod and walleye pollock. To evaluate the efficacy of trawl exclusion zones at maintaining sufficient quantities of prey for sea lions, we used tag release-recovery methods to estimate local fish abundance and movement rates inside and outside the zones. This study focused on Atka mackerel. Results to date indicate that fish movement plays an important role in determining the potential for commercial fishing to cause localized depletions
of fish. Fish movement is also key to assessing the efficacy of trawl exclusion zones at maintaining local concentrations of fish for foraging sea lions.

Logerwell, E. A., Hollowed, A. B., Wilson, C. D., Walline, P., Munro, P., Conners, M. E., . . . Rand, K. (2006). *Fish Ecology Plays a Key Role in Understanding the Potential for Commercial Fishing to Impact Prey Fields of Endangered Steller Sea Lions*. Paper presented at PICES 15 Annual Meeting. Retrieved from

https://search.proquest.com/asfa/docview/20767031/20B97E46930A4205PQ/1?accountid=282 58

The Fishery Interaction Team (FIT) at the Alaska Fisheries Science Center was formed in 2000 to investigate the potential ecosystem effects of commercial fishing. FIT researchers are presently interested in interactions between commercial fisheries and endangered Steller sea lions. The research activities of FIT currently focus on three commercially fished groundfish species in Alaska: Pacific cod, Atka mackerel and walleye pollock. To investigate whether fishing impacts Steller sea lion prey fields, we conducted at-sea experiments that used a before-after, treatment-control type design to compare the change in fish abundance within heavily-trawled areas during the fishing season to the change within adjacent no-trawl zones. These studies focused on Pacific cod and walleye pollock. To evaluate the efficacy of trawl exclusion zones at maintaining sufficient quantities of prey for sea lions, we used tag release-recovery methods to estimate local fish abundance and movement rates inside and outside the zones. This study focused on Atka mackerel. In addition, fish food habits, reproductive biology and pelagic habitat selection were studied during field research experiments. Results to date indicate that fish ecology (movement, feeding, habitat selection and reproduction) plays an important role in understanding the potential for commercial fishing to cause localized depletions of fish. Fish ecology is also key to assessing the role of trawl exclusion zones at maintaining local concentrations of fish for foraging sea lions.

Loughlin, T. R. (1998). The Steller Sea Lion: A Declining Species. *Biosphere conservation: for nature,* wildlife, and humans, 1(2), 91-98. <u>https://doi.org/10.20798/biospherecons.1.2_91</u>

Steller sea lions (Eumetopias jubatus) are the largest of the sea lion and fur seal subfamily and show a marked difference in size with males two to three times larger than females. Males can be as large as 1,120 kg and grow to 3.25 m; they are about the size of a Kodiak grizzly bear (Ursus arctos). Females average 250 kg and are approximately 3.2 m long. The Steller sea lion breeding range extends across the North Pacific Ocean rim, from the Kuril Islands and Okhotsk Sea, through the Aleutian Islands and Bering Sea, along Alaska's southern coast, and south to central California. Steller sea lions eat a variety of fishes and invertebrates. In Alaska, the principal prey is walleye pollock (Theragra chalcogramma) with Pacific cod (Gadus macrocephalus), Atka mackerel (Pleurogrammus monopterygius), octopus, squid, herring (Clupea harengus), flatfishes, and sculpins also consumed. There were reportedly over 300,000 Steller sea lions in the world in the late 1970s. Since then, the Alaskan sea lion population has plummeted to a small fraction of earlier levels resulting in the species being listed as threatened under the U.S. Endangered Species Act (ESA) in November 1990; the western stock was changed to endangered in 1997. Possible causes for the decline may include redistribution, changed vital rates, pollution, predation, subsistence use, commercial harvest, disease, natural fluctuation, environmental changes, and commercial fishing. The last two are now considered the most probable links to the decline. Steller sea lions may be affected by commercial fishing directly through incidental catch in nets, by

entanglement in derelict debris, by shooting, or indirectly through competition for prey, disturbance, or disruption of prey schools. Current research is trying to determine the relationship between commercial fisheries and the decline and to monitor status. Management regimes include restrictions on incidental take, prohibition of shooting sea lions, no trawl buffer zones around some rookeries, and other measures.

National Marine Fisheries Service. (2010). Endangered Species Act Section 7 Consulatation Biological Opinion for the Authorization of Groundfish Fisheries under the Fishery Management Plan for Groundfish Fo the Bering Sea and Aleutian Islands Management Area and the Fishery Management Plan for Groundfish of the Gulf of Alaska. . National Marine Fisheries Service Alaska Region. Retrieved from https://alaskafisheries.noaa.gov/pr/ssl/final-2010-biop

This Biological Opinion, prepared in compliance with section 7 of the Federal Endangered Species Act (ESA), documents the consultation on the effects of the authorization of groundfish fisheries in the Bering Sea and Aleutian Islands region (BSAI) under the Fishery Management Plan (FMP) for Groundfish of the Bering Sea and Aleutian Islands Management Area, and on the authorization of groundfish fisheries in the Gulf of Alaska (GOA) under the FMP for Groundfish of the Gulf of Alaska, including the prosecution of parallel groundfish fisheries in Alaska state waters. This Biological Opinion is comprehensive in scope and considers the fisheries and the overall management framework established by the respective FMPs to determine whether that framework contains necessary measures to ensure the protection of listed species and critical habitat.

National Marine Fisheries Service. (2014). Endangered Species Act Section 7 Biological Opinion: Authorization of the Alaska Groundfish Fisheries under the Proposed Revised Steller Sea Lion Protection Measures. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/17196</u>

This ESA section 7 consultation considers the action proposed by the NMFS Alaska Region Sustainable Fisheries Division (SFD) to modify the federal groundfish fisheries and State of Alaska parallel groundfish fisheries for Atka mackerel, Pacific cod, and pollock primarily in the Aleutian Islands subarea. This consultation also considers proposed research to better understand the potential effects of these fisheries on Steller sea lions and on the efficacy of conserving prey in areas closed to fishing.

National Marine Fisheries Service Alaska Region. (1999). Environmental Assessment for an Extension of an Emergency Rule to Implement Reasonable and Prudent Steller Sea Lion Protection Measures in the Pollock Fisheries of the Bering Sea and Aleutian Island Area and the Groundfish Fishery of the Gulf of Alaska. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/19159</u>

This emergency rule would implement three types of management measures for the pollock fisheries of the BSAI and GOA: (1) Measures to temporally disperse fishing effort, (2) measures to spatially disperse fishing effort, and (3) pollock trawl exclusion zones around important Steller sea lion rookeries and haulouts.

National Marine Fisheries Service Alaska Region. (2006). Environmental Assessment for the Issuance of an Exempted Fishing Permit for Using Commercial Pollock Fishing Vessels for Acoustic Surveys within Portions of Steller Sea Lion Protection Areas in the Aleutian Islands Subarea. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/19219</u>

This document is an Environmental Assessment (EA) of the potential impacts of issuing an exempted fishing permit (EFP) to allow pollock fishing vessels to conduct acoustic surveys and limited pollock harvest within selected areas of Steller sea lion protection areas in the Aleutian Islands subarea. The purpose of the EFP is to assess pollock abundance in a portion of the Aleutian Islands and to test the technical feasibility of setting quotas for pollock at a finer temporal and spatial resolution using near real-time acoustic surveying. Exemption from certain pollock fishing closure areas within Steller sea lion protection areas in the Aleutian Islands subarea for pollock are encountered to conduct the test and to compensate the study participant. The project is intended to improve the Aleutian Islands pollock stock assessment, conservation, and management. The analysis found no significant impacts on the human environment for this action.

National Marine Fisheries Service Alaska Region. (2014). Final Environmental Impact Statement Steller Sea Lion Protection Measures for Groundfish Fisheries in the Bering Sea and Aleutians Islands Management Area. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/4905</u>

This environmental impact statement provides decision-makers and the public with an evaluation of the environmental, social, and economic effects of alternatives to the Steller sea lion protection measures for the Bering Sea and Aleutian Islands Management Area groundfish fisheries, in particular the Atka mackerel, Pacific cod, and pollock fisheries in the Aleutian Islands. The western distinct population segment (WDPS) of Steller sea lions is listed as endangered under the Endangered Species Act, and the population in portions of the Aleutian Islands is declining. Atka mackerel, Pacific cod, and pollock are principal prey species for Steller sea lions in the Aleutian Islands. This proposed action would implement Steller sea lion protection measures for the Aleutian Islands Atka mackerel, Pacific cod, and pollock fisheries to mitigate the potential fishery impacts on the WDPS of Steller sea lions. This document addresses the requirements of the National Environmental Policy Act.

Pennoyer, S., & Fruchter, S. B. (1999). Environmental Assessment for a Regulatory Amendment to Reapportion Total Allowable Catch of Atka Mackerel and Reduce Fishery Effects on Steller Sea Lions; Change in Atka Mackerel Interim. Retrieved from https://repository.library.noaa.gov/view/noaa/19231

This final rule would implement regulations that divide the Atka mackerel total allowable catch (TAC) specified for the Aleutian Islands Subarea (AI) into two seasonal allowances; reduce the percentage of Atka mackerel TAC harvested from Steller sea lion critical habitat (CH) over a 4 year period in the Western and Central Districts of the AI; and extend the seasonal no-trawl zone around Seguam and Agligadak rookeries in the AI Eastern District into a year-round closure.

Perez, M. A. (2006). Analysis of Marine Mammal Bycatch Data from the Trawl, Longline, and Pot Groundfish Fisheries of Alaska, 1998-2004, Defined by Geographic Area, Gear Type, and Catch Target Groundfish Species. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-167. Retrieved from <u>https://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-167.pdf</u> In 2003, Perez (2003) reported on an analysis of marine mammal incidental take data in federally managed groundfish fisheries in Alaska from 1989 to 2001. At that time, these fisheries were defined in the List of Fisheries by geographic area and gear type. In recent years, fishery definitions have changed to also specify target species. This report presents a re-analysis of the marine mammal incidental take data for the trawl, longline, and pot fishing gear from 1998 to 2001, separated by target species, and includes previously unpublished data from 2002 to 2004. Rates and variance of bycatch (incidental take mortalities and serious injuries) were calculated by stratified ratio estimates, using the sum of the marine mammals observed killed or seriously injured (including trailing gear) by fishing operations divided by the sum of the observed tonnage of fish catch in monitored hauls from the NORPAC database of the North Pacific Groundfish Observer Program, Alaska Fisheries Science Center. Estimates of total bycatch for each of 22 groundfish trawl, longline, and pot fisheries (based on intended catch target groundfish species) in Alaska were calculated using the total fishery data from the Catch Accounting System (CAS; successor to the Blend) database of the NMFS Alaska Regional Office (AKR). The target groundfish species for all NORPAC hauls in the CAS were estimated by the AKR using a sequential, hierarchical combination of a three-step process. In this study, NORPAC hauls were matched to their counterparts in the CAS by vessel, gear type, area, processing sector, and trip target date. Sixteen species of marine mammals were observed incidentally killed or injured by the groundfish fisheries in the U.S. Exclusive Economic Zone offAlaska during 1998-2004. The 22 trawl, longline and pot groundfish fisheries of Alaska were estimated to have incidentally taken 189 marine mammals during 1998-2004. Average annual rates of take for each marine mammal species and for each target fishery were calculated for the most recent 5 years (2000-2004) for use in the List of Fisheries evaluation.

Perez, M. A., & Loughlin, T. R. (1991). Incidental Catch of Marine Mammals by Foreign and Joint Venture Trawl Vessels in the U.S. EEZ of the North Pacific, 1973-88. National Marine Fisheries Service. NMFS 104. Retrieved from https://repository.library.noaa.gov/view/noaa/6032

During 1973-88, 3,661 marine mammals of 17 species were reported as incidental catch by U.S. fishery observers aboard foreign and joint venture trawl vessels in the U.S. Exclusive Economic Zone in the North Pacific Ocean and the Bering Sea. Northern sea lions (*Eumetopias jubatus*) accounted for 90% of the reported incidental mortality in the Gulf of Alaska and eastern Bering Sea. Nearly half of these sea lions were taken in trawl nets in the Shelikof Strait, Alaska, joint venture fishery during 1982-84. However, high incidental mortality rates (>25 sea lions per 10,000 metric tons ofgroundfish catch) also occurred in the foreign fisheries near Kodiak Island and in the Aleutian Islands area in earlier years. Estimated annual mortality of incidentally caught northern sea lions in Alaska declined from 1,000 to 2,000 animals per year during the early 1970s and 1982 to fewer than 100 animals in 1988. In the Bering Sea most sea lions incidentally caught were males, while in the GulfofAlaska females were more frequently caught. Females may also have been dominant in the incidental mortality of adult female sea lions by foreign trawl fisheries in these areas could have partially contributed to the reported declines in northern sea lion populations in Alaska during the 1970s, but it cannot alone account for the present decline in population size.

Perrin, W. F., Donovan, G. P., & Barlow, J. (1994). *Gillnets and Cetaceans: Incorporating the Proceedings* of the Symposium and Workshop on the Mortality of Cetaceans in Passive Fishing Nets and *Traps.* Report of the International Whaling Commission Special Issue 15. Cambridge. This volume is based on the symposium and workshop held in La Jolla, California, in 1990. After a report of the workshop and a report to the United Nations Conference on the Environment and Development on significant direct and incident catches of small cetaceans, 51 papers on incidental catches, generally of small cetaceans are published. These are arranged regionally, covering the North Atlantic (including the Baltic and Mediterranean); Central America and Caribbean; W South Atlantic; Africa and Indian Ocean; Asia and North Pacific pelagic; E North Pacific; SE Pacific. As well as general studies of marine fisheries and their by-catches of cetaceans and other marine mammals, individual species studied are: harbour porposies Phocoena phocoena, franciscana Pontoporia blainvillei, marine tuxuci Sotalia fluviatilis, right whale Eubalaena glacilias, sperm whale Physeter macrocephalus, southern minke whale Balaenoptera bonaerensis and dusky dolphin Lagenorhynchus obscurus. Lastly, there is a section of causes and solutions to the reduction of net entanglement of small cetaceans.

Petras, E. (2003). A Review of Marine Mammal Deterrents and Their Possible Applications to Limit Killer Whale (Orcinus Orca) Predation on Steller Sea Lions (Eumetopias Jubatus). National Marine Fisheries Service Alaska Fisheries Science Center. AFSC Processed Report 2003-02. Retrieved from https://repository.library.noaa.gov/view/noaa/11967

The population of Steller sea lions (*Eumetopias jubatus*) in the western Aleutian Islands has declined significantly and is currently listed as an endangered species. Among the possible limiting factors for this population is predation by transient killer whales (Orcinus orca). The purpose of this report is to provide some analysis of the feasibility of limiting killer whale predation on Steller sea lions in the western Aleutian Islands using marine mammal deterrents. This report provides a review of various marine mammal deterrents, used primarily in fisheries, to either prevent marine mammal entanglement or predation. Deterrent methods are evaluated based upon various factors including effectiveness, particularly with killer whales, potential impacts on non-target species, including Steller sea lions, and feasibility of use in the western Aleutian Islands. Possible deterrent options are considered, however, all would require significant research before implementation. Based upon a thorough review of the literature, lack of previous long-term success and high degrees of uncertainty, it is unlikely that deterrents would be successful in this application. by Elizabeth Petras.

Raum-Suryan, K. L., Jemison, L. A., & Pitcher, K. W. (2009). Entanglement of Steller Sea Lions (*Eumetopias Jubatus*) in Marine Debris: Identifying Causes and Finding Solutions. *Marine Pollution Bulletin*, 58(10), 1487-1495. <u>https://doi.org/10.1016/j.marpolbul.2009.06.004</u>

Entanglement in marine debris is a contributing factor in Steller sea lion (SSL; *Eumetopias jubatus*) injury and mortality. We quantified SSL entanglement by debris type, sex and age class, entanglement incidence, and estimated population level effects. Surveys of SSL haul-outs were conducted from 20002007 in Southeast Alaska and northern British Columbia. We recorded 386 individuals of all age classes as being either entangled in marine debris or having ingested fishing gear. Packing bands were the most common neck entangling material (54%), followed by rubber bands (30%), net (7%), rope (7%), and monofilament line (2%). Ingested fishing gear included salmon fishery flashers (lures: 80%), longline gear (12%), hook and line (4%), spinners/spoons (2%), and bait hooks (2%). Entanglement incidence was 0.26% (SD = 0.0064, n = 69 sites). "Lose the Loop!" Simple procedures such as cutting entangling loops of synthetic material and eliminating the use of packing bands can prevent entanglements.

Salveson, S., & Gudes, S. B. (2001). Environmental Assessment/Regulatory Impact Review for the Extension and Revision of the Emergency Interim Rule for 2001 Harvest Specifications for the Alaska Groundfish Fisheries and for Steller Sea Lion Protective Fisheries Management Measures Implemented under the Authority of the Fishery Management Plans for the Groundfish Fishery of the Bering Sea and Aleutian Islands Area and Groundfish of the Gulf of Alaska July 4, 2001. National Marine Fisheries Service. Retrieved from https://repository.library.noaa.gov/view/noaa/19222

The action analyzed is the extension and amendments to an emergency interim rule implementing 2001

Steller sea lion protection measures and harvest specifications for the groundfish fisheries off Alaska. Provisions of the action allow the continuation of groundfish harvest off Alaska and modifies protection measure for the endangered Steller sea lions.

Sampson, D. B. (1995). An Analysis of Groundfish Fishing Activities near Steller Sea Lion Rookeries in Alaska. Oregon State University, Hatfield Marine Science Center, Newport, Oregon, 40 Retrieved from http://www.marinemammal.org/wp-content/pdfs/sampson1995.pdf

During the past few decades large commercial fisheries for groundfish developed in the Gulf of Alaska and Bering Sea. There has been speculation that these fishing operations may have reduced the available fish stocks and thereby contributed to the dramatic declines in the Alaskan populations of Steller sea lion (*Eumetopias jubatus*) that occurred during the same period. Previous studies that attempted to relate estimates of sea lion abundance with annual catches of walleye pollock (Theragra chalcogramma) produced inconclusive results. In this investigation principal component analysis was applied to data from 1979-90 on sea lion counts for 25 sea lion rookeries in the Gulf of Alaska and Aleutian Islands, and independently to fishery observer data from 1980-89 for the commercial groundfish fishing operations that occurred within a distance of about 37 kilometers of these rookeries. The component scores from the two data sets were then correlated to explore for similarities between the pattern of sea lion decline and the pattern of fishing operations.

Schaefer, R. H., & Pennoyer, S. (1991). Environmental Assessment/Regulatory Impact Review/Initial Regulatory Flexibility Analysis for Amendment 25 to the Groundfish of the Gulf of Alaska Management Plan and Amendment 20 to the Groundfish of the Bering Sea and Aleutian Islands Management Plan - Assessment of a Proposed Prohibition to Groundfish Trawling in the Vicinity of Gulf of Alaska and Bering Sea and Aleutian Islands Steller Sea Lion Rookeries. National Marine Fisheries Service. Retrieved from https://repository.library.noaa.gov/view/noaa/18148

This environmental assessment was prepared to examine the environmental consequences of imposing additional constraints on commercial fisheries managed under the Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA) Groundfish Fishery Management Plans (FMP). The purpose of additional restrictions is to minimize the potential adverse effects of the BSAI and GOA groundfish fisheries on Steller sea lions, a threatened species, and to foster the species's recovery. This assessment considers five alternatives: (1) No action; (2) Prohibiting groundfish trawling within 10 nautical miles (nm) of GOA and BSAI Steller sea lion rookeries year round; (3) Prohibiting groundfish trawling within 20 nm of GOA and BSAI Steller sea lion rookeries year round; (4) Prohibiting groundfish trawling within 10 nm of GOA

and BSAI Steller sea lion rookeries from May 1-September 30 and within 20 nm from October 1 - April 30; and (5) Prohibiting groundfish trawling within 20 nm of GOA and BSAI Steller sea lion rookeries from May 1 - September 30 summer and within 60 nm from October 1 - April 30. NMFS' preferred alternative is Alternative 2.

Stewart, B. S. (2012). Center for Independent Experts (CIE) External Independent Peer Review on the 2010 Biological Opinion on the Effects of the Federal Groundfish Fisheries and State Parallel Fisheries on Listed Species in Alaska, Including Steller Sea Lions. Center for Independent Experts (CIE) National Marine Fishery Service.

The substantial decline of the Steller sea lion (Eumetopias jubatus) in the latter part of the 20th Century prompted listing of the species as threatened under the US Endangered Species Act (16 U.S.C. § 1531 et. seq) in 1990. Following a reclassification of the species into a Western Distinct Population Segment (WDPS, west of 144oW longitude) and an Eastern Distinct Population Segment (EDPS, east of 144oW longitude), the WDPS was reclassified as endangered whereas the EDPS has remained classified as threatened. Proposed actions by NOAA/NMFS to 1) authorize commercial groundfish fisheries under the Fishery Management Plan for groundfish of the Bering Sea and the Aleutian Islands (BSAI) management area; 2) authorize commercial groundfish fisheries under the Fishery Management Plan for groundfish of the Gulf of Alaska (GOA); and 3) authorize State of Alaska parallel groundfish fisheries required NOAA/NMFS to prepare a Biological Opinion determine whether those agency actions are likely to jeopardize the continued existence of the EDPS or the WDPS of Steller sea lions) or likely to result in the destruction or adverse modification of critical habitat of the EDPS or the WDPS. The Biological Opinion concluded that a) "...the action, as proposed, is likely to jeopardize the continued existence of the western DPS of Steller sea lion [sic]" (page xxxi, Page 345) and b) "...the action, as proposed, is likely to adversely modify the designated critical habitat for the western DPS of Steller sea lion [sic]" (page xxxiv, Page 348). The conclusion was principally based on consideration of the status and trends in abundance (through 2008) of 4 sub-regions in the western reach of the WDSP. The Center for Independent Experts (CIE) chartered a three-person panel to review the Biological Opinion of 2010, additional relevant published and unpublished literature and additional new information presented at a public meeting in Seattle on 1 & 2 August 2012, and evaluate whether its findings were supported by the available science and the interpretations of that scientific evidence. My evaluation of the information and data presented and the arguments constructed in the Biological Opinion, the additional information presented at the public meeting, and the legal framework governing the assessment is that the conclusions of the Biological Opinion are not supported. The ESA constrains the analysis to population units no smaller than a DPS. The data indicate that the WDPS and the EDPS have been increasing for most of the past decade, including a 30% increase in births in the WDPS from 2002 through 2011. Though a number of hypotheses (bottom-up including effects of commercial fisheries causing nutritional stress to sea lions and consequent reductions in survival and fecundity; and top-down including substantial predation on sea lions by killer whales) have been proposed to account for the earlier population decline and the potential for further declines or lack of recovery, there has been no causal evidentiary support for any of them. The Biological Opinion often equates language of possibility (e.g., may, may have, appears to be, might, possible, plausible, could, could have, has possibly, could be argued) with language of substantial chance (i.e., likely), transliterating the former to conclude that that the actions were likely to jeopardize the continued existence of the DPS and likely to adversely modify critical habitat of the DPS. Speculative and hypothetical suggestions for jeopardy and adverse modification do not, I think, meet the standard established by the Endangered Species Act to conclude that the actions have a substantial chance (likely) of jeopardy and adverse modification.

Because the conclusions of the Biological Opinion are not supported by the evidentiary record or by persuasive arguments, the RPA is not a relevant consideration. In any event I think that the construction of the hypothesis to test the potential affirmative consequences of implementing the Reasonable Prudent Alternative (RPA) is not strong because of the proposal to use a potential correlation of two weak proxies to judge causation.

Stokes, K. (2012). Biological Opinion on the Effects of the Federal Groundfish Fisheries and State Parallel Fisheries on Listed Species in Alaska, Including Steller Sea Lions.

The Biological Opinion (BiOp) to be reviewed here relates to Federal and State Fishery Management Plans (FMP) in the Alaska Region and their potential to cause jeopardy under Section 7 of the Endangered Species Act (ESA). Jeopardy is poorly defined in the Act and in implementing regulations and does not provide clear standards. A Recovery Plan for Steller sea lions (SSL) was completed in 2008 in which criteria for reclassification and delisting under the ESA were laid out. The BiOp was developed by NMFS Alaska Region Protected Resources Division (PRD) starting in 2006. A Draft was circulated in August 2010 and a Public Comment version in September 2010. Following limited consultation a Final BiOp was issued in November 2010. Because the implications of the BiOp are real and economically harsh, and because the SSL is a listed species, it is not surprising that the BiOp has added to and continued the long---running and heated debate about SSL and fisheries management. NMFS did not release comments on public submissions and there has been no formal opportunity for review of the Final BiOp though this was called for by the Scientific and Statistical Committee (SSC) of the North Pacific Fishery Management Council (NPFMC) in 2010. This report is one of three independent reviews undertaken through the Center for Independent Experts (CIE) at the request of NMFS. It has primarily been a desk---based review although a two day meeting was held in Seattle in august 2012 to allow presentations primarily on new information since September 2008. That meeting accommodated all request to make presentations. The Terms of reference (ToR) for this review require separate chapters on the BiOp as of November 2010 (and information as of September 2010) and on implications for the BiOp, if any, given information available since September 2010. The review thus contains two main chapters as well as a common background and comment on review process.

Thompson, G. G., & Palsson, W. (2017). Assessment of the Pacific Cod Stock in the Aleutian Islands. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from <u>https://www.fisheries.noaa.gov/resource/data/2017-alaska-fisheries-science-center-aleutian-islands-pacific-cod-stock</u>

A stock assessment undertaken for Aleutian Islands (AI) Pacific cod.

Thorne, R. E., & Thomas, G. L. (2007). Herring and the "Exxon Valdez" Oil Spill: An Investigation into Historical Data Conflicts. *ICES Journal of Marine Science*, *65*(1), 44-50. <u>https://doi.org/10.1093/icesjms/fsm176</u>

It was generally believed that the 1989 "Exxon Valdez" oil spill did not cause the collapse of the Prince William Sound Pacific herring (Clupea pallasi) population because of a 4-year gap between the spill and the collapse. However, we noted in a previous paper that some data suggested an earlier timing for the herring decline. We examine historical patterns of herring spawn, anomalies in historical fisheries model

predictions, changes in predation behaviour of Steller sea lions (*Eumetopias jubatus*), and a decadal database of acoustic measurements of herring biomass. Behaviour of adult herring makes them especially vulnerable to damage from oil spills, something that was either unknown or misunderstood at the time of the spill. We therefore argue that the start of the herring decline was coincident with the oil spill, and that the decline took place over a 5-year period, rather than the single-year collapse previously reported. Although a comprehensive management approach is now in use for herring, the tools were not in place at the time of the oil spill or the subsequent collapse.

Thorsteinson, F. V., & Lensink, C. J. (1962). Biological Observations of Steller Sea Lions Taken During an Experimental Harvest. *Journal of Wildlife Management, 26*(4), 353-359. Retrieved from <u>https://www.jstor.org/stable/3798011</u>

Steller sea lions (Eumetopias jubata) have been the subject of recent studies in Alaska because of their alleged depredations on salmon and halibut fisheries. Mathisen (1959) estimated that a minimum of 150,000 sea lions inhabited Alaskan waters. Kenyon and Rice (1961), on the basis of more complete observations in the Aleutian Islands, have estimated a minimum of 181,892 animals. With the two-fold purpose of possibly reducing the sea lion herds and providing an economical high protein meat for fur farms, fish hatcheries, and similar purposes, the Bureau of Commercial Fisheries awarded a contract to a commercial fishing company in the spring of 1959 to develop techniques for harvesting sea lions in Alaskan waters.

Trites, A. W., Christensen, V., & Pauly, D. (1997). Competition between Fisheries and Marine Mammals for Prey and Primary Production in the Pacific Ocean. *Journal of Northwest Atlantic Fishery Science, 22*, 173-187. Retrieved from <u>https://journal.nafo.int/Volumes/Articles/ID/259/Competition-Between-Fisheries-and-Marine-Mammals-for-Prey-and-Primary-Production-in-the-Pacific-Ocean</u>

The degree of competition between fisheries and marine mammals in the Pacific Ocean was estimated for 7 statistical areas defined by the Food and Agriculture Organization of the United Nations (FAO). Catch statistics compiled from FAO sources show that the amount of fish caught in the Pacific Ocean rose from 2 million tons in the late-1940s to over 50 million tons in the early-1990s. Recent stagnation and declines occurring in some areas of the Pacific suggest that Pacific fisheries cannot continue to expand as they had previously. Based on estimates of population size, total biomass and daily consumption rates, it was estimated that the 84 species of marine mammals inhabiting the Pacific Ocean consume about three times as much food as humans harvest. A large fraction (>60%) of the food caught by marine mammals consisted of deep sea squids and very small deep sea fishes not harvestable by humans, thus limiting the extent of direct competition between fisheries and marine mammals. Moreover, the most important consumers of commercially exploited fish are other predatory fish, not marine mammals. Although direct competition between fisheries and marine mammals for prey appears rather limited, there may be considerable indirect competition for primary production. The primary production required to sustain marine mammals in each of the 7 FAO areas varies within a narrow range, suggesting that the diversity and abundance of marine mammals may have slowly evolved to fully exploit their niche and maximize their use of available primary production. This contrasts with the rapid expansion of fisheries and their relatively recent dependence on primary production, which may have led to what we call 'food web competition'.

Trites, A. W., Flinn, R., Joy, R., & Battaile, B. (2010). Was the Decline of Steller Sea Lions in the Aleutian Islands from 2000 to 2009 Related to the Atka Mackerel Fishery. *Fisheries Centre Working Paper*, 10. Retrieved from <u>http://52.20.14.83/sites/default/files/tritesetal_sslatkamackerel2010.pdf</u>

The goal of our study was to determine whether there was a relationship between the decline of Steller sea lions and the Atka mackerel fishery in Fishery Management Areas 541, 542 and 543 from 2000-2009. Data available to us included the numbers of non-pup sea lions counted in 2000, 2002, 2004, 2005, 2006, 2007, 2008 and 2009 by the US National Marine Fisheries Service, and the amounts and locations of Atka mackerel caught per haul for all trawlers targeting Atka mackerel in the Aleutian Islands from 2000-2009. We applied Generalized Estimating Equation models to these data to test whether numbers of sea lions or changes in numbers of sea lions were related to the frequency of trawling (number of hauls) and amounts of fish caught within 10, 20 or 40 nautical miles of sea lion rookeries and haulouts. We considered the total amount of fish removed within the three nautical mile zones (i.e., 10, 20 and 40 nm) as a measure of possible depletion of sea lion prey, and used the average catch per haul within each zone as a localized relative measure of stock size of Atka mackerel available to sea lions.

Trites, A. W., & Larkin, P. A. (1992). The Status of Steller Sea Lion Populations and the Development of Fisheries in the Gulf of Alaska and Aleutian Islands. Fisheries Centre, University of British Columbia. Pacific States Marine Fisheries Commission. Retrieved from <u>https://www.zoology.ubc.ca/~consort/pdfs/TritesLarkin92fisheries-devel.pdf</u>

The goal of our study was to assess the status of Steller sea lions in Alaska, review their population biology, and develop a simulation model to explore the role that harvesting and incidental kills by fisheries may have played in the sea lion decline. We also attempted to relate the population declines to the amount of fish caught in the Gulf of Alaska and Aleutian Islands, and to the number of vessels fishing from 1950 to 1990.Using life tables to estimate population size, the numbers of Steller sea lions were estimated for all rookeries for which information was available in each of six areas in the Gulf of Alaska and Aleutian Islands. The total population appears to have risen from 150,000 to 210,000 from the mid 1950s to 1967. The population was then stable for roughly ten years, then increased to 225,000 by 1979. Since then it has decreased to about 85,000. Most of the decline took place in Area 3 (Kodiak region) but there were also significant declines in Areas 4 to 6 (westward of Kodiak). Increases have occurred in the smaller populations of Areas 1 and 2 (southeast Alaska and Prince William Sound).

US Congress House Committee on Natural Resources. (2012). NOAA's Steller sea lion science and fishery management restrictions : does the science support the decisions? : oversight field hearing before the Committee on Natural Resources, U.S. House of Representatives. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/10146</u>

Report on oversight hearing regarding management of fisheries and studies on Steller Sea Lions.

Wada, K. (1998). Steller Sea Lions: Present Status of Studies of Migratory Ecology, and Conflict between Fisheries and Conservation in Japan. *Biosphere conservation: for nature, wildlife, and humans,* 1(1), 1-6. <u>https://doi.org/10.20798/biospherecons.1.1 1</u> Steller sea lions (*Eumetopias jubatus*) occur around Hokkaido Island, Japan, and are mixing there with migratory groups came from the Kuril Islands and small islands around Sakhalin Island during October through May and numerous studies have been published on their ecology while in Japanese waters. While the sea lions are in Japanese coastal waters they commonly inflict serious damage to local fisheries, and since 1961, the Hokkaido regional government financially supported their removal to lessen the damage to fisheries. Total number, 22, 481 of the animals were eliminated around Hokkaido, and were main reason for drastic decline of the Kuril Islands population from 20, 000 in the 1960s to 4, 000 in the 1990s. This animal elimination did not contribute to lessen fisheries damage because a conflict between fisheries and the animal feeding came from over-fishing of fisheries resources. The world-wide Steller sea lion population is declining rapidly, resulting in Russia and the United States implementing numerous legal regulations for their conservation. In this review, I discuss the damage to fisheries caused by Steller sea lions in Japan and then introduce some conservation efforts for Steller sea lions in Japan.

Wynne, K. (1990). Marine Mammal Interactions with the Salmon Drift Gillnet Fishery on the Copper River Delta, Alaska, 1988-1989. Alaska Sea Grant College Program University of Alaska Fairbanks. AK-SG-90-05. Retrieved from https://seagrant.uaf.edu/lib/aksg/9005/mmi-interactions.pdf

Marine mammal interactions with the salmon drift gillnet fishery on the Copper River Delta, Alaska were examined in 1988 and 1989 using field observations, dockside interviews, and beached carcass surveys. Past and present conflicts include scavenging of netted salmon and damaging gillnets by pinnipeds, and incidental and intentional killing of marine mammals because of net encounters, The frequency and nature of marine mammal-drift net conflicts on the Copper River Delta varied geographically and seasonally with the species involved. Northern sea lion conflicts occurred predominantly in May and carly June and were most frequent, in surf and nearshore waters. Harbor seal conflicts were most severe in August in surf and channels and often involved recently weaned pups, Sea otter-drift net encounters were most frequent when mother-pup pairs and fishermen were using the same tidally restricted channels in the western region of the delta, Porpoises and other cetaceans were incidentally caught in drift nets set in nearshore and offshore waters throughout the delta. A conservative estimate of financial loss due to pinniped depredation on salmon the Copper River Delta in 1988 represents less than 19'n of the ex-vessel value of salmon landed. Incidental and intentional marine mammal takes were too infrequent and dispersed to establish a realistic estimate of fishery-wide take rates. Based on comparisons with 197S take rates, our data show a significant reduction in drift net-related intentional killing of pinnipeds. While not statistically different, the number of sea otter-drift net encounters on the Copper River Delta increased between 1978 and 1988 and will likely continue as sea otters increase. The successful release of entangled sea otters and cetaceans shows that not all incidental captures are lethal and demonstrates the need and feasibility of informing fishermen of nonlethal removal techniques. A larger, stratified sampling effort is required to estimate realistic fishery-wide take and mortality rates.

Zeppelin, T. K., Tollit, D. J., Call, K. A., Orchard, T. J., & Gudmundson, C. J. (2004). Sizes of Walleye Pollock (Theragra Chalcogramma) and Atka Mackerel (Pleurogrammus Monopterygius) Consumed by the Western Stock of Steller Sea Lions (*Eumetopias Jubatus*) in Alaska from 1998 to 2000. *Fishery Bulletin*, 102(3), 509-521. Retrieved from <u>https://spo.NMFS.noaa.gov/sites/default/files/pdfcontent/2004/1023/tollit2.pdf</u> Prey-size selectivity by Steller sea lions (Eumetopias jubatus) is relevant for understanding the foraging behavior of this declining predator, but studies have been problematic because of the absence and erosion of otoliths usually used to estimate fish length. Therefore, we developed regression formulae to estimate fish length from seven diagnostic cranial structures of walleye pollock (Theragra chalcogramma) and Atka mackerel (Pleurogrammus monopterygius). For both species, all structure measurements were related with fork length of prey (r² range: 0.78-0.99). Fork length (FL) of walleye pollock and Atka mackerel consumed by Steller sea lions was estimated by applying these regression models to cranial structures recovered from scats (feces) collected between 1998 and 2000 across the range of the Alaskan western stock of Steller sea lions. Experimentally derived digestion correction factors were applied to take into account loss of size due to digestion. Fork lengths of walleye pollock consumed by Steller sea lions ranged from 3.7 to 70.8 cm (mean=39.3 cm, SD=14.3 cm, n=666) and Atka mackerel ranged from 15.3 to 49.6 cm (mean=32.3 cm, SD= 5.9 cm, n=1685). Although sample sizes were limited, a greater proportion of juvenile (≤ 20 cm) walleye pollock were found in samples collected during the summer (June-September) on haul-out sites (64% juveniles, n=11 scats) than on summer rookeries (9% juveniles, n=132 scats) or winter (February-March) haul-out sites (3% juveniles, n=69 scats). Annual changes in the size of Atka mackerel consumed by Steller sea lions corresponded to changes in the length distribution of Atka mackerel resulting from exceptionally strong year classes. Considerable overlap (>51%) in the size of walleye pollock and Atka mackerel taken by Steller sea lions and the sizes of these species caught by the commercial trawl fishery were demonstrated.

Section V: Food Habits and Diving

Adams, T. C., Davis, R. W., & Iverson, S. J. (1997). The Use of Fatty Acid Profiles in Determining the Diet of Steller Sea Lions (*Eumetopias Jubatus*). *FASEB Journal*, 11(3), 168-168. Retrieved from <u>http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch_&qid=13&SID=8AKBSJ5RixL6hagr5Wp&page=1&doc=1</u>

Food preferences in carnivores can be examined using the fatty acid (FA) profiles of their blubber or milk. This technique is particularly useful for ex-amining food preferences of animals for which stomach contents or observations of feeding are difficult to obtain. In monoga.stric animals, dietary FA remain intact during digestion and are deposited into blubber stores or mobilized for milk production in a relatively unchanged form. tlilk samples were collected from 35 adult female Steller sea lions in the late spring of 1993-1996 from three locations in the Gulf of Alaska. All females sampled were believed to be within the first 40 days postpartum. Milk lipids were extracted in chloroform using a modified Folch procedure. Falt)' acid methyl esters (FAME) were prepared from the purified lipid extract and analyzed using temperature programmed capillary gas-liquid chromatography. The fatty acid data was analyzed using classification and regression trees in S-plus (StatSci, Sealtle), a non-parametric multivariate technique for classifying data. The best nued tree had 5 termi-nal nodes in which only 2 of the 35 observations were incorrectly classified by location of the animal. In addition, the fatty acid profiles of these animals ap-peared to resemble the fatty acid profiles of prey from their respecti\'e regions. Thus milk fatly acids indicate that Steller sea lions are feeding differently in different regions of their home range. The next step in these investigations is to further classify prey items by region, species and size class.

 Altukhov, A. V., Burkanov, V. N., Kruchenkova, E. P., Goltsman, M. E., Dulchenko, N. A., Mamaev, E. G., & Rivanenkova, M. L. (2008). The Attendance Patterns of Nursing Steller Sea Lion (*Eumetopias Jubatus*) Females on Mednyi Island (the Commander Islands) and Dolgaya Rock (the Kuril Islands). *Zoologichesky Zhurnal, 87*(7), 876-884. Retrieved from https://drive.google.com/file/d/0B9uVlv0IC8WuNIJhUDcwbTYybUk/edit

Attendance patterns of the Steller sea lion (*Eumetopias jubatus*) females on Mednyi Island (the Commander Islands) and Dolgaya Rock (the Kuril Islands) were similar. The attendance is dominated by 24-hour cycles. Females leave a rookery synchronously in the evening and return in the following morning. Foraging trips are restricted to night hours. The authors' data do not agree with the results obtained on rookeries in the Gulf of Alaska, where foraging trips of reproductive females are much longer, their duration is more variable, and the time of return to the rookery is less synchronized. The area of the shelf zone on the Kuril and Commander Islands is significantly smaller. Here, fish and cephalopods that compose the main diet of sea lions are concentrated to a greater degree than around continental islands and the coast of Alaska. The feeding patches of sea lions around the Kuril and Commander Islands are suggested to be more abundant and more predicted than at continental islands. The data obtained support the hypothesis that attendance patterns reflect the local state of the foraging base and can be used as an indicator of food abundance.

Andrews, R. D., Calkins, D. G., Davis, R. W., Norcross, B. L., Peijnenberg, K., & Trites, A. W. (2002). Foraging Behavior and Energetics of Adult Female Steller Sea Lions. *Steller sea lion decline: Is it food II*, 19-22. Retrieved from http://www.marinemammal.org/wp-content/pdfs/steller sea lions foraging.pdf

The current decline in the population of Steller sea lions (SSL) in western Alaska may be attributable to food shortages in critical areas. Unfortunately, the feeding ecology of SSLs is poorly understood. Population modeling suggests that a decline in juvenile survival is a likely explanation for the recent SSL population decline. Such an increase in juvenile mortality could be due to the inability of mothers to adequately nourish their pups during lactation, or could be due to weaned juveniles not being able to successfully forage on their own. Other pinniped species have been observed to respond to apparent nutritional stress by increasing female foraging trip durations during lactation and/or increasing energy expenditure during foraging.

Atkinson, S., Calkins, D., Burkanov, V., Castellini, M., Hennen, D., & Inglis, S. (2008). Impact of Changing Diet Regimes on Steller Sea Lion Body Condition. *Marine Mammal Science*, *24*(2), 276-289. <u>https://doi.org/10.1111/j.1748-7692.2008.00188.x</u>

A leading theory for the cause of the decline of Steller sea lions is nutritional stress, which led to chronic high juvenile mortality and possibly episodic adult mortality. Nutritional stress may have resulted from either poor quality or low abundance of prey. The objective of this study was to determine whether we could predict shifts in body condition (i.e., body mass or body fat content) over different seasons associated with a change in diet (i.e., toward lower quality prey). Captive Steller sea lions (n = 3) were fed three different diet regimes, where Diet I approximated the diet in the Kodiak area in the 1970s prior to the documented decline in that area, Diet 2 approximated the species composition in the Kodiak area after the decline had begun, and Diet 3 approximated the diet in southeast Alaska where the Steller sea lion population has been increasing for over 25 yr. All the animals used in this study were still

growing and gained mass regardless of diet. Body fat (90 varied between 1396 and 28176, but was not consistently high or low for any diet regime or season. Mean intake (in kg) of Diet 2 was significantly greater for all sea lions during all seasons. All animals did, however, tend to gain less body mass on Diets 2 and 3, as well as during the breeding and postbreeding seasons. They also tended to gain more mass during the winter and on Diet 1, though these differences were not statistically significant. Thus, changing seasonal physiology of Steller sea lions appears to have more impact on body condition than quality of prey, provided sufficient quantity of prey is available. Steller sea lions are opportunistic predators and are evidently able to thrive on a variety of prey. Our results indicate that Steller sea lions are capable of compensating for prey of low quality.

Beck, C. A., Rea, L. D., Iverson, S. J., Kennish, J. M., Pitcher, K. W., & Fadely, B. S. (2007). Blubber Fatty Acid Profiles Reveal Regional, Seasonal, Age-Class and Sex Differences in the Diet of Young Steller Sea Lions in Alaska. *Marine Ecology Progress Series, 338*, 269-280. https://doi.org/10.3354/meps338269

Blubber fatty acid (FA) profiles of young Steller sea lions *Eumetopias jubatus* (< 24 mo old; n = 477) were investigated to determine whether regional, seasonal, age-class and sex differences occur in the diets of these demographic groups, Blubber FA profiles of spring (March to May) pups differed significantly by region, probably reflecting regional differences in the diet of adult females, who provide their pups with milk. While there were statistically significant seasonal and age-class differences in both Prince William Sound (PWS) and SE Alaska (SEA), differences in FA profiles between sexes were only evident in the blubber of yearlings from PWS. Within SEA, blubber FA profiles of summer pups differed significantly from all other seasonal/age-class groups in that region. This is consistent with movements of female-pup pairs from rookeries to haul-outs and hence differences in female foraging. In SEA, seasonal differences in blubber FA composition were evident and similar between yearlings and pups. In contrast, there was a gradual change in the FA profile of pup blubber from summer to spring in PWS, which did not follow the same seasonal pattern of yearling profiles. These differences in FA profiles suggest either differences in the timing of weaning between the 2 areas or shifts in the diets of lactating females, or both.

Bredesen, E. L., Coombs, A. P., & Trites, A. W. (2006). *Relationship between Steller Sea Lion Diets and Fish Distributions in the Eastern North Pacific*. <u>https://doi.org/10.4027/slw.2006.10</u>

Distributions of fish species were compared with diet information for Steller sea lions (*Eumetopias jubatus*) to assess the level of correspondence between potential prey availability and sea lion feeding habits. Fish distributions were compiled as part of the Sea Around Us Project at the UBC Fisheries Centre, and were based on published distributions and habitat preferences (e.g., latitude, depth). Sea lion scat samples were collected during the 1990s from seven geographic regions from Oregon to the western and central Aleutian Islands. The frequencies of occurrence of four prevalent species (walleye pollock, Theragra chalcogramma; Pacific herring, Clupea pallasii; Pacific cod, Gadus macrocephalus; and North Pacific hake, Merluccius productus) in the Steller sea lion diet were compared to their distributions in the North Pacific Ocean. The data suggest that Steller sea lion diets broadly reflect the distributions of these major prey species. However, some of the fish species that were regionally predicted to be present in high abundance were not proportionally reflected in the Steller sea lion diet, suggesting that other factors in addition to fish abundance influence their diets.

Bryan, D. R., Levine, M., & McDermott, S. (2018). *Results of the 2016 and 2017 Central and Western Aleutian Islands Underwater Camera Survey of Steller Sea Lion Prey Fields*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-381 Retrieved from <u>https://repository.library.noaa.gov/view/noaa/19417</u>

Recent satellite tagging efforts indicate that foraging areas of endangered adult female Steller sea lions (SSL) in the central and western Aleutian Islands include shallow, nearshore regions. However, prey availability in these regions remains poorly understood because traditional bottom trawl surveys either cannot sample or lack precision on the rocky, nearshore habitats where sea lions forage. We attempted to overcome these sampling challenges by opportunistically deploying a towed underwater stereocamera system near SSL rookeries and haulouts during the National Oceanic and Atmospheric Administration, Alaska Fisheries Science Center, Marine Mammal Laboratory's ship-based population surveys of SSL in 2016 and 2017. A total of 63, 15-minute transects were conducted in depths ranging from 20 to 100 m. Fish and associated habitat were identified, quantified, and measured along transects. While stereo-image quality did not allow for the identification of all fish to the species level, it did allow for identification of many prey species (i.e., Atka mackerel (Pleurogrammus monopterygius), Pacific cod (Gadus macrocephalus)) and species groups (i.e., rockfishes, flatfishes, and sculpins) that are consumed by SSL during the summer. Camera transects encompassed substrates ranging from sand to high-relief boulder fields, and greater fish abundance was associated with rockier terrain. Substrates and associated fish abundances varied widely over small (10-100 m) spatial scales, suggesting that nearshore survey activities should be structured to account for extreme spatial variability. The relatively low cost of our camera system, combined with its ability to be deployed quickly during available vessel time, make it a promising tool for future fish surveys of nearshore and untrawlable habitat.

Calkins, D. G. (1998). Prey of Steller Sea Lions in the Bering Sea. *Biosphere conservation: for nature,* wildlife, and humans, 1(1), 33-44. <u>https://doi.org/10.20798/biospherecons.1.1_33</u>

One hundred and ten Steller sea lions (Eumetopias jubatus) that moved to the seasonal ice edge in the Bering Sea in late winter of 1981 were collected. Stomachs were examined to determine prey. Two areas were studied, one near the Russian coast in Olyutorskiy Gulf and one in US waters in the central Bering sea. Origin of the animals was probably rookeries and haulouts in the Aleutian Islands, the Commander Islands and the east coast of Asia. Only males were present. All age classes from 1 to 16 were taken but no pups of the year. Prey were found in 92 stomachs. Walleye pollock (Theragra chalcogramma) dominated overall, accounting for 67% of prey by weight. The second most important prey was Pacific cod (Gadus macrocephalus) which accounted for 15% by weight. Other important prey were squids and octopus, cephalopods; sculpins, Cottidae; Pacific herring, Clupea herengus; flatfishes, Pleuronectidae; other unidentified bony fishes; and Phocid seals, Phocidae. Pollock consumed by sea lions in the Bering Sea were similar in size to those consumed in the Gulf of Alaska in the 1980s but were smaller than those consumed in the Gulf of Alaska in the 1970's. Larger sea lions ate larger pollock. Pollock were important in the diets of sea lions in numerous other studies in both the Gulf of Alaska and Bering Sea. This is in marked contrast to prey remains found in scats from adult females at rookeries and haulouts during summer from the Aleutian Islands and Gulf of Alaska in 1990-1993. This could simply reflect a real shift in diet from 1981 to the 1990s but is complicated by differences in season, location and sex. Predation on other pinnipeds appears to be common by Steller sea lions.

Calkins, D. G., Atkinson, S., Mellish, J. A., Waite, J. N., & Carpenter, J. R. (2013). The Pollock Paradox: Juvenile Steller Sea Lions Experience Rapid Growth on Pollock Diets in Fall and Spring. *Journal of Experimental Marine Biology and Ecology, 441*, 55-61. https://doi.org/10.1016/j.jembe.2013.01.011

Of the numerous hypotheses put forward to explain the decline in abundance of the western stock of Steller sea lions (SSL, Eumetopias jubatus Schreber, 1776), the nutritional stress hypothesis has been the most difficult to test Nutritional stress implies that either the quantity or quality of available prey is insufficient to maintain the health and fitness of the predator. Based on the results of feeding studies with captive animals, it has been suggested that juvenile SSL may reach a digestive capacity that limits their ability to consume enough calories when on a low energy diet, resulting in serious implications for SSLs that primarily eat pollock in the Gulf of Alaska and the Bering Sea. In the present study, wild juvenile SSL (n = 7) were temporarily held in a captive setting and fed a 100% pollock diet, in both fall (n = 3) and spring (n = 4) for a range of 29-49 days. All animals experienced rapid growth, ranging from 0.2 to 1.1 kg per day, or approximately 25% of their body mass over the duration of the feeding trial. In addition, body fat increased significantly (9.0 +/- 3.2%) between capture and the end of the feeding trials. Daily intake of pollock ranged from 7.6 to 10.9% of the SSL's body mass. Proximate composition of the pollock revealed variability among lots, however this had no impact on sea lion growth rates. Our results suggest that the dietary implications of pollock as a primary prey item for juvenile SSL need to be revisited, as an understanding of the feeding ecology of this species is crucial for management and recovery of this species, which is listed under the US Endangered Species Act (ESA).

Chilvers, B. L., Wilkinson, I. S., Duignan, P. J., & Gemmell, N. J. (2006). Diving to Extremes: Are New Zealand Sea Lions (Phocarctos Hookeri) Pushing Their Limits in a Marginal Habitat? *Journal of Zoology, 269*(2), 233-240. <u>https://doi.org/10.1111/j.1469-7998.2006.00059.x</u>

When studying diving behaviour, it is important to know whether a species is operating at or close to its maximum physiological capacity, because if it is, it will be less capable of compensating for normal environmental or human-induced fluctuations in its environment. New Zealand (NZ) sea lions Phocarctos hookeri are among the world's rarest pinnipeds with a restricted distribution and abundance to the most southerly limit of their known range, NZ's sub-Antarctic. Female NZ sea lions are the deepest and longest diving of the otariids, foraging further from their breeding rookeries than any other sea lion. In this study, the diving behaviours of 18 female NZ sea lions from Enderby Island, Auckland Islands, were recorded during early lactation over two austral summers, 2003 and 2004. While at sea, sea lions dived almost continuously, spending on average 52.7% of their time submerged (> 6 m). The mean dive depth (+/- SE) for all dives was 129.5 +/- 5.3 m (range 94.6 +/- 1.1 to 178.9 +/- 1.6 m). The mean duration of dives was 4.0 +/- 0.1 min with an average of 40 +/- 2.9% of all dive times spent in the deepest 85% of the dive. Although there was high variation in diving behaviour among individuals, overall, animals were found to be diving beyond their estimated aerobic dive limits on 68% of all dives. Given that female NZ sea lions have a high percentage of dives that are beyond their theoretical aerobic limits, we ask whether this represents a miscalculation in aerobic limits, is it a species highly adapted to carry an anaerobic load or a species that is physically stretched to their limits? A species that is presumably under physiological stress just to maintain its current low static population numbers is also likely to be more susceptible to external impacts and this needs consideration for their management.

Cornick, L., & Horning, M. (2000). Simulated Foraging Experiments on Captive Diving Mammals: A Feasibility Study with Steller Sea Lions (*Eumetopias Jubatus*). *FASEB Journal*, 14(4), A440-A440.

[NO ABSTRACT AVAILABLE]

Cornick, L. A., Inglis, S. D., Willis, K., & Horning, M. (2006). Effects of Increased Swimming Costs on Foraging Behavior and Efficiency of Captive Steller Sea Lions: Evidence for Behavioral Plasticity in the Recovery Phase of Dives. *Journal of Experimental Marine Biology and Ecology, 333*(2), 306-314. <u>https://doi.org/10.1016/j.jembe.2006.01.010</u>

A significant component of foraging energetics is the cost of locomotion, which for marine animals, is the cost of swimming. increases in the cost of swimming may have significant impacts on foraging efficiency. Minimizing the cost of swimming can contribute to the optimization of foraging strategies by reducing the energetic cost of foraging. Results of several field studies suggest that an increase in the cost of locomotion may have comparable effects on foraging behavior and efficiency to a decrease in prey availability. We tested the hypothesis that an increased cost of swimming, brought on by increased hydrodynamic drag, has the same effect on dive behavior and efficiency as reduced prey availability under standard locomotion. Experiments were performed using two adult female Steller sea lions at the Alaska SeaLife Center in Seward, AK, using the same animals and general experimental design previously used to test the effects of reduced prey encounter rate on dive behavior and efficiency. Animals were fitted with a drag-inducing harness for half of the 500 simulated foraging dives in order to increase the cost of swimming. Individual dive duration and foraging time were significantly reduced in all costincreased dives, comparable to the effects of reduced prey encounter rate. However, on a bout-by-bout basis, dive and foraging efficiency were only slightly reduced, which is likely due to an average 50% reduction in post-dive surface recovery duration during cost-increased dives. Increased heat flux across the body surface measured in a parallel study confirmed a significant increase in work during dragincreased dives. These results suggest that sea lions are able to compensate for changes in the cost of foraging and maintain their foraging efficiency by altering their dive strategy over an entire bout of dives when operating well within their aerobic scope.

Costa, D. P., Kuhn, C. E., Weise, M. J., Shaffer, S. A., & Arnould, J. P. Y. (2004). When Does Physiology Limit the Foraging Behaviour of Freely Diving Mammals? *International Congress Series*, 1275, 359-366. <u>https://doi.org/10.1016/j.ics.2004.08.058</u>

Diving animals offer a unique opportunity to study the importance of physiological constraint and the limitation it can impose on animal's behaviour in nature. This paper examines the interaction between physiology and behaviour and its impact on the diving capability of five eared seal species (Family Otariidae; three sea lions and two fur seals). An important physiological component of diving marine mammals is the aerobic dive limit (ADL). The ADL of these five seal species was estimated from measurements of their total body oxygen stores, coupled with estimates of their metabolic rate while diving. The tendency of each species to exceed its calculated ADL was compared relative to its diving behaviour. Overall, our analyses reveal that seals which forage benthically (i.e. on the sea floor) have a greater tendency to approach or exceed their ADL compared to seals that forage epipelagically (i.e. near the sea surface). Furthermore, the marked differences in foraging behaviour and physiology appear to be coupled with a species demography. For example, benthic foraging species have smaller populations

and lower growth rates compared to seal species that forage epipelagically. These patterns are relevant to the conservation and management of diving vertebrates.

Cottrell, P. E., & Trites, A. W. (2002). Classifying Prey Hard Part Structures Recovered from Fecal Remains of Captive Steller Sea Lions (*Eumetopias Jubatus*). *Marine Mammal Science*, 18(2), 525-539. <u>https://doi.org/10.1111/j.1748-7692.2002.tb01053.x</u>

Feces were collected from six Steller sea lions (Eumetopias jubatus) that consumed known amounts of Atka mackerel (Pleurogrammus monopterygius), Pacific herring (Clupea barengus), pink salmon (Oncorhynchus gorbuscha), walleye pollock (Theragra chalcogramma), and squid (Loligo opalacens). The goal was to determine the numbers and types of taxon-specific hard parts that pass through the digestive tract and to develop correction factors for certain abundantly occurring structures. Over 20,000 fish and squid were consumed during 267 d of fecal collection. During this period, over 119,000 taxon-specific hard parts, representing 56 different structures, were recovered. Skeletal structures and non-skeletal structures accounted for 72% and 28% of all hard parts, respectively. The branchiocranium, axial skeleton, and dermocranium regions of the skeletal system accounted for the greatest number of hard parts recovered. Over 70% of all recovered hard parts were represented by one to six taxa specific structures for each prey type. The average number of hard parts (3.1-31.2) and structure types (2.0-17.7) recovered per individual prey varied across taxa and were used to derive correction factors (to reconstruct original prey numbers). A measure of the variability of hard part recovery among sea lions showed no difference for certain herring, pollock, and squid structures, however, there was a significant difference for salmon and Atka mackerel structures. Identifying all taxon- specific prey hard parts increases the likelihood of identifying and estimating the number of prey consumed.

Csepp, D. J., Honeyfield, D. C., Vollenweider, J. J., & Womble, J. N. (2017). *Estuarine Distribution, Nutritional and Thiaminase Content of Eulachon (Thaleichthys Pacificus) in Southeast Alaska, with Implications for Steller Sea Lions*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC 356. <u>https://doi.org/10.7289/V5/TM-AFSC-356</u>

Eulachon (Thaleichthys pacificus) are small, pelagic fish whose spawning habits and marine distribution are not well understood. Eulachon are a nutrient-rich, seasonally important source of food for predators, including Steller sea lions (Eumetopias jubatus) in southeast Alaska. Echo integrated-trawl surveys were conducted from 3 April to 6 May 2006 to estimate eulachon population structure and biomass, identify fish movement, location, and acoustic targets. The presence of Steller sea lions and other marine predators attracted to pre-spawning aggregations of eulachon were used to fine-tune the timing and location of our survey sites. We identified the distribution of pre-spawning adults, sub-adult, and juvenile eulachon in five estuaries of northern southeast Alaska during the 2006 spring spawning season and analyzed their nutritional and thiaminase content. Mean eulachon weight and nutritional energy varied between sites, from a low of 10.68 g body weight ± 2.93 g with a total energy of 94.4 kJ/fish in Berners Bay, to a high of 33.22 g body weight ± 5.99 g with a total energy of 291.9 kJ/fish in Lutak Inlet. Of the five estuaries surveyed, juvenile and sub-adult eulachon were found only in Taku Inlet, Berners Bay, and Chilkat Inlet and were concentrated at a distinct depth of 50-80 m throughout the estuaries. Adult eulachon were found in three of the five estuaries: Lutak Inlet, Taku Inlet, and Berners Bay with no fish identified with our fishing gear or acoustics in Taiya Inlet. Eulachon school biomass and the duration these schools spend in the estuaries correlated with sea lion abundance. Sea lion numbers were directly proportional to eulachon biomass. Spawning eulachon move quickly into

their freshwater spawning river, with estuary size directly proportional to the time spent in the estuary. Thiaminase, a potentially harmful enzyme, was found in eulachon at all five sites, with a mean activity range of 5.0-7.0 umols·g⁻¹·min⁻¹. The ingestion of thiaminase laced eulachon by Steller sea lions does not appear to affect the health of sea lions in our study area because they were not ingested long enough for the thiaminase to take effect. The role that thiaminase plays in the health of marine predators is not well understood and warrants further study and could play a role in the junk food theory that was used to explain Steller sea lion declines in other areas especially in populations with low dietary diversity.

Deagle, B. E., Tollit, D. J., Jarman, S. N., Hindell, M. A., Trites, A. W., & Gales, N. J. (2005). Molecular Scatology as a Tool to Study Diet: Analysis of Prey DNA in Scats from Captive Steller Sea Lions. *Molecular Ecology*, 14(6), 1831-1842. <u>https://doi.org/10.1111/j.1365-294X.2005.02531.x</u>

The DNA of prey present in animal scats may provide a valuable source of information for dietary studies. We conducted a captive feeding trial to test whether prey DNA could be reliably detected in scat samples from Steller sea lions (Eumetopias jubatus). Two sea lions were fed a diet of fish (five species) and squid (one species), and DNA was extracted from the soft component of collected scats. Most of the DNA obtained came from the predator, but prey DNA could be amplified using prey-specific primers. The four prey species fed in consistent daily proportions throughout the trial were detected in more than 90% of the scat DNA extractions. Squid and sockeye salmon, which were fed as a relatively small percentage of the daily diet, were detected as reliably as the more abundant diet items. Prey detection was erratic in scats collected when the daily diet was fed in two meals that differed in prey composition, suggesting that prey DNA is passed in meal specific pulses. Prey items that were removed from the diet following one day of feeding were only detected in scats collected within 48 h of ingestion. Proportions of fish DNA present in eight scat samples (evaluated through the screening of clone libraries) were roughly proportional to the mass of prey items consumed, raising the possibility that DNA quantification methods could provide semi-quantitative diet composition data. This study should be of broad interest to researchers studying diet since it highlights an approach that can accurately identify prey species and is not dependent on prey hard parts surviving digestion.

deHart, P. A. P. (2006). A Multiple Stable Isotope Study of Steller Sea Lions and Bowhead Whales: Signals of a Changing Northern Environment. University of Alaska Fairbanks. Retrieved from <u>http://hdl.handle.net/11122/8904</u>

The North Pacific and Arctic marine realm is currently experiencing dramatic environmental changes as a result of global climate change. Stable isotope analysis of western arctic bowhead whales (WABW, Balaena mysticetus) and Steller sea lions (SSL, *Eumetopias jubatus*) were conducted to examine the influence of these changes on life history characteristics (migration and foraging) of these marine mammals. WABW baleen plates were analyzed for their stable oxygen and hydrogen isotope composition (d super(18)O and dD) and were compared to the d super(18)O and dD in water and zooplankton prey along their seasonal migratory route. The d super(18)O and dD varied along the baleen (8 to 18[per; -180 to -80[per, respectively) and corresponded to stable isotopic differences in zooplankton from the winter (Bering Sea) and summer (eastern Beaufort Sea) habitats of WABW. Baleen d super(18)O and dD confirmed the seasonal annual migration of WABW and were subsequently compared to historical sea ice concentrations (SIC). This illustrated that WABW migration patterns appeared to have altered concomitant with changes in SIC. Years with a higher SIC (colder climate

regimes) correlated with the largest difference in dD between winter and summer in WABW baleen during the period from 1972 to 1988. For a similar time period (1955 to 2000), the feeding ecology of SSL was also examined by analyzing the stable carbon and nitrogen isotope compositions (d super(13)C and d super(15)N, respectively) of archived SSL bone and tooth collagen. Both d super(15)N and d super(13)C varied greatly with location and sample year (14.6 to 20.5[per; - 16.7 to -11.8[per, respectively), with a significant change in d super(13)C observed around the 1976 regime shift. Bottomup processes may have limited growth of SSL populations throughout this region over time, with animals focusing their foraging on offshore regions to mitigate this environmental change. Stable isotope analyses of historical samples of WABW (baleen) and SSL (bone and tooth collagen) both illustrated that recent environmental changes influenced the ecology (migration and feeding) of these marine mammals in the recent past.

Doll, A. C., Taras, B. D., Stricker, C. A., Rea, L. D., O'Hara, T. M., Cyr, A. P., . . . Wunder, M. B. (2018). Temporal Records of Diet Diversity Dynamics in Individual Adult Female Steller Sea Lion (*Eumetopias Jubatus*) Vibrissae. *Oecologia*, 188(1), 263-275. <u>https://doi.org/10.1007/s00442-018-4173-8</u>

Detailed information on the nutrition of free-ranging mammals contributes to the understanding of life history requirements, yet is often quite limited temporally for most species. Reliable dietary inferences can be made by analyzing the stable carbon (C) and nitrogen (N) isotopic values (delta C-13 and delta N-15) of some consumer tissues; exactly which tissue is utilized dictates the inferential scope. Steller sea lion (SSL) vibrissae are grown continuously without shedding and thus provide a continuous multi-year record of dietary consumption. We applied a novel kernel density approach to compare the delta C-13 and delta N-15 values along the length of SSL vibrissae with delta C-13 and delta N-15 distributions of potential prey species. This resulted in time-series of proportion estimates of dietary consumption for individual SSL. Substantial overlap in delta C-13 and delta N-15 distributions for prey species prevented a discrete species-scale assessment of SSL diets; however, a post hoc correlational analysis of diet proportion estimates revealed grouping by trophic level. Our findings suggest that adult female SSL diets in the western and central Aleutian Islands shift significantly according to season: diets contain a higher proportion of lower trophic level species (Pacific Ocean perch, northern rockfish, Atka mackerel and walleye pollock) in the summer, whereas in the winter SSL consume a much more diverse diet which includes a greater proportion of higher trophic level species (arrowtooth flounder, Kamchatka flounder, darkfin sculpin, Pacific cod, Pacific octopus, rock sole, snailfish, and yellow Irish lord).

Donnelly, C. P., Trites, A. W., & Kitts, D. D. (2003). Possible Effects of Pollock and Herring on the Growth and Reproductive Success of Steller Sea Lions (*Eumetopias Jubatus*): Insights from Feeding Experiments Using an Alternative Animal Model, Rattus Norvegicus. *British Journal of Nutrition*, 89(1), 71-82. <u>https://doi.org/10.1079/bjn2002750</u>

The decline of Steller sea lions (*Eumetopias jubatus*) in the Gulf of Alaska appears to have been associated with a switch of diet from one dominated by fatty forage fishes (such as herring; Clupea pallasi) to one dominated by low-fat fish (such as pollock; Theragra chalcogramma). Observations made during the decline include reduced body size of sea lions, low pregnancy rates, and high mortality. We used the general mammalian model, the laboratory rat (Rattus norvegicus), to test whether changing the quality of prey consumed could cause changes in size and reproductive performance. Five groups of twelve female, weanling rats were fed diets composed of herring (H), pollock (P), pollock supplemented

with herring oil (PH), pollock supplemented with pollock oil (PP), or a semi-purified diet (ICN). Mean body weights were greatest for H, followed by PH, P, PP and finally ICN, although ICN was the only group significantly different from the others (P<0.05). Food intakes before mating were 10 % higher for groups on the lower-fat diets (P and ICN), resulting in similar energy intakes in all groups. The protein efficiency ratio was highest for the H diet, slightly lower for all pollock diets, and significantly lower for ICN (P<0.05). The fetal weights for mothers fed P were significantly reduced (P<0.05). The present study shows that the energy content was a major limiting factor in the nutritional quality of pollock. When food intake was adjusted to meet energetic requirements, there were no detrimental consequences from eating pollock. However, supplementation of pollock meal with additional pollock oil may reduce growth and reproductive performance, although the reasons for this were not apparent.

du Dot, T. J., Rosen, D. A. S., & Trites, A. W. (2008). Steller Sea Lions Show Diet-Dependent Changes in Body Composition During Nutritional Stress and Recover More Easily from Mass Loss in Winter Than in Summer. *Journal of Experimental Marine Biology and Ecology, 367*(1), 1-10. https://doi.org/10.1016/j.jembe.2008.08.005

Controlled feeding experiments were undertaken with captive Steller sea lions (Eumetopias jubatus) to assess seasonal (winter vs. summer) physiological responses of individual animals to reduced quantities and qualities of food that are hypothesised to occur in the wild. Eight animals were randomly divided into two experimental groups fed isocaloric diets: Group H ate Pacific herring (Clupea pallasi) throughout the experiment while Group P was switched to walleye pollock (Theragra chalcogramma) during a 28-day food restriction (after a 28-day baseline) and back to herring during a 28-day controlled re-feeding. Diet type did not impact the rates of body mass lost when food was restricted, but did influence the type of internal energy reserve (protein vs. lipids) the sea lions predominantly used. In both summer and winter, Group H lost significantly more lipids and less lean mass than Group P that was fed pollock during the restriction phase. The response of Group H was consistent with the predicted pattern of nutritional stress physiology (i.e. protein sparing and utilization of lipid reserves). Group P lost a surprisingly high proportion of body protein while consuming restricted levels of pollock, which could lead to muscle impairment and vital organ failure on a long-term basis. When given increased amounts of herring during the controlled re-feeding phase, the capacity of both groups to compensate for the previous mass loss was found to depend on season and was independent of previous diet. All of the sea lions increased their rates of mass gain and returned to their pre-experimental weight during winter, but not during summer. Some intrinsic energetic plasticity related to seasonal adaptation to the environment may render winter an easier period than summer to recover from nutritional stress.

Fadely, B. S., Robson, B. W., Sterling, J. T., Greig, A., & Call, K. A. (2005). Immature Steller Sea Lion (*Eumetopias Jubatus*) Dive Activity in Relation to Habitat Features of the Eastern Aleutian Islands. *Fisheries Oceanography*, 14(s1), 243-258. <u>https://doi.org/10.1111/j.1365-2419.2005.00379.x</u>

Current flow and bathymetry in the Aleutian Islands define unique habitats that influence prey distribution and foraging behaviour of top-level predators. We explored whether oceanographic features and bathymetry influenced the diving activity of 30 immature sea lions (ages 5–21 months) equipped with satellite-linked depth recorders in the eastern Aleutian Islands (EAI) during 2000–02. Sea surface temperature (SST) and chlorophyll a concentrations were obtained from remote sensing satellite imagery and associated with locations where sea lion diving was recorded. Most locations associated

with diving to >4m were within 10 nautical miles (nm) of shore and associated with onshelf waters <100m deep. Use of offshore and deeper waters in the Bering Sea increased during May, as did trip durations. General movements at that time were generally northwesterly from the North Pacific Ocean to the Bering Sea. Diving activity varied coincidently with increases in SST and chlorophyll a concentrations, but also with sea lion age. Associations with habitat features did not consistently explain variability in dive count, time at depth, dive focus or focal depth. Nearshore diving tended to be influenced by distance from shore or seafloor depth, whereas increased SST coincided with activity of sea lions diving >30 m offshore. Immature sea lions developing into independent foragers in the relatively shallow pass areas of the EAI do so at a time of rapid changes in oceanography and prey availability.

Fahlman, A., Hastie, G. D., Rosen, D. A. S., Naito, Y., & Trites, A. W. (2008). Buoyancy Does Not Affect Diving Metabolism During Shallow Dives in Steller Sea Lions *Eumetopias Jubatus*. Aquatic Biology, 3(2), 147-154. <u>https://doi.org/10.3354/ab00074</u>

Changes in buoyancy due to seasonal or abnormal changes in body composition are thought to significantly affect the energy budget of marine mammals through changes in diving costs. We assessed how changes in body composition might alter the foraging efficiency of Steller sea lions *Eumetopias jubatus* by artificially adjusting the buoyancy of trained individuals. PVC tubes were attached to harnesses worn by Steller sea lions that had been trained to feed at fixed depths (10 to 30 m) and to resurface inside a metabolic dome. Buoyancy was altered to simulate the naturally occurring differences in body composition reported in adult females (similar to 12 to 26% subcutaneous fat). Diving characteristics (transit times and time at depth) and aerobic energy expenditure (gas exchange) were measured. We found that foraging cost decreased with the duration of the dive and increased with dive depth. However, changes in body composition did not affect the diving metabolic rate of Steller sea lions for dives between 10 and 30 m. We propose that Steller sea lions may adjust their diving lung volume to compensate for changes in buoyancy to avoid additional metabolic costs.

Fahlman, A., Svard, C., Rosen, D. A. S., Jones, D. R., & Trites, A. W. (2008). Metabolic Costs of Foraging and the Management of O(2) and Co(2) Stores in Steller Sea Lions. *Journal of Experimental Biology*, 211(22), 3573-3580. <u>https://doi.org/10.1242/jeb.023655</u>

The metabolic costs of foraging and the management of O(2) and CO(2) stores during breath-hold diving was investigated in three female Steller sea lions (*Eumetopias jubatus*) trained to dive between 10 and 50 m (N=1142 dives). Each trial consisted of two to eight dives separated by surface intervals that were determined by the sea lion (spontaneous trials) or by the researcher (conditioned trials). During conditioned trials, surface intervals were long enough for O(2) to return to pre-dive levels between each dive. The metabolic cost of each dive event (dive + surface interval; DMR) was measured using flow-through respirometry. The respiratory exchange ratio (V) over dot(O2)/(V) over dot (CO2)) was significantly lower during spontaneous trials compared with conditioned trials. DMR was significantly higher during spontaneous trials and decreased exponentially with dive duration. A similar decrease in DMR was not as evident during conditioned trials. DMR could not be accurately estimated from the surface interval (SI) following individual dives that had short SIs (< 50 s), but could be estimated on a dive by dive basis for longer SIs (> 50 s). DMR decreased by 15%, but did not differ significantly from surface metabolic rates (MRS) when dive duration increased from 1 to 7 min. Overall, these data suggest that DMR is almost the same as MRS, and that Steller sea lions incur an O(2) debt during spontaneous

diving that is not repaid until the end of the dive bout. This has important consequences in differentiating between the actual and 'apparent' metabolic rate during diving, and may explain some of the differences in metabolic rates reported in pinniped species.

Fahlman, A., Wilson, R. P., Rosen, D. A. S., & Trites, A. W. (2007). Swimming Versus Gliding During Dives to Depth in Steller Sea Lions (*Eumetopias Jubatus*). *FASEB Journal, 21*(5), A593-A593. Retrieved from

http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch &qid=14&SID=8AKBSJ5RixL6hagr5Wp&page=1&doc=1

Ascent rates, descent rates (m · sec-1), and overall dynamic body acceleration (ODBA, G) were measured during simulated foraging dives (n = 25) to depths ranging between 10 to 50 m in 2 female Steller sea lions (body masses, F00BO = 135.0 and F97SI = 213.1 kg). Ascent rates ($1.33 \pm 0.29 \text{ m} \cdot \text{sec-1}$) of sea lion F97SI (n = 11) were greater than descent rates ($1.06 \pm 0.22 \text{ m} \cdot \text{sec-1}$) for dives between 10 to 20 m (P < 0.01). In contrast, ascent rates ($1.59 \pm 0.20 \text{ m} \cdot \text{sec-1}$, n = 9) of sea lion F00BO did not differ significantly from descent rates ($1.65 \pm 0.14 \text{ m} \cdot \text{sec-1}$) for dives between 10 to 30 m (P < 0.4), but were significantly slower ($1.49 \pm 0.15 \text{ m} \cdot \text{sec-1}$) than descent rates ($1.74 \pm 0.16 \text{ m} \cdot \text{sec-1}$, n = 5) for dives to 50 m (P < 0.01). Overall dynamic body acceleration (ODBA, G, Wilson et al. J. Anim. Ecol. 2006) displayed consistent patterns between animals, indicating that Steller sea lions glide passively as they descend beyond 5 m, but swim actively during the entire ascent.

Fritz, L. W., & Hinckley, S. (2005). A Critical Review of the Regime Shift-"Junk Food"-Nutritional Stress Hypothesis for the Decline of the Western Stock of Steller Sea Lion. *Marine Mammal Science*, 21(3), 476-518. <u>https://doi.org/10.1111/j.1748-7692.2005.tb01245.x</u>

Steller sea lions (*Eumetopias jubatus*) in the central and western Gulf of Alaska, Aleutian Islands, and Bering Sea have declined by 80% in the last 30 yr. One hypothesis for the decline in this western Steller sea lion population is that a climate regime shift in 1976-1977 changed the species composition of the fish community and reduced the nutritional quality (energy density) of the sea lion prey field. This in turn led to nutritional stress and reduced individual fitness, survival, and reproduction of sea lions. Implications of this regime shift - "junk food" hypothesis are that (1) the recruitment and abundance of supposed high quality species (e.g., Pacific herring, Clupea pallasi) decreased while those of supposed low quality (e.g., species in the family Gadidae) increased following the regime shift, (2) Steller sea lion diets shifted in response to this change in fish community structure, and (3) a diet composed principally of gadids (e.g., walleye pollock, Theragra chalcogramma) is detrimental to sea lion fitness and survival. We examine data relating to each of these implications and find little support for the hypothesis that increases in the availability and consumption of gadids following the regime shift are primarily responsible for the decline of the western population of Steller sea lion.

Gamel, C. M., & Davis, R. W. (2005). Reproductive Energetics and Female Attendance Patterns of Cape Fur Seals (Arctocephalus Pusillus Pusillus) During Early Lactation. *American Midland Naturalist*, 153(1), 152-170. <u>https://doi.org/10.1674/0003-0031(2005)153[0152:Reafap]2.0.Co;2</u>

The Cape fur seal (Arctocephalus pusillus pusillus) is a common pinniped species along the southern African coastline. While much information is available about this species, little is known concerning its

reproductive energetics. With radio telemetry, we monitored attendance Patterns for 1 to 4 mo from 1996-1999. Attendance of 29 nursing females averaged 1.86 +/- 0.77 of on shore and 5.23 +/- 2.87 d at sea. Mean cycle nine was 7.09 +/- 4.33 d, of which 29.6% was spent on shore and 70.4% at sea. A significant increase in length of time at sea was observed during the first 4 mo of lactation. Reproductive condition was quantified using measures of body condition and milk composition. Milk ingestion and field metabolic rates established a baseline for the energetics of 1 mo old pups. Body composition averaged 11.05 +/- 2.31% lipid and 19.15 +/- 2.60% protein. Milk front 17 individuals was composed of 58.07 +/- 6.79% water, 2.02 +/- 0.58% ash, 10.76 +/- 1.23% protein and 23.16 +/- 8.24% lipid. Milk energy content averaged 11.02 +/- 3.10 kJ ml(-1). Thirteen pups consumed milk at a rate of 136.58 +/- 29.11 ml kg(-1) d(-1). Mean energy intake was 1505.10 +/- 120.80 kJ kg(-1) d(-1), with 37.16 +/- 8.04% going to body maintenance and 62.84 +/- 8.04% to growth. Fat and protein tissue was deposited at a rate of 16.10 +/- 4.93 g d(-1) and 21.40 +/- 59.20 g d(-1), respectively. PUP mass gain averaged 9930 +/- 3154.10 g d(-1). Male and female pups differed significantly in body mass and field metabolic rate.

Gende, S. M., & Sigler, M. F. (2006). Persistence of Forage Fish 'Hot Spots' and Its Association with Foraging Steller Sea Lions (*Eumetopias Jubatus*) Southeast Alaska. *Deep-Sea Research Part II-Topical Studies in Oceanography*, 53(3-4), 432-441. <u>https://doi.org/10.1016/j.dsr2.2006.01.005</u>

Whereas primary and secondary productivity at oceanic 'hotspots' may be a function of upwelling and temperature fronts, the aggregation of higher-order vertebrates is a function of their ability to search for and locate these areas. Thus, understanding how predators aggregate at these productive foraging areas is germane to the study of oceanic hot spots. We examined the spatial distribution of forage fish in southeast Alaska for three years to better understand Steller sea lion (*Eumetopias jubatus*) aggregations and foraging behavior. Energy densities (millions KJ/km(2)) of forage fish were orders of magnitude greater during the winter months (November-February), due to the presence of schools of overwintering Pacific herring (Clupea pallasi). Within the winter months, herring consistently aggregated at a few areas, and these areas persisted throughout the season and among years. Thus, our study area was characterized by seasonally variable, highly abundant but highly patchily distributed forage fish hot spots. More importantly, the persistence of these forage fish hot spots was an important characteristic in determining whether foraging sea lions utilized them. Over 40% of the variation in the distribution of sea lions on our surveys was explained by the persistence of forage fish hot spots. Using a simple spatial model, we demonstrate that when the density of these hot spots is low, effort necessary to locate these spots is minimized when those spots persist through time. In contrast, under similar prey densities but lower persistence, effort increases dramatically. Thus an important characteristic of pelagic hot spots is their persistence, allowing predators to predict their locations and concentrate search efforts accordingly.

 Gerlinsky, C., Rosen, D., & Trites, A. (2014). Sensitivity to Hypercapnia and Elimination of Co2 Following Diving in Steller Sea Lions (*Eumetopias Jubatus*). *Journal of Comparative Physiology B: Biochemical, Systemic & Environmental Physiology, 184*(4), 535-544. <u>https://doi.org/10.1007/s00360-014-0819-y</u>

The diving ability of marine mammals is a function of how they use and store oxygen and the physiological control of ventilation, which is in turn dependent on the accumulation of CO. To assess the influence of CO on physiological control of dive behaviour, we tested how increasing levels of inspired CO (hypercarbia) and decreasing inspired O (hypoxia) affected the diving metabolic rate, submergence

times, and dive recovery times (time to replenish O stores and eliminate CO) of freely diving Steller sea lions. We also measured changes in breathing frequency of diving and non-diving individuals. Our findings show that hypercarbia increased breathing frequency (as low as 2 % CO), but did not affect metabolic rate, or the duration of dives or surface intervals (up to 3 % CO). Changes in breathing rates indicated respiratory drive was altered by hypercarbia at rest, but blood CO levels remained below the threshold that would alter normal dive behaviour. It took the sea lions longer to remove accumulated CO than it did for them to replenish their O stores following dives (whether breathing ambient air, hypercarbia, or hypoxia). This difference between O and CO recovery times grew with increasing dive durations, increasing hypercarbia, and was greater for bout dives, suggesting there could be a build-up of CO load with repeated dives. Although we saw no evidence of CO limiting dive behaviour, the longer time required to remove CO may eventually exhibit control over the overall time they can spend in apnoea and overall foraging duration.

Goto, Y., Wada, A., Hoshino, N., Takashima, T., Mitsuhashi, M., Hattori, K., & Yamamura, O. (2017). Diets of Steller Sea Lions Off the Coast of Hokkaido, Japan: An Inter-Decadal and Geographic Comparison. *Marine Ecology-an Evolutionary Perspective, 38*(6). https://doi.org/10.1111/maec.12477

Inter-decadal and geographic variations in the diets of Steller sea lion, *Eumetopias jubatus*, were examined based on the contents of 408 stomachs collected from coastal areas around Hokkaido Island during the periods 1994-1998 and 2005-2012. The most important prey species in the 1990s were gadid fishes (walleye pollock [Gadus chalcogrammus], Pacific cod [Gadus microcephalus] and saffron cod [Eleginus gracilis]). The frequency of occurrence and gravimetric contribution of gadids decreased in the 2000s latter period at three study sites (Rausu, Shakotan and Rebun) and were replaced by Okhotsk Atka mackerel (Pleurogrammus azonus) and smooth lumpsucker (Aptocyclus ventricosus). However, analysis based on gravimetric composition indicated that the dietary diversity of prey showed only a slight inter-decadal difference, reflecting the wide diversity of prey ingested during both study periods. These results indicate that Steller sea lions along the Hokkaido coast are opportunistic feeders that utilize a wide variety of prey, and appear to feed mainly upon prey that is easily obtained.

Goundie, E. T., Rosen, D. A. S., & Trites, A. W. (2015). Low Prey Abundance Leads to Less Efficient Foraging Behavior in Steller Sea Lions. *Journal of Experimental Marine Biology and Ecology, 470*, 70-77. <u>https://doi.org/10.1016/j.jembe.2015.05.008</u>

Breath-hold divers should adjust their dive behaviors to maximize the benefits and minimize the costs of foraging on prey patches of different densities at different depths. However, few studies have quantified how animals respond to changes in prey availability (depth and density), and how this affects their foraging efficiency. We tested the effects of changes in prey availability on the foraging behavior and efficiency of Steller sea lions (Eumetopias *jubatus*) by measuring diving metabolic rate, dive durations, and food intake of 4 trained sea lions diving in the open ocean on controlled prey patches of different densities at different depths. Sea lions completed bouts of 5 consecutive dives on high- or low-density prey patches at two depths (10 m and 40 m). We found that the rate of energy expenditure did not change under any of the imposed foraging conditions (mean +/- SD: 022 +/- 0.02 kJ min(-1) kg(-1)), but that the proportion of time spent consuming prey increased with prey patch density due to changes in diving patterns. At both depths, sea lions spent a greater proportion of the dive bout foraging on prey patches with high prey density, which led to high rates of energy gain (4.3 +/- 0.96 kJ min(-1) kg(-1)) and

high foraging efficiency (cost:benefit was 1:20). In contrast, the sea lions spent a smaller proportion of their dive bout actively feeding on prey patches with low prey density, and consequently had a lower energetic gain (0.91 + - 0.29 kJ min(-1) kg(-1)) and foraging efficiency (1:4). The 5-fold differences in foraging efficiency between the two types of prey patches were greater than the 3-fold differences that we expected based on differences in food availability. Our results suggest that sea lions faced with reduced prey availability forage less efficiently and therefore would have greater difficulty obtaining their daily energy requirements.

Grellier, K., & Hammond, P. S. (2006). Robust Digestion and Passage Rate Estimates for Hard Parts of Grey Seal (Halichoerus Grypus) Prey. Canadian Journal of Fisheries and Aquatic Sciences, 63(9), 1982-1998. <u>https://doi.org/10.1139/f06-092</u>

Application of digestion correction factors to measurements and counts of fish otoliths and cephalopod beaks recovered from seal scats is required before the size or quantity of prey consumed can be accurately estimated. We carried out 86 feeding trials with seven grey seals (Halichoerus grypus) and 18 prey species to derive estimates of digestion coefficients (to account for partial digestion), recovery rates (to account for complete digestion), and passage rates (to estimate the time between consumption and excretion of an item). Mean digestion coefficients were greatest for sandeel (Ammodytes marinus) and then less for large gadoid, flatfish, and Trisopterus spp. otoliths; and finally squid (Loligo forbesii) beaks. Recovery rates were greatest for squid beaks and then less for large gadoid, Trisopterus spp., flatfish, and sandeel otoliths. Greater than 95% of otoliths and beaks recovered were passed within 4 days (~88 h) of consumption. The large differences in partial and complete digestion rates found among prey species reinforce the importance of obtaining robust estimates of these quantities. Results from this study are the most comprehensive and systematically obtained for any species of pinniped and will allow accurate and precise estimation of the number and size of fish represented by otoliths recovered from grey seal scat samples collected in the wild.

Hansen, D. J., Alaska Sea Grant Coll, P., & Alaska Sea Grant Coll, P. (1997). Shrimp Fishery and Capelin Decline May Influence Decline of Harbor Seal (Phoca Vitulina) and Northern Sea Lion (Eumetopias Jubatus) in Western Gulf of Alaska (Vol. 97). Retrieved from https://seagrant.uaf.edu/bookstore/pubs/AK-SG-97-01.html

The decline of the harbor seal, Phoca vitulina richardsi, in the western Gulf of Alaska was concurrent with the collapse of the shrimp-trawl fishery in the same area between 1976 and 1981. Over approximately the same time period (1976-1979 to 1985), the rate of decline of specific local breeding populations of the northern sea lion, *Eumetopias jubatus*, increased. Shrimp, slow-moving and relatively easy to catch, have been reported as the primary prey item of newly weaned harbor seal pups, and they may play a similarly important role in the diet of northern sea lion pups; young pinniped pups may need time and practice to acquire the speed and agility to catch fast-moving prey such as finfishes. Capelin, Mallotus villosus, a forage fish of harbor seals and northern sea lions, also declined in abundance in the early 1980s in the western Gulf of Alaska; capelin may be of importance to older pinniped pups, providing a high-lipid food source for the buildup of fat reserves for thermal insulation and growth. With the decline in abundance of both shrimp and capelin, young inexperienced harbor seals and sea lions may no longer be able to compete successfully with other predators for these food items. Thus, harbor seal and sea lion pups may be starving after they leave the rookeries.

Haynes, T., Nelson, S., & Padula, V. (2011). Dynamics of Multi-Species Feeding Associations in Marine Waters near Juneau, Alaska. *Marine Ornithology, 39*, 227-234. Retrieved from <u>https://sora.unm.edu/sites/default/files/MO_39_2_227-234.pdf</u>

During the summer of 2008, we examined the dynamics of multi-species feeding associations (MSFAs) in marine waters near Juneau, southeast Alaska. We conducted 1400 m wide strip transects to determine regional and seasonal differences in the composition of flocks. We conducted focal observations of 39 flocks to determine: (1) which bird species trapped prey at the surface, allowing for the initiation of the MSFA; (2) the roles of the numerically dominant species; and (3) how each flock terminated. Sixteen avian species participated in flocks, with flock size ranging from two to 543 individual birds (mean \pm Sd = 37 ± 63 birds). Bird species richness ranged from one to five species (3 ± 1 species). Capelin Mallotus villosus, sampled by dip net (n = 44 prey balls), were the only prey species found targeted by flocks. Mean flock densities on transects ranged from 0.21 \pm 0.29 flocks/10 km2 in Stevens Passage to 2.42 \pm 1.93 flocks/10 km2 in Tracy Arm. Of the 174 flocks surveyed, 172 were MSFAs and 170 of those involved at least one species of pursuit diving bird. Focal observations revealed that pursuit divers produced prey at the surface, leading to initiation of 16 of the 22 flocks, with murrelets Brachyramphus sp. producing 14 flocks, Pacific loons Gavia pacifica producing one, and murrelets and Pacific loons together producing one. Of the remaining six flocks, foraging salmonids produced prey at the surface at two, while the producers at four flocks were unobserved. Flock initiators included both small and large gull species as well as Bald eagles Haliaeetus leucocephalus. Of the 39 focal observations, 31 terminated when pursuit divers stopped foraging and dispersed, subsequently followed by the dispersal of surface feeders. eight focal observation flocks were terminated by Humpback Whales Megaptera novaeangliae lunge feeding at the center of the flock. Bald eagles frequently participated in flocks in May and June but very infrequently in July and August, likely switching to a spawning salmon diet later in the season.

Hoberecht, L. K. (2006). Investigating the Use of Blubber Fatty Acids to Detect Steller Sea Lion (Eumetopias Jubatus) Foraging on Ephemeral High-Quality Prey (Alaska). University of Washington. Retrieved from

https://search.proquest.com/asfa/docview/20320120/EEB5BA2DBA7B4410PQ/1?accountid=28 258

One hypothesis for the decline of the western stock of Steller sea lions (*Eumetopias jubatus*) is dietary related nutritional stress, which may have adversely affected juvenile survival and female fecundity. Fatty acids in the blubber of sea lions are an index of diet. Comparisons of blubber fatty acids between different groups (age, sex, location) of Steller sea lions may indicate if dietary differences exist. Diet estimates can be produced by matching blubber fatty acids to those of potential prey. Two reference databases of Steller sea lion prey fatty acids were compiled for use with captive and free-ranging sea lion samples. The captive and free-ranging databases consisted of 141 and 650 prey items representing 7 and 25 species respectively. Analyses of database fatty acids indicated differences in prey by species and family. Captive Steller sea lions were used to simulate ephemeral feeding events and investigate the use of the Quantitative Fatty Acid Signature Analysis (QFASA) to model diet. The captive study showed that ephemeral events were inconsistently detected unless small schooling fish were grouped together. The captive study also indicated that blubber fatty acids most likely reflect diet from the previous 3-4 months. Blubber samples were collected from adult male (n = 118), adult female (n = 110), and juvenile (n = 35) Steller sea lions in three regions of varying population growth (Western Gulf of Alaska, Central Gulf of Alaska, and Southeast Alaska) in 2002--2004 using a novel remote biopsy system. Analyses of

fatty acid data indicated dietary differences among the three regions, and between adult males and females, particularly in areas of stable or increasing population growth. Differences before and after access to ephemeral feeding events were not clearly detected. Differences before and after breeding were evident, with early samples being more similar. Using QFASA, important prey types were determined for free-ranging animals. Pollock, salmon, small schooling fish, and flatfish appear important in all 3 regions. Ephemeral feeding event utilization was evident for some groups, but not significant due to variability between individual animals. In areas of population decline, sea lions fed on a larger range of prey.

Hobson, K. A., & Sease, J. L. (1998). Stable Isotope Analyses of Tooth Annuli Reveal Temporal Dietary Records: An Example Using Steller Sea Lions. *Marine Mammal Science*, 14(1), 116-129. <u>https://doi.org/10.1111/j.1748-7692.1998.tb00694.x</u>

Stable isotope analysis of teeth of marine mammals can provide valuable information on trophic level and source of feeding. However, the isotopic analysis of whole teeth presents only an average dietary estimate for individuals across the period of growth of that tooth. While such analyses can be valuable, particularly in the case of fossil material, in contrast, isotopic analysis of individual annuli of teeth can provide dietary information for each year of tooth growth, in some cases representing the whole of the animal's life. We measured stable-carbon isotope ratios (C-13/C-12) in the inorganic (hydroxyapatite) and stable-nitrogen isotope ratios (N-15/N-14) in the organic (primarily collagenous) components of individual tooth annuli of 18 male Steller sea lions (Eumetopias jubatus) obtained from archived collections from the Bering Sea and Gulf of Alaska and from single northern fur seals (Callorhinus ursinus) and northern elephant seals (Mirounga angustirostris) from the central Aleutian Islands and eastern Gulf of Alaska, respectively. In several individuals, we detected considerable variation in stable isotope values among annuli, up to 6.1 parts per thousand for delta(15)N and 5.1 parts per thousand for delta(13)C values. Enrichment in delta(15)N and depletion of delta(13)C values in the first annulus may correspond to dietary inputs from mother's milk during the period of suckling. Other variations among years may be caused by dietary changes or movements of individuals between regions differing in isotopic signatures of foodweb primary production. Our study indicates that the isotopic analysis of individual tooth annuli represents a fine-scale cool for dietary reconstructions involving marine mammals, and cautions against the use of whole-tooth material averaged over several annuli.

 Hobson, K. A., Sease, J. L., Merrick, R. L., & Piatt, J. F. (1997). Investigating Trophic Relationships of Pinnipeds in Alaska and Washington Using Stable Isotope Ratios of Nitrogen and Carbon. *Marine Mammal Science*, 13(1), 114-132. <u>https://doi.org/10.1111/j.1748-7692.1997.tb00615.x</u>

We measured stable-nitrogen (delta(15)N) and stable-carbon (delta(13)C) isotope ratios in muscle and hair from 7 northern fur seals (Callorhinus ursinus) from the Pribilof Islands, Alaska, and 27 Steller sea lions (*Eumetopias jubatus*), and 14 harbor seals (Phoca vitulina) from the Gulf of Alaska and coast of Washington Scare, in order to contrast dietary information derived from isotopic vs. available conventional dietary studies. Stable-nitrogen-isotope analysis of muscle revealed that harbor seals were enriched over sea lions (mean delta(15)N = 18.6 parts per thousand vs. 17.5 parts per thousand) which were in Nn enriched over northern fur seals (mean delta(15)N = 16.6 parts per thousand. Trophic segregation among these species likely results primarily from differential reliance on herring (Clupea harengus), Atka mackerel (Pleurogrdmmus monopterygius), and large us. small walleye pollock (Theregra chalcogramma). According to their delta(15)N values, adult male Steller sea lions showed a

higher trophic position than adult females (mean delta(15)N: 18.0 parts per thousand vs. 17.2 parts per thousand) whereas adult female northern fur seals were trophically higher than juvenile male fur seals (mean delta(15)N: 16.5 parts per thousand vs. 15.0 parts per thousand). Each of these observed differences likely resulted from differential reliance on squid or differences in the size range of pollock consumed. Three northern fur seal pups showed higher delta(15)N enrichment over adults (mean 17.7 parts per thousand vs. 15.8 parts per thousand) due to their reliance on their mother's milk. Stable-carbon isotope measurements of hair revealed a dine toward more negative values with latitude. Segregation in hair delta(13)C between Steller sea lions and harbor seals off the coast of Washington (mean delta(13)C: -13.6 parts per thousand vs. -15.0 parts per thousand) reflected the greater association of harbor seals with freshwater input from the Columbia River. Our study demonstrates the utility of the stable isotope approach to augment conventional dietary analyses of pinnipeds and other marine mammals.

Hobson, K. A., Sinclair, E. H., York, A. E., Thomason, J. R., & Merrick, R. E. (2004). Retrospective Isotopic Analyses of Steller Sea Lion Tooth Annuli and Seabird Feathers: A Cross-Taxa Approach to Investigating Regime and Dietary Shifts in the Gulf of Alaska. *Marine Mammal Science*, 20(3), 621-638. <u>https://doi.org/10.1111/j.1748-7692.2004.tb01183.x</u>

Stable isotope (delta(15)N and delta(13)C) values of individual tooth annuli of female Steller sea lions (n = 120) collected from the 1960s through the 1980s were used for retrospective analyses of temporal changes in food webs in the Gulf of Alaska and North Pacific Ocean. We also examined isotopically contour feathers of tufted puffins (n = 135) and crested auklets (n = 37) through this period to test for broader isotopic patterns indicative of whole food web changes. Steller sea lions decreased slightly in delta(13)C and increased in delta(15)N values, suggesting an increasing trophic level and change in foraging location or oceanographic isotopic signature. Steller sea lion first and second tooth annuli were enriched in N-15 and depleted in C-13 compared with subsequent annuli, indicating the effects of maternal influence through weaning. The general pattern of increasing delta(15)N values among Steller sea lions supports previous conclusions regarding a reduction or redistribution of forage fishes and an increase of demersal and semi-demersal species in the North Pacific ecosystem. There were no significant changes in delta(15)N values for either bird species. However, delta(13)C values in both bird species again suggested changes in foraging location or a shift in oceanographic currents.

Kastelein, R. A., Vaughan, N., & Wiepkema, P. R. (1990). The Food Consumption of Steller Sea Lions (*Eumetopias Jubatus*). *Aquatic Mammals, 15*(4), 137-144. Retrieved from <u>https://www.aquaticmammalsjournal.org/share/AquaticMammalsIssueArchives/1990/Aquatic_Mammals_15_4/Kastelein_Vaughan.pdf</u>

The food consumption of one male and two female Steller sea lions (*Eumetopias jubatus*) and their eight offspring at the Harderwijk Marine Mammal Park was measured during several successive years. Food intake changes due to age, sex, time of year, reproductive stage and individuality of each animal are described, and compared to data from field studies.

Logerwell, E. A., & Schaufler, L. E. (2005). New Data on Proximate Composition and Energy Density of Steller Sea Lion (*Eumetopias Jubatus*) Prey Fills Seasonal and Geographic Gaps in Existing Information. *Aquatic Mammals*, 31(1), 62. <u>https://doi.org/10.1578/AM.31.1.2005.62</u> Energy density data of prey items are necessary to estimate food requirements of predators. The goal of this study was to provide proximate composition and energy density information for Steller sea lion (Eumetopias jubatus) prey species where there are seasonal and/or geographic gaps in the existing data. Opportunistic collections were made on board National Oceanic and Atmospheric Administration fisheries research surveys in the Aleutian Islands region, eastern Bering Sea, and Gulf of Alaska, targeting particular species of interest. Proximate analyses were conducted in the laboratory and energy density was calculated from lipid and protein content. Pacific herring, sand lance, and rockfish were found to contain the highest amount of lipid and provide the most energy. Atka mackerel, surf smelt, capelin, salmon, sandfish, pollock, yellow Irish lords, Pacific cod, squid, skates, and rock sole had intermediate energy densities. Smooth lumpsucker and snailfish were found to contain the least amount of energy. This study is the first to provide proximate composition data for adult pollock during the nonspawning seasons in the Gulf of Alaska and Aleutian Islands region. This study also provides the first proximate composition data for juvenile pollock in the Aleutian Islands region and eastern Bering Sea, and for Pacific cod in the eastern Bering Sea. This study fills another critical gap by presenting the only information on proximate composition of adult Atka mackerel, one of the most important prey of Steller sea lions in the Aleutian Islands region. These improvements in the seasonal and geographic coverage of fish proximate and energy density data will allow for seasonally and geographically specific estimates of Steller sea lion prey requirements, a necessary improvement over annual estimates made previously. These data can also contribute to bioenergetic modeling of prey requirements of other predators in Alaska such as groundfish, fur seals, and marine birds.

Loughlin, T. R., Perlov, A. S., Baker, J. D., Blokhin, S. A., & Makhnyr, A. G. (1998). Diving Behavior of Adult Female Steller Sea Lions in the Kuril Islands, Russia. *Biosphere conservation: for nature, wildlife, and humans, 1*(1), 21-31. https://doi.org/10.20798/biospherecons.1.1_21

Satellite-linked time-depth recorders (SLTDR) were attached to eight adult female Steller sea lions (*Eumetopias jubatus*) at three islands in the Kuril Islands, Russia, during June 1991. The purpose of the study was to enhance our understanding of adult female Steller sea lion dive characteristics and foraging behavior in Russian waters for comparison to similar studies in Alaska during the breeding season. Mean dive depth was 53m (n=7,143) and mean dive duration was 112 sec (n=7,775). Steller sea lions had trips to sea lasting about 1 day, but some trips lasted up to 4 days. Virtually all dives were in the late afternoon through early morning, and 99.5% of the dives> 100m occurred between 2100-0300 hrs. Most (94%) locations indicated that the sea lions foraged within 10 km of the capture island, but some traveled as far as 263km. Dive depth and duration varied by individual and by island. Five sea lions from Lovushki Island had statistically longer duration (p<0.05) and deeper (p<0.05) dives than three females from Brat Chirpoyev and Raykoke Islands. The Lovushki Island animals also tended to dive in shallower water over a large reef complex suggesting that they foraged near bottom while sea lions from the other two islands foraged near the surface in deep water. The results support the hypothesis that adult female Steller sea lions in the Kuril Islands have dive characteristics similar to Alaska sea lions.

Loughlin, T. R., Sterling, J. T., Merrick, R. L., Sease, J. L., & York, A. E. (2003). Diving Behavior of Immature Steller Sea Lions (*Eumetopias Jubatus*). *Fishery Bulletin*, *101*(3), 566-582. Retrieved from https://spo.NMFS.noaa.gov/sites/default/files/08loughl.pdf Understanding the ontogenetic relationship between juvenile Steller sea lions (Eumetopias jubatus) and their foraging habitat is key to understanding their relationship to available prey and ultimately their survival. We summarize dive and movement data from 13 young-of-the-year (YOY) and 12 yearling Steller sea lions equipped with satellite dive recorders in the Gulf of Alaska and Aleutian Islands (n=18), and Washington (n=7) from 1994 to 2000. A total of 1413 d of transmission (x=56.5 d, range: 14.5-104.1 d) were received. We recorded 222,073 dives, which had a mean depth of 18.4 m (range of means: 5.8-67.9 m; SD=16.4). Alaska YOY dived for shorter periods and at shallower depths (mean depth=7.7 m, mean duration=0.8 min, mean maximum depth=25.7 m, and maximum depth=252 m) than Alaska yearlings (x=16.6 m, 0=1.1 min, x= 63.4 m, 288 m), whereas Washington yearlings dived the longest and deepest (mean depth=39.4 m, mean duration=1.8 min, mean maximum depth=144.5 m, and maximum depth= 328 m). Mean distance for 564 measured trips was 16.6 km; for sea lions less than or equal to 10 months of age, trip distance (7.0 km) was significantly less than for those >10 months of age (24.6 km). Mean trip duration for 10 of the 25 sea lions was 12.1 h; for sea lions <10 months of age, trip duration was 7.5 h and 18.1 h for those >10 months of age. We identified three movements types: long-range trips (>15 km and >20 h), short-range trips (<15 km and <20 h) during which the animals left and returned to the same site, and transits to other haul-out sites. Long-range trips started around 9 months of age and occurred most frequently around the assumed time of weaning, whereas short-range trips happened almost daily (0.9 trips/day, n=426 trips). Transits began as early as 7 months of age, occurred more often after 9 months of age, and ranged between 6.5 and 454 km. The change in dive characteristics coincided with the assumed onset of weaning. These yearling sea lion movement patterns and dive characteristics suggest that immature Steller sea lions are as capable of making the same types of movements as adults.

Mathews, E. A., & Adkison, M. D. (2010). The Role of Steller Sea Lions in a Large Population Decline of Harbor Seals. *Marine Mammal Science*, *26*(4), 803-836. <u>https://doi.org/10.1111/j.1748-7692.2010.00375.x</u>

We provide the first direct evidence that Steller sea lions will prey on harbor seals. Direct observations of predation on marine mammals at sea are rare, but when observed rates of predation are extrapolated, predation mortality may be found to be significant. From 1992 to 2002, harbor seals in Glacier Bay declined steeply, from 6,200 to 2,500 (similar to 65%). After documenting that Steller sea lions were preying on seals in Glacier Bay, we investigated increased predation by sea lions as a potential explanation for the large decline. In five independent data sets spanning 21-25 yr and including 14,308 d of observations, 13 predation events were recorded. We conducted a fine-scale analysis for an intensively studied haul-out (Spider Island) and a broader analysis of all of Glacier Bay. At Spider Island, estimated predation by sea lions increased and could account for the entirety of annual pup production in 5 of 8 yr since 1995. The predation rate, however, was not proportional to the number of predators. Predation by Steller sea lions is a new source of mortality that contributed to the seal declines; however, life history modeling indicates that it is unlikely that sea lion predation is the sole factor responsible for the large declines.

McKenzie, J., & Wynne, K. M. (2008). Spatial and Temporal Variation in the Diet of Steller Sea Lions in the Kodiak Archipelago, 1999 to 2005. *Marine Ecology Progress Series, 360*, 265-283. <u>https://doi.org/10.3354/meps07383</u> Spatial and temporal variation in the diet of Steller sea lions *Eumetopias jubatus* was investigated using scat (fecal) samples collected from 4 regions in the Kodiak Archipelago. Over 2700 scats with identifiable prey were collected from the northern, eastern, southern and western sides of Kodiak Island from 1999 to 2005. Of 76 prey types identified using hard remains, the most important species in terms of frequency of occurrence and numerical abundance were Pacific sand lance Ammodytes hexapterus, walleye pollock Theragra chalcogramma, arrowtooth flounder Atheresthes stomias, Pacific cod Gadus macrocephalus, salmon Oncorhynchus spp., and Pacific herring Clupea pallasi. Significant differences in diet composition were found among regions, seasons, and years, suggesting that the diet of sea lions is strongly influenced by local and temporal distributions and abundances of prey. Herring dominated scat collections from the west coast and accounted for most (14 to 30%) of the differences in regional diet in spring and winter. Annual variation in diet was relatively low in winter, whereas spring and fall diets varied from year to year, with regional-specific shifts in dominant prey. Results from our study generally agree with diet studies conducted in the 1990s, but differ markedly in the relative importance of the major prey species.

Merrick, R. L., Chumbley, M. K., & Byrd, G. V. (1997). Diet Diversity of Steller Sea Lions (*Eumetopias Jubatus*) and Their Population Decline in Alaska: A Potential Relationship. *Canadian Journal of Fisheries and Aquatic Sciences*, 54(6), 1342-1348. <u>https://doi.org/10.1139/cjfas-54-6-1342</u>

We examined the diet of Steller sea lions (*Eumetopias jubatus*) during June-August 1990-1993 from six areas in the Aleutian Islands and Gulf of Alaska and related these diets to sea lion population changes that occurred during the period. Seven general prey categories were identified, but either walleye pollock (Theragra chalcogramma) or Atka mackerel (Pleurogrammus monopterygius) dominated in every area. The diversity of prey consumed varied among sites. Only the eastern Aleutian Islands area had all seven categories in the diet, and there, walleye pollock and Atka mackerel each made up around 30% of the diet. The remainder was composed mostly of small schooling fish (e.g., Pacific herring (Clupea pallasi) and salmon (Oncorhynchus spp.)). The diet in the Gulf of Alaska included mostly walleye pollock whereas the central and western Aleutian diet was composed mostly of Atka mackerel. Populations in the six areas decreased up to 49% during 1990-1994. A strong positive correlation (r = 0.949, P = 0.004) was found between diet diversity and the amount of decline in an area: as diet diversity decreased, populations decreased. This suggests that sea lions need a variety of prey available, perhaps to buffer significant changes in abundance of any single prey.

Merrick, R. L., & Loughlin, T. R. (1997). Foraging Behavior of Adult Female and Young-of-the-Year Steller Sea Lions in Alaskan Waters. *Canadian Journal of Zoology*, *75*(5), 776-786. <u>https://doi.org/10.1139/z97-099</u>

One explanation for recent declines in the Alaskan Steller sea lion (*Eumetopias jubatus*) population is that the availability of preferred prey has changed. Part of our evaluation of this hypothesis involved the use of conventional radio and satellite-linked time-depth recorder transmitters to compare summer and winter foraging of adult female and young-of-the-year Steller sea lions in Alaska waters. Foraging effort was not significantly different seasonally for postpartum adult females, though females with dependent young in winter may increase their foraging effort. In winter, all adult females made longer trips over larger home ranges and dove deeper. Young sea lions exerted less foraging effort, had the shallowest and briefest dives, and had home ranges intermediate in size to the two groups of adult females. Their foraging ability appears to develop throughout the first year. We conclude that adult female sea lions

can exploit prey throughout the Gulf of Alaska and Bering Sea, and are constrained only by their reproductive status and seasonal changes in prey availability. Young sea lions' diving is more limited because their physiological and behavioral development constrains them from diving like an adult. Perhaps most important, dives remain shallow through the first year. Consequently, young sea lions could be more easily food-limited by changes in prey distribution.

O'Daniel, D., & Schneeweis, J. C. (1992). Steller Sea Lion, *Eumetopias Jubatus*, Predation on Glaucous-Winged Gulls, Larus Glaucescens. *Canadian field-naturalist*, *106*(2), 268. Retrieved from <u>https://search.proquest.com/asfa/docview/16498361/338B58841A744476PQ/1?accountid=282</u> 58

We observed a Steller sea lion (*Eumetopias jubatus*) preying on glaucous-winged gulls (Larus glaucescens) in the eastern Aleutian Islands. To our knowledge, this is the first record of such behavior by this species.

Olesiuk, P. F., Bigg, M. A., Ellis, G. M., Crockford, S. J., & Wigen, R. J. (1990). An Assessment of the Feeding Habits of Harbour Seals (Phoca Vitulina) in the Strait of Georgia British Columbia Based on Scat Analysis. Department of Fisheries and Oceans Biological Sciences Branch. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1730. Retrieved from http://publications.gc.ca/pub?id=9.578889&sl=0

Seasonal and regional variations in the diet of harbour seals in the Strait of Georgia were described based on 2,841 scat samples collected from 58 sites (11 estuaries and 47 non-estuary haul outs) in all months, and the diet compared with the diet in other regions of the province based on 159 samples. Prey remnants were separated from other faecal matter using an elutriator and prey identified using a wide variety of structures including otoliths, teeth, vertebrae, cranial, appendicular and caudal elements, and scutes and spines. Otoliths alone provided an incomplete and biased representation of the diet. We derived and employed a new index, referred to as split-sample frequency of occurrence, to assess the relative importance of prey. The validity of the assumptions underlying the index, and scat analyses in general, were addressed. Annual prey consumption was estimated by combining dietary information with data on the abundance and distribution of seals and estimates of their daily food requirements.

Oregon Department of Fish and Wildlife Marine Mammal Research. *Estimates of Fish Biomass Consumed by Pinnipeds in Oregon.*

ODFW Marine Mammal Research staff estimate that pinnipeds in Oregon consume between approximately 45,000-70,000 tons of fish annually (Table 1). This range of estimates is not unbiased, however, and likely underestimates the true level of uncertainty in prey consumption. Our confidence in the biomass requirements listed in Table 1 is probably highest for harbor seals, which are residents with a stable statewide population size, and lowest for California sea lions which are migrants with a constantly fluctuating statewide population size. There is currently no reliable method to translate biomass requirements into prey-specific consumption estimates. Prey-specific consumption varies by numerous factors including: pinniped species, sex, age, behavior, and breeding condition; location and season; and relative prey abundance and composition. Furthermore, the primary method of studying pinniped diet – scat analysis – is subject to numerous potential biases which make it difficult to reconstruct consumption. Nevertheless, scat analysis can provide a qualitative picture of the types and relative frequency of prey recovered from fecal samples and we provide results from our analyses of harbor seal, Steller sea lion, and California sea lions in Tables 2-4, respectively.

Pauly, D., Trites, A., Capuli, E., & Christensen, V. (1998). Diet Composition and Trophic Levels of Marine Mammals. *ICES Journal of Marine Science*, 55(3), 467-481. <u>https://doi.org/10.1006/jmsc.1997.0280</u>

Standardized diet compositions were derived for 97 species of marine mammals from published accounts of stomach contents as well as from morphological, behavioural and other information. Diet was apportioned among eight categories of prey types (benthic invertebrates, large zooplankton, small squids, large squids, small pelagic fishes, mesopelagic fishes, miscellaneous fishes and higher invertebrates). Trophic levels were estimated for each species of marine mammals and compared with published estimates derived using stable isotope ratios. Trophic levels ranged from 3.2–3.4 in baleen whales and sea otters, to 3.8–4.4 in most pinnipeds and odontocete whales, to 4.5–4.6 in killer whales. Such information can be used for ecosystem modelling and related studies.

Perez, M. A., & McAlister, W. B. (1993). Estimates of Food Consumption by Marine Mammals in the Eastern Bering Sea. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC 14. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/6108</u>

One important aspect of the management of commercial fisheries in an ecosystem context involves understanding the diet and consumption rates of fish species by their natural predators. Such knowledge allows for comparison of commercial fish catches with consumption through predation by species groups such as marine mammals. For the Bering Sea, the limited data available only allows a preliminary assessment of food consumption by marine mammals. Estimates of food consumption for this study were based on marine mammal population and diet data reported in the literature. Where direct consumption data were not available, consumption was estimated from population data and energy requirements. Food consumption by marine mammals (except walrus) in the eastern Bering Sea and Aleutian Islands region was estimated at 3.21 x 106 metric tons (t) per year. Fish comprised 42% of food consumed, an estimated 1.34 x 106 t of fish eaten per year. Pinnipeds ate 65% of the estimated annual consumption of fish. Marine mammals ate an estimated 3.2% of the standing stock of all fish species occurring in the eastern Bering Sea and Aleutian Islands region. Accounting for variations in population size over time of marine mammals in the Bering Sea, the estimated historical consumption of fish by all marine mammals was 0.44 x 106 t to 3.04 x 106 t, which represents 1.0% to 7.3% of the standing stock of all fish species. Commercial groundfish fisheries during the period 1988-90 caught about 7.1% (1.79 x 106 t) of the stock of commercially important groundfish species each year, whereas, at present, marine mammals annually consume an estimated 2.0% (0.45 x 106 t) of the standing stock of those fish species. This is 75% lower than the average commercial catch.

Phillips, E. M., & Harvey, J. T. (2009). A Captive Feeding Study with the Pacific Harbor Seal (*Phoca Vitulina Richardii*): Implications for Scat Analysis. *Marine Mammal Science*, 25(2), 373-391. https://doi.org/10.1111/j.1748-7692.2008.00265.x Abstract Seven prey species (ntotal > 2,700) were fed to seven captive male Pacific harbor seals (Phoca vitulina richardii) in 177 experimental meals to quantify biases associated with scat analysis and current consumption models. Hard parts from an individual meal were recovered in an average of 3.8 ± 1.8 scats (range 1–10; mean ± SD). Overall, $57.7 \pm 33.2\%$ of otoliths and $89.5 \pm 15.5\%$ of squid beaks were recovered. Recovery rates varied, and prey with smaller, fragile otoliths were recovered in lesser quantities than prey with larger, robust otoliths. Recovery rates of all prey except pink salmon were improved by a mean of 31.7% when all diagnostic structures were included in estimates. Estimated recovery of pink salmon was 9.5 times that fed seals based on the all-structure technique. Mean length reduction of recovered otoliths was $20.4 \pm 10.1\%$. Correction factors calculated from average length reduction improved length estimates for all fish species. Grade-specific length correction factors (gLCFs) reduced variability in all of the estimates and significantly improved estimates of prey with highly eroded otoliths including Pacific hake and shortbelly rockfish. The Biomass Reconstruction (BR) model accurately predicted biomass consumption within 4% of known consumption, whereas estimates based on frequency of occurrence were inaccurate.

Pitcher, K. W., Rehberg, M. J., Pendleton, G. W., Raum-Suryan, K. L., Gelatt, T. S., Swain, U. G., & Sigler, M. F. (2005). Ontogeny of Dive Performance in Pup and Juvenile Steller Sea Lions in Alaska. *Canadian Journal of Zoology, 83*(9), 1214-1231. <u>https://doi.org/10.1139/z05-098</u>

Development of competent diving ability is critical to obtaining nutritional independence in marine mammals such as Steller sea lions (SSLs), *Eumetopias jubatus* (Schreber, 1776). We studied diving performance in pup (75) and juvenile (36) SSLs using satellite data recorders. In general, dives by SSLs were brief and shallow. Overall, 82.3% of dives were <2 min long and 86.9% of dives were <10 m deep. Long (>5 min) and deep dives (>100 m) constituted only 2.49% and 0.77%, respectively, of total dives. We used linear mixed-effects models to investigate the relationships between the response variables maximum-daily-depth, time-at-depth, mean-dive-duration, dive rate, and time-at-sea and the predictor variables age, sex, population (eastern and western Alaska populations), time-of-day, and month-ofyear. All response variables except dive rate were positively related (P < 0.05) to age. Dive rate declined (P < 0.001) with age. Time-of-day, month, population, sex, and some first-order interactions were all significantly (P < 0.05) related to some measure of diving performance. With large samples we were able to identify significant relationships between the response variables and the predictor variables, even though the total amount of variation explained by the models was low, because most dives were short and shallow regardless of age, sex, population, time-of-day, or month-of-year. Depths and durations of dives by juvenile animals increased throughout the range of ages studied and were similar to or greater than those previously reported for juveniles and adult females. We expect maximum depths and durations to continue to increase with age until body mass plateaus at about 10 years of age. Therefore, we expect older animals to be more efficient foragers, as they would have greater aerobic dive limits as well as more experience locating and capturing prey.

Rehberg, M. J., Andrews, R. D., Swain, U. G., & Calkins, D. G. (2009). Foraging Behavior of Adult Female Steller Sea Lions During the Breeding Season in Southeast Alaska. *Marine Mammal Science*, 25(3), 588-604. <u>https://doi.org/10.1111/j.1748-7692.2008.00278.x</u>

During the 1990s, the Steller sea lion (*Eumetopias jubatus* Schreber) Western Alaska stock (WS) suffered steep population decline while the Eastern Alaska stock (ES) steadily increased. One bottom-up forcing hypothesis explaining this decline predicted lactating adult female foraging behavior would be different

between stocks. To investigate this effect, we monitored 11 ES females at two breeding rookeries using satellite dive recorders (SDR) during the early breeding seasons of 1992-1993, examined their behavior with respect to prey, physiological limitations, and habitat, and made limited comparisons to observations of WS female behavior reported in the literature. ES females were not operating at the extremes of ability, with most diving within the limits of aerobic metabolism, less than one-quarter of possible foraging time during trips spent submerged and most foraging trips requiring less than one-half the lipid store fasting ability of dependent pups. Thus, females may have some capacity to alter behavior to accommodate future changes in foraging conditions, but the extent of this plasticity is unknown. Because recent work suggests WS recovery is impeded by low natality, future studies should test differences between reproductive and non-reproductive mature females in order to properly assess the contribution of foraging ecology to SSL population dynamics.

Rehberg, M. J., & Burns, J. M. (2008). Differences in Diving and Swimming Behavior of Pup and Juvenile Steller Sea Lions (*Eumetopias jubatus*) in Alaska. *Canadian Journal of Zoology, 86*(6), 539-553. <u>https://doi.org/10.1139/z08-018</u>

Reduced juvenile survival caused by prey depletion is one hypothesis for the decline in the western Alaska population of Steller sea lions (*Eumetopias jubatus* (Schreber, 1776)). To understand the exposure of young sea lions to these depletions, the swimming and diving behavior of pups, juveniles, and subadults was evaluated relative to prey behavior. Pups made shorter and shallower dives (13 m, 0.9 min) than juveniles or subadults, as expected based on physiological limitations, but juveniles and subadults dived to similar depths and durations (29 m, 1.7 min and 38 m, 2.0 min, respectively). Activity patterns of juveniles and subadults reflected diurnal prey migrations, while pup activity did not. Longitudinal trends in pup dive behavior reflected both physiological and behavioral development, while juvenile dive behaviors reflected seasonal changes in prey availability. Results suggest that adult females must continue to provide nutritional support to pups during winter because of the limited diving ability of these young animals. For this reason, the flexible lactation strategies that allow for longer nursing periods during periods of low prey availability and reduce female fecundity may improve juvenile survival.

Richmond, J. P., Burns, J. M., & Rea, L. D. (2004, 0, 2004). Examination of Blood and Muscle Development in the Steller Sea Lion (Eumetopias Jubatus): Implications for Diving and Foraging Ability. Retrieved from <u>https://search.proquest.com/asfa/docview/17300616/406027999193461DPQ/1?accountid=282</u> 58

Increased oxygen stores significantly enhance the amount of time that marine mammals can maintain aerobic metabolism while diving. For a given foraging depth, greater breathhold ability improves foraging efficiency; therefore, understanding the development of oxygen stores in juvenile marine mammals should improve our ability to interpret behavioral patterns in newly weaned individuals. To examine the development of total body oxygen stores in Steller sea lions we monitored changes in blood and muscle oxygen stores, and calculated total body oxygen stores to estimate aerobic dive limit (ADL) in animals from 1 to 29 months of age. Blood oxygen stores were determined by measuring hematocrit (Hct), hemoglobin (Hb), and plasma volume, while muscle oxygen stores were determined by measuring myoglobin concentration and muscle mass. In addition, since blood comprised greater than 50% of the total oxygen stored in sea lions, we hypothesized that erythropoietin (EPO), a hormone that
increases the production of red blood cells in response to tissue hypoxia, may have a significant influence on the development of these stores. EPO was strongly correlated to increases in Hct and Hb throughout development. Juvenile blood oxygen stores increased to values similar to adults by 9 months of age. Muscle oxygen stores and total body oxygen stores reached values similar to adult female by 21 months, but remained lower than those of adult males even at 29 months. While older yearlings and juveniles had mass specific total body oxygen stores that were similar to those of adult females, their estimated ADL remained lower than that of adults, most likely due to juvenile's smaller size and higher metabolic rates. These findings suggest that the physiology of juvenile Steller sea lions is immature and may constrain dive behavior.

Richmond, J. P., Burns, J. M., & Rea, L. D. (2006). Ontogeny of Total Body Oxygen Stores and Aerobic Dive Potential in Steller Sea Lions (*Eumetopias Jubatus*). *Journal of Comparative Physiology B-Biochemical Systemic and Environmental Physiology*, 176(6), 535-545. https://doi.org/10.1007/s00360-006-0076-9

Two key factors influence the diving and hence foraging ability of marine mammals: increased oxygen stores prolong aerobic metabolism and decreased metabolism slows rate of fuel consumption. In young animals, foraging ability may be physiologically limited due to low total body oxygen stores and high mass specific metabolic rates. To examine the development of dive physiology in Steller sea lions, total body oxygen stores were measured in animals from 1 to 29 months of age and used to estimate aerobic dive limit (ADL). Blood oxygen stores were determined by measuring hematocrit, hemoglobin, and plasma volume, while muscle oxygen stores were determined by measuring myoglobin concentration and total muscle mass. Around 2 years of age, juveniles attained mass specific total body oxygen stores that were similar to those of adult females; however, their estimated ADL remained less than that of adults, most likely due to their smaller size and higher mass specific metabolic rates. These findings indicate that juvenile Steller sea lion oxygen stores remain immature for more than a year, and therefore may constrain dive behavior during the transition to nutritional independence.

Riemer, S. D., Wright, B. E., & Brown, R. F. (2011). Food Habits of Steller Sea Lions (*Eumetopias Jubatus*) Off Oregon and Northern California, 1986-2007. *Fishery Bulletin*, *109*(4), 369-381. Retrieved from https://spo.NMFS.noaa.gov/sites/default/files/pdf-content/2011/1094/1094riemer.pdf

We described the diet of the eastern stock of Steller sea lions (*Eumetopias jubatus*) from 1416 scat samples collected from five sites in Oregon and northern California from 1986 through 2007. A total of 47 prey types from 30 families were identified. The most common prey was Pacific hake (Merluccius productus), followed by salmonids (Oncorhynchus spp.), skates (Rajidae), Pacific lamprey (Lampetra tridentata), herrings (Clupeidae), rockfish (Sebastes spp.), and northern anchovy (Engraulis mordax). Steller sea lion diet composition varied seasonally, annually, and spatially. Hake and salmonids were the most commonly identified prey in scats collected during the summer (breeding season), whereas hake and skate were most common in the non-breeding season. Continued research on Steller sea lion diet and foraging behavior in the southern extent of their range is necessary to address issues such as climate change, interaction with competing California sea lions, and predation impacts on valuable or sensitive fish stocks.

Rosen, D. A. S., & Trites, A. W. (2000). Pollock and the Decline of Steller Sea Lions: Testing the Junk-Food Hypothesis. *Canadian Journal of Zoology-Revue Canadienne De Zoologie, 78*(7), 1243-1250. <u>https://doi.org/10.1139/cjz-78-7-1243</u>

The decline of Steller sea lions (*Eumetopias jubatus*) in the Gulf of Alaska and the Aleutian Islands may be the result of them eating too much pollock (a gadid fish) instead of a more balanced and diverse diet containing fattier fishes, such as herring or sandlance. We sought to test this junk-food hypothesis by feeding six captive Steller sea lions (ages 0.9-4.5 years) only pollock or herring. All sea lions gained mass while eating herring. However, eating only pollock for short periods (11-23 d) caused the study animals to lose an average of 6.5% of their initial body mass (0.6 kg/d) over an average feeding trial of 16 d (initial mass averaged 125 kg). The animals were allowed to eat as much pollock as they wanted but did not increase their food intake to compensate for the low energy they were receiving. The sea lions showed progressive metabolic depression while losing body mass on a pollock-only diet. The loss of body mass while eating pollock, and the increased energy loss from digesting the larger quantity of fish needed to compensate for the lower energy loss from digesting the larger quantity of fish needed to compensate for the lower energy content of pollock. Thus, our sea lions would have had to eat 35-80% more pollock than herring to maintain similar net energy intakes. Results from our captivefeeding studies are consistent with the junk-food hypothesis and have serious implications for Steller sea lions that have been eating primarily pollock in the Gulf of Alaska and the Aleutian Islands.

Rosen, D. A. S., & Trites, A. W. (2004). Satiation and Compensation for Short-Term Changes in Food Quality and Availability in Young Steller Sea Lions (*Eumetopias Jubatus*). *Canadian Journal of Zoology*, 82(7), 1061-1069. <u>https://doi.org/10.1139/z04-082</u>

Foraging theory predicts that animals should proportionately increase their food intake to compensate for reduced food energy content and (or) prey availability. However, the theoretical intake levels will, at some point, exceed the digestive capacity of the predator. We tested the ability of Steller sea lions, *Eumetopias jubatus* (Schreber, 1776), to compensate for short-term changes in prey energy density and availability, and quantified the maximum amount of food a young sea lion could consume. Five 1-2-yearold captive Steller sea lions were offered either herring (high energy) or capelin (low energy) each day or every second day. When prey were available on a daily basis, the sea lions compensated for differences in the energy content of herring and capelin by consuming sufficient quantities of each (8.3 vs. 14.0 kg.d(-1), respectively) to maintain equivalent gross energy intakes. When herring was available only on alternate days, the sea lions increased their consumption by 52% to 11.5 kg.d(-1), which was not sufficient to maintain an average gross intake equal to that maintained when herring was available every day. When capelin was available only on alternate days, some animals increased their intake for a few days, but average intake (15.2 kg.d(-1)) was far below levels observed during daily feeding. Generally, the sea lions appeared to reach their digestive limit at a level equivalent to 14%-16% of their body mass. Our findings suggest that Steller sea lions can alter their food intake in response to shortterm changes in prey quality or availability, but that these variables can quickly combine to necessitate food intake levels that exceed the physiological digestive capacities of young animals.

Rosen, D. A. S., & Trites, A. W. (2005). Examining the Potential for Nutritional Stress in Young Steller Sea Lions: Physiological Effects of Prey Composition. *Journal of Comparative Physiology B-Biochemical Systemic and Environmental Physiology*, 175(4), 265-273. https://doi.org/10.1007/s00360-005-0481-5 The effects of high- and low-lipid prey on the body mass, body condition, and metabolic rates of young captive Steller sea lions (*Eumetopias jubatus*) were examined to better understand how changes in prey composition might impact the physiology and health of wild sea lions and contribute to their population decline. Results of three feeding experiments suggest that prey lipid content did not significantly affect body mass or relative body condition (lipid mass as a percent of total mass) when sea lions could consume sufficient prey to meet their energy needs. However, when energy intake was insufficient to meet daily requirements, sea lions lost more lipid mass (9.16 +/- 1.80 kg +/- SE) consuming low-lipid prey compared with eating high-lipid prey (6.52 +/- 1.65 kg). Similarly, the sea lions lost 2.7 +/- 0.9 kg of lipid mass while consuming oil-supplemented pollock at maintenance energy levels but gained 5.2 +/-2.7 kg lipid mass while consuming identical energetic levels of herring. Contrary to expectations, there was a 9.7 +/- 1.8 % increase in metabolism during mass loss on submaintenance diets. Relative body condition decreased only 3.7 +/- 3.8% during periods of imposed nutritional stress, despite a 10.4 +/-4.8 % decrease in body mass. These findings raise questions regarding the efficacy of measures of relative body condition to detect such changes in nutritional status among wild animals. The results of these three experiments suggest that prey composition can have additional effects on sea lion energy stores beyond the direct effects of insufficient energy intake.

Scherer, R. D., Doll, A. C., Rea, L. D., Christ, A. M., Stricker, C. A., Witteveen, B., . . . Wunder, M. B. (2015). Stable Isotope Values in Pup Vibrissae Reveal Geographic Variation in Diets of Gestating Steller Sea Lions *Eumetopias Jubatus*. *Marine Ecology Progress Series*, 527, 261-274. https://doi.org/10.3354/meps11255

Multiple factors, including limitation in food resources, have been proposed as possible causes for the lack of recovery of the endangered western segment of the Steller sea lion population in the United States. Because maternal body condition has important consequences on fetal development and neonatal survival, the diets of pregnant females may be particularly important in regulating population sizes. We used the stable carbon and nitrogen isotope values of vibrissae from Steller sea lion pups as an indirect indicator of maternal diets during gestation. Combining these data with isotope data from potential prey species in a Bayesian mixing model, we generated proportional estimates of dietary consumption for key prey. Our analysis indicated that females in the most westerly metapopulations relied heavily on Atka mackerel and squid, whereas females inhabiting the Gulf of Alaska region had a fairly mixed diet, and the metapopulation of Southeast Alaska showed a strong reliance on forage fish. These results are similar to previous data from scat collections; however, they indicate a possible underrepresentation of soft-bodied prey (squid) or prey with fragile skeletons (forage fish) from analyses of data from scats. This study supports the utility of stable isotope modeling in predicting diet composition in gestating adult female Steller sea lions during winter, using pup vibrissae.

Sigler, M. F., Gende, S. M., & Csepp, D. J. (2017). Association of Foraging Steller Sea Lions with Persistent Prey Hot Spots in Southeast Alaska. *Marine Ecology Progress Series, 571*, 233-243. <u>https://doi.org/10.3354/meps12145</u>

Understanding how air-breathing marine vertebrates find and utilize prey provides insight into their foraging mechanisms and ultimately their population productivity and trends. Utilization depends on their ability to locate areas where productive foraging conditions exist. We quantified the abundance of forage fish in southeast Alaska during acoustic surveys between October and April to improve our

understanding of Steller sea lion *Eumetopias jubatus* foraging behavior. Energy densities (millions kJ km-2) of forage fish were orders of magnitude greater between November and February due to the presence of large schools of Pacific herring Clupea pallasi. Herring schools were highly aggregated, although the location of these aggregations shifted southward from November to April. Thus, a productive foraging area in one month did not necessarily equate to a productive area in the next month. However, by surveying on successive days and weeks, we found that herring aggregations persisted at shorter time scales. When the study area was partitioned into 1×1 km blocks, the day-to-day abundance of prey within a block was highly correlated with prey abundance the following day (correlation coefficient, r = 0.75, p < 0.001) and with prey abundance for the following week (r = 0.55, p < 0.001). More importantly, the persistence of these prey hot spots was an important characteristic in determining whether foraging sea lions utilized them. The odds of observing a foraging sea lion were about 1 in 3 for locations where prey hot spots were persistent. The persistence of these hot spots allowed predators to predict their locations and concentrate search efforts accordingly.

Sigler, M. F., Tollit, D. J., Vollenweider, J. J., Thedinga, J. F., Csepp, D. J., Womble, J. N., . . . Trites, A. W. (2009). Steller Sea Lion Foraging Response to Seasonal Changes in Prey Availability. *Marine Ecology Progress Series, 388*, 243-261. <u>https://doi.org/10.3354/meps08144</u>

We hypothesized that: (1) Steller sea lion *Eumetopias jubatus* diet choice is a function of prey availability, (2) sea lions move to take advantage of times and locations of seasonal prey concentrations and (3) the number present depends on the amount of prey available (numerical response). Over 3 yr, typically on a quarterly basis, in Frederick Sound, SE Alaska, multiple measurements were taken of Steller sea lion abundance (aerial surveys), diet (scats), dive behavior (satellite telemetry) and prey availability and caloric density (nearshore, pelagic and demersal fish surveys). We found that Steller sea lions shifted diet composition in response to changes in prey availability of pollock Theragra chalcogramma, hake Merluccius productus, herring Clupea pallasi and salmon Oncorhynchus spp. They selected intermediate-sized fish and avoided small (<10 cm) and large (>60 cm) fish, and moved between areas as prey became available seasonally. The number of sea lions present depended on the amount of prey available; a standing biomass of 500 to 1700 t of prey in a nonbreeding area such as Frederick Sound, depending on species composition, can attract and sustain about 500 sea lions. Pollock was more frequent in sea lion diet in inside waters of SE Alaska—including Frederick Sound, Stephens Passage and Lynn Canal—than anywhere else in Alaska and contributed ~1/3 of the dietary energy in Frederick Sound. This finding implies that a diet with substantial year-round contributions from less nutritious, but abundant prey such as pollock can form part of a healthy diet as long as more nutritious prey such as herring, salmon or eulachon Thaleichthys pacificus also are consumed. Our study supports the conclusion that the Steller sea lion is an opportunistic marine predator with a flexible foraging strategy that selects abundant, accessible prey and shifts among seasonally available species.

Sigler, M. F., Womble, J. N., & Vollenweider, J. J. (2004). Availability to Steller Sea Lions (*Eumetopias Jubatus*) of a Seasonal Prey Resource: A Prespawning Aggregation of Eulachon (*Thaleichthys Pacificus*). Canadian Journal of Fisheries and Aquatic Sciences, 61(8), 1475-1484. https://doi.org/10.1139/f04-086

The availability of seasonally abundant energy-rich prey can be a significant factor for the survival and reproductive success of predator populations. Large numbers of Steller sea lions (*Eumetopias jubatus*) were attracted to a prespawning aggregation of eulachon (Thaleichthys pacificus) in Berners Bay in

southeast Alaska during April–May in 2002 and 2003. Sea lion abundance increased as eulachon gathered in Berners Bay, peaked as eulachon abundance peaked, and decreased as the eulachon moved up-river. As sea lion abundance increased in Berners Bay, sea lion abundance decreased at Benjamin Island, a sea lion haulout located 22 km away. The eulachon provided an abundant, energy-rich, predictable prey source for the Steller sea lions: (i) eulachon energy density was 9.70 ± 0.24 kJ·g–1, much higher than that of any forage species reported in the North Pacific Ocean except northern lampfish (Stenobrachius leucopsarus); (ii) a large surplus of prey was available per sea lion while the eulachon aggregation was present; and (iii) the spawning run usually begins between late April and early May. The eulachon pulse may be critical to Steller sea lions during a period of high energetic demands.

Sinclair, E., Johnson, D. S., Zeppelin, T. K., & Gelatt, T. S. (2013). Decadal Variation in the Diet of Western Stock Steller Sea Lions (Eumetopias Jubatus). National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-248. Retrieved from https://repository.library.noaa.gov/view/noaa/4402

Steller sea lions (*Eumetopias jubatus*) are listed as an endangered species in western Alaska due to a precipitous decline that occurred in the 1980s and 1990s. In 2000, cascading declines slowed or ceased and clusters of rookeries between the eastern Aleutian Islands and eastern Gulf of Alaska began to show signs of population growth. Reasons for the decline and for a range-wide failure to recover are unresolved, but reduction in the availability of prey due to commercial fishing or environmental perturbation has been hypothesized. Discerning the diet and patterns of prey use by Steller sea lions (SSL) is fundamental to isolating the mechanisms driving population health. Here we evaluate the frequency of occurrence (FO) of prey species in 3,412 scats of adult female and juvenile SSL collected during 1999-2009, across the range of the U. S. Western Stock. Thirteen primary prey are identified based on their occurrence in \geq 5% of total scats. We reduce the dimension of the diet profile of the 13 primary prey to two categorical groups through principal component analysis (PC). A hierarchical cluster analysis of PC scores on collection site locations describes four geographic regions of SSL diet (with Amak Island as an outlier) nearly identical to those identified in a previously published 1990-1998 (n = 3,762) dataset. Geographic regions of diet continue to correspond with regional population trends of SSL.

Sinclair, E. H., Walker, W. A., & Gearin, P. J. (2019). The Diet of Free-Ranging Male Steller Sea Lions (*Eumetopias Jubatus*) in the Eastern Bering Sea: A Retrospective Analysis Based on Stomach Contents of an Endangered Pinniped. *Canadian Journal of Zoology*, 97(3), 195-202. <u>https://doi.org/10.1139/cjz-2018-0057</u>

This study illuminates historical diet and foraging locations of endangered western U.S. stock Steller sea lions (*Eumetopias jubatus* (Schreber, 1776)). Prey were identified from stomachs of 22 males collected in the eastern Bering Sea from the ice edge in March 1985 and nearshore St. Paul Island in September-October 1985 and 1986. Percent frequency of occurrence (PFO) and percent number (PN) were highest for walleye pollock (Gadus chalcogrammus Pallas, 1814; PFO 69%, PN 15%, mean length 17 cm), Pacific herring (Clupea pallasii Valenciennes in Cuvier and Valenciennes, 1847; PFO 62%, PN 16%, mean length 26 cm), shorthorn sculpin (Myoxocephalus scorpius (Linnaeus, 1758); PFO 54%, PN 30%), and Pacific giant octopus (Enteroctopus dofleini (Wulker, 1910); PFO 39%, PN 8%, mean weight 31 kg) in spring, and northern rock sole (Lepidopsetta polyxystra Orr and Matarese, 2000; PFO 78%, PN 47%, mean length 35 cm), Pacific cod (Gadus macrocephalus Tilesius, 1810; PFO 56%, PN 12%, mean length 62 cm), walleye

pollock (PFO 44%, PN 7%, mean length 49 cm), and red Irish lord (Hemilepidotus hemilepidotus (Tilesius, 1811); PFO 11%, PN 9%) in fall. Species of Cryptacanthidae, Liparidae, and Zoarcidae were highly represented and exclusive to spring collections. Predictable seasonal concentrations and movements of mature prey along frontal boundaries of the continental shelf and ice edge may be critical to male Steller sea lion fitness during the non-breeding season.

Sinclair, E. H., & Zeppelin, T. K. (2002). Seasonal and Spatial Differences in Diet in the Western Stock of Steller Sea Lions (*Eumetopias Jubatus*). *Journal of Mammalogy, 83*(4), 973-990. https://doi.org/10.1644/1545-1542(2002)083<0973:SASDID>2.0.CO;2

We identified prey remains from 3,762 scats (feces) of Steller sea lions (*Eumetopias jubatus*). Scats were collected from 1990–1998 on island sites across most of the range of the United States western stock of the species. Walleye pollock (Theragra chalcogramma) and Atka mackerel (Pleurogrammus monopterygius) were the 2 most common species of prey, followed by salmonids (Oncorhynchus) and Pacific cod (Gadus macrocephalus). An additional 16 species of fish and unidentified cephalopods were considered primary in the diet, either because they occurred in >5% of scats collected across the range in winter and summer or because they consistently occurred among the top 3 prey items in particular islands or island groups. Capelin (Mallotus villosus) occurred at very low frequencies despite their predominance in the diet of Steller sea lions before the 1980s. Regions of diet similarity suggest areaspecific foraging strategies, with strong seasonal patterns in consumption of most species of prey. Patterns in prey consumption and characteristics of prey indicate that Steller sea lions target prey that are densely schooled in spawning or migratory aggregations at the continental shelf or along oceanographic boundary zones. We suggest that regional diet patterns among the western stock reflect regional foraging strategies of females learned at islands near the natal rookery site.

Suzuki, I., Sato, K., Fahlman, A., Naito, Y., Miyazaki, N., & Trites, A. W. (2014). Drag, but Not Buoyancy, Affects Swim Speed in Captive Steller Sea Lions. *Biology Open*, *3*(5), 379-386. <u>https://doi.org/10.1242/bio.20146130</u>

Swimming at an optimal speed is critical for breath-hold divers seeking to maximize the time they can spend foraging underwater. Theoretical studies have predicted that the optimal swim speed for an animal while transiting to and from depth is independent of buoyancy, but is dependent on drag and metabolic rate. However, this prediction has never been experimentally tested. Our study assessed the effects of buoyancy and drag on the swim speed of three captive Steller sea lions (Eumetopias jubatus) that made 186 dives. Our study animals were trained to dive to feed at fixed depths (10-50 m) under artificially controlled buoyancy and drag conditions. Buoyancy and drag were manipulated using a pair of polyvinyl chloride (PVC) tubes attached to harnesses worn by the sea lions, and buoyancy conditions were designed to fall within the natural range of wild animals (similar to 12-26% subcutaneous fat). Drag conditions were changed with and without the PVC tubes, and swim speeds were recorded and compared during descent and ascent phases using an accelerometer attached to the harnesses. Generalized linear mixed-effect models with the animal as the random variable and five explanatory variables (body mass, buoyancy, dive depth, dive phase, and drag) showed that swim speed was best predicted by two variables, drag and dive phase (AIC = -139). Consistent with a previous theoretical prediction, the results of our study suggest that the optimal swim speed of Steller sea lions is a function of drag, and is independent of dive depth and buoyancy.

Thomas, G. L., & Thorne, R. E. (2001). Night-Time Predation by Steller Sea Lions. *Nature, 411*(6841), 1013. <u>https://doi.org/10.1038/35082624</u>

Examines the foraging behavior of Steller sea lions at Prince Williams Sound in Alaska. Primary cause of the decline in Steller sea lion populations; Instrument used in surveying the sea lions' foraging behavior; Potential explanation on the sea lions' foraging behavior.

Thomton, J. D., Mellish, J. A. E., Hennen, D. R., & Horning, M. (2008). Juvenile Steller Sea Lion Dive Behavior Following Temporary Captivity. *Endangered Species Research*, 4(1-2), 195-203. <u>https://doi.org/10.3354/esr00062</u>

Wild-caught juvenile Steller sea lions <I>*Eumetopias jubatus*/I> (n = 21) were maintained in temporary captivity for up to 12 wk to investigate health, disease, nutrition and behavior. We assessed the effects of captivity on post-release dive behavior and movement of each animal using externally mounted satellite data recorders. Based on a 74.1 \pm 9.6 (SE) d tag transmission period, the mean dive depth (26.2 \pm 4.0 [SE] m), dive duration (1.4 \pm 0.1 [SE] min), dive rate (10.1 \pm 0.5 [SE] dives h¹), trip duration (10.8 \pm 0.7 [SE] h), haul-out duration (11.3 \pm 0.9 [SE] h) and time wet (46.9 \pm 2.6 [SE]%) were within the range of previously published values. Movement (190.0 \pm 31.9 [SE] km) between haul-outs and rookeries during the tracking period was also typical of juvenile Steller sea lions in Alaska. This study indicates that temporary captivity has little or no detrimental effect on dive performance or movement in the tracking period following release.

Tollit, D., Fritz, L., Joy, R., Miller, K., Schulze, A., Thomason, J., . . . Gelatt, T. (2017). Diet of Endangered Steller Sea Lions (*Eumetopias Jubatus*) in the Aleutian Islands: New Insights from DNA Detections and Bioenergetic Reconstructions. *Canadian Journal of Zoology*, 95(11), 853-868. <u>https://doi.org/10.1139/cjz-2016-0253</u>

The endangered western stock of Steller sea lion (Eumetopias jubatus (Schreber, 1776)) still declines in the western Aleutian Islands and accurate diet information is vital to test leading hypotheses. We undertook the first bioenergetic diet reconstruction using both molecular and hard part prey identifications from >600 scats collected in March–April 2008 and 2012. Atka mackerel (Pleurogrammus monopterygius (Pallas, 1810)) remained a primary prey (17%–27% by energy), but large (mean 60 cm) Pacific cod (Gadus macrocephalus Tilesius, 1810) also emerged as important prey (20%-24%) in a more diverse diet than previously reported, with Cottidae and smooth lumpsucker (Aptocyclus ventricosus (Pallas, 1769)) also contributing 210%. DNA detections highlighted a potentially important and previously underestimated prey, giant Pacific octopus (Enteroctopus dofleini (Wülker, 1910) (diet contribution 2%–15%, dependent on prey size assumptions). Although 504 unique DNA identifications resulted in significant increases for cephalopods, Pacific cod, and smooth lumpsucker, hard part alone species rankings were similar to composite ones and bioenergetic species rankings similar to occurrence-based ones. Retention or regurgitation of large cephalopod beaks, the removal of large cod heads, and skeletal fragility of lumpsuckers may explain these differences. DNA identifications provide valuable comparative and complementary prey occurrence data for pinnipeds, but composite diet estimates are optimal.

Tollit, D. J., Heaslip, S. G., Barrick, R. L., & Trites, A. W. (2007). Impact of Diet-Index Selection and the Digestion of Prey Hard Remains on Determining the Diet of the Steller Sea Lion (*Eumetopias Jubatus*). *Canadian Journal of Zoology, 85*(1), 1-15. <u>https://doi.org/10.1139/z06-174</u>

Nine prey species (n = 7431) were fed to four captive female Steller sea lions (Eumetopias jubatus (Schreber, 1776)) in 11 feeding trials over 75 days to investigate the effectiveness of different methods used to determine diet from prey hard remains. Trials aimed to replicate short (1-2 days) and long feeding bouts, and consisted of single species and mixed daily diets. Overall, 25.2% ± 22.2% (mean ± SD, range 0%–83%) otoliths were recovered, but recovery rates varied by species (ANOVA, P = 0.01) and were linearly related to otolith robustness (R2 = 0.88). Squid beaks were recovered at higher frequencies (mean 96%) than the otoliths of all species. Enumerating both non-otolith skeletal structures and otoliths (together termed bones) increased species recovery rates by twofold, on average (P < 0.001), with increases up to 2.5 times for Pacific herring (Clupea pallasii Valenciennes in Cuvier and Valenciennes, 1847) and 3–4 times for salmonids. Using bones reduced interspecific differences (P = 0.08), but recovery varied among sea lions. Bones were distributed over more scats per meal (mean 2.9 scats, range 0-5) than otoliths (mean 1.9 scats, range 0-4). In three different 15-day mixed diet trials, biomass reconstruction (BR) indices performed better than frequency of occurrence indices in predicting diet fed. Applying our experimentally derived numerical correction factors (to account for species differences in complete prey digestion) further improved BR estimates, resulting in all 12 unweighted comparisons within 5% (for otoliths) and 12% (for bones) of the actual diet fed.

Tollit, D. J., Heaslip, S. G., & Trites, A. W. (2004). Sizes of Walleye Pollock (Theragra Chalcogramma) Consumed by the Eastern Stock of Steller Sea Lions (*Eumetopias Jubatus*) in Southeast Alaska from 1994 to 1999. *Fishery Bulletin, 102*(3), 522-532. Retrieved from https://spo.NMFS.noaa.gov/sites/default/files/pdf-content/2004/1023/tollit2.pdf

Lengths of walleye pollock (Theragra chalcogramma) consumed by Steller sea lions (Eumetopias jubatus) were estimated by using allometric regressions applied to seven diagnostic cranial structures recovered from 531 seats collected in Southeast Alaska between 1994 and 1999. Only elements in good and fair condition were selected. Selected structural measurements were corrected for loss of size due to erosion by using experimentally derived condition-specific digestion correction factors. Correcting for digestion increased the estimated length of fish consumed by 23%, and the average mass of fish consumed by 88%. Mean corrected fork length (FL) of pollock consumed was 42.4 +/- 11.6 cm (range = 10.0 - 78.1 cm, n = 909). Adult pollock (FL > 45.0 cm) occurred more frequently in seats collected from rookeries along the open ocean coastline of Southeast Alaska during June and July (74% adults, mean FL = 48.4 cm) than they did in seats from haulouts located in inside waters between October and May (51% adults, mean FL = 38.4 cm). Overall, the contribution of juvenile pollock (5:20 cm) to the sea lion diet was insignificant; whereas adults contributed 44% to the diet by number and 74% by mass. On average, larger pollock were eaten in summer at rookeries throughout Southeast Alaska than at rookeries in the Gulf of Alaska and the Bering Sea. Overall it appears that Steller sea lions are capable of consuming a wide size range of pollock, and the bulk of fish fall between 20 and 60 cm. The use of cranial hard parts other than otoliths and the application of digestion correction factors are fundamental to correctly estimating the sizes of prey consumed by sea lions and determining the extent that these sizes overlap with the sizes of pollock caught by commercial fisheries.

Tollit, D. J., Wong, M., Winship, A. J., Rosen, D. A. S., & Trites, A. W. (2003). Quantifying Errors Associated with Using Prey Skeletal Structures from Fecal Samples to Determine the Diet of Steller's Sea Lion (*Eumetopias Jubatus*). *Marine Mammal Science*, 19(4), 724-744. https://doi.org/10.1111/j.1748-7692.2003.tb01127.x

We examined the digestion and passage times of bones and other hard parts from pollock, herring, salmon, and sandlance recovered from two juvenile captive Steller's sea lions (*Eumetopias jubatus*) subjected to varying activity levels. Key bones that could be identified to species were distributed over an average of 3.2 scats (range 1–6) following a single meal, with pollock remains occurring in significantly more scats than other species. Relying on otoliths alone to determine the presence of prey resulted in significantly fewer prey being identified than if other structures were also used (such as vertebrae, jaw bones, and teeth), particularly for salmon. Using either technique, there were significant differences in the likelihood that bones would be recovered from the series of scats produced following a meal, with pollock recovery exceeding herring (by three-fold) and sandlance (by eight-fold). Differences between species were reduced when recovery was calculated on a per scat basis rather than over multiple scats. Active animals passed greater numbers of bones, but the overall effect on prey recovery estimates was not significant. Defecation times of prey structures from a meal were variable and ranged from an initial 2–56 h to a final 28–148 h. The time interval to pass 95% of recovered structutes varied by a factor of two among prey species, and was highest for pollock due to retention beyond 65 h.

Tollit, D. J., Wong, M. A., & Trites, A. W. (2015). Diet Composition of Steller Sea Lions (*Eumetopias Jubatus*) in Frederick Sound, Southeast Alaska: A Comparison of Quantification Methods Using Scats to Describe Temporal and Spatial Variabilities. *Canadian Journal of Zoology*, 93(5), 361-376. <u>https://doi.org/10.1139/cjz-2014-0292</u>

We compared eight dietary indices used to describe the diet of Steller sea lions (Eumetopias jubatus (Schreber, 1776)) from 2001 to 2004 in Frederick Sound, southeast Alaska. Remains (n = 9666 items) from 59+ species categories were identified from 1684 fecal samples (scats) from 14 collection periods. The most frequently occurring prey were walleye pollock (Theragra chalcogramma (Pallas, 1814) = Gadus chalcogrammus Pallas, 1814; 95%), Pacific herring (Clupea pallasii Valenciennes in Cuvier and Valenciennes, 1847; 30%), Pacifichake (Merluccius productus (Ayres, 1855); 29%), and arrowtooth flounder (Atheresthes stomias (Jordan and Gilbert, 1880)= Reinhardtius stomias (Jordan and Gilbert, 1880); 21%). These species, along with Pacific salmon (genus Oncorhynchus Suckley, 1861) and skate (genus Raja L., 1758), accounted for 80%–90% of the reconstructed biomass and energy contribution, with pollock contributing 37%–60%. Overall, 80% offish were 14–42 cm long and mainly pelagic, though 40% of scats contained benthic-associated prey. Steller sea lions switched from adult pollock to strong cohorts of juvenile pollock, and took advantage of spawning concentrations of salmon in autumn and herring in late spring and summer, as well as a climate-driven increase in hake availability. Observed temporal and site differences in diet confirm the need for robust long-term scat sampling protocols. All major indices similarly tracked key temporal changes, despite differences in occurrence and biomassenergy-based diet estimates linked to prey size and energy-density effects and the application of correction factors.

Trites, A. W., & Calkins, D. G. (2008). Diets of Mature Male and Female Steller Sea Lions (*Eumetopias Jubatus*) Differ and Cannot Be Used as Proxies for Each Other. *Aquatic Mammals, 34*(1), 25. https://doi.org/10.1578/AM.34.1.2008.25

Disturbance of otariid breeding sites (rookeries) to determine diet from fecal remains (scats) could be eliminated if the diets of males using adjoining bachelor haulouts could be used as a proxy for diets of breeding females. We collected scats from sexually mature Steller sea lions (*Eumetopias jubatus*) at one male resting site (haulout) and three female dominated breeding sites (rookeries) at Forrester Island, southeast Alaska (June and July, 1994 to 1999) to test whether the diets of bachelor bulls differed from that of breeding females. Female diets were fairly evenly distributed between gadids, salmon, and small oily fishes (forage fish) and contained lesser amounts of rockfish, flatfish, cephalopods, and other fishes. The female diet did not differ significantly between the three rookeries, but it did differ significantly from that of males. Males consumed significantly fewer salmon and more pollock, flatfish, and rockfish compared to females. The males also consumed larger pollock compared to females. These dietary differences may reflect a sex-specific difference in foraging areas or differences in hunting abilities related to the disparity in physical sizes of males and females. The similarity of the female diets between rookeries suggests that female diets can be determined from samples collected at a single site within a rookery complex. Unfortunately, summer diets of breeding females cannot be ascertained from hard parts contained in the scats of mature male Steller sea lions.

Trites, A. W., Calkins, D. G., & Winship, A. J. (2007). Diets of Steller Sea Lions (*Eumetopias Jubatus*) in Southeast Alaska, 1993–1999. *Fishery Bulletin, 105*(2), 234-248. Retrieved from http://aquaticcommons.org/8894/

The diet of Steller sea lions (*Eumetopias jubatus*) was determined from 1494 scats (feces) collected at breeding (rookeries) and nonbreeding (haulout) sites in Southeast Alaska from 1993 to 1999. The most common prey of 61 species identified were walleye pollock (Theragra chalcogramma), Pacific herring (Clupea pallasii), Pacific sand lance (Ammodytes hexapterus), Pacific salmon (Salmonidae), arrowtooth flounder (Atheresthes stomias), rockfish (Sebastes spp.), skates (Rajidae), and cephalopods (squid and octopus). Steller sea lion diets at the three Southeast Alaska rookeries differed significantly from one another. The sea lions consumed the most diverse range of prey categories during summer, and the least diverse during fall. Diet was more diverse in Southeast Alaska during the 1990s than in any other region of Alaska (Gulf of Alaska and Aleutian Islands). Dietary differences between increasing and declining populations of Steller sea lions in Alaska correlate with rates of population change, and add credence to the view that diet may have played a role in the decline of sea lions in the Gulf of Alaska and Aleutian Islands.

Waite, J. N., & Burkanov, V. N. (2006). Steller Sea Lion Feeding Habits in the Russian Far East, 2000-2003.
). In Sea Lions of the World. A.W. Trites, S.K. Atkinson, D.P. DeMaster, L.W. Fritz, T.S. Gelatt, L.D. Rea, and K.M. Wynne (Eds.) Sea Grant Alaska. <u>https://doi.org/10.4027/slw.2006.16</u>

During the breeding seasons of 2000-2003 we collected 1,724 scats from seven rookeries and eighteen haul-outs on the Kamchatka Peninsula and in the Kuril Islands, Okhotsk Sea, and Commander Islands to analyze the diet of Steller sea lions (*Eumetopias jubatus*) in the Russian Far-East. The most frequently encountered prey items in all scats combined were Atka mackerel (Pleurogrammus monopterygius), walleye pollock (Theragra chalcogramma), salmon (Oncorhynchus sp.), sculpins (Cottidae), cephalopods,

Pacific sand lance (Ammodytes hexapterus), Pacific herring (Clupea pallasit), Northern smoothtongue (Leuroglossus stilbius), snailfish (Liparidae), and Pacific cod (Gadus macrocephalus). Spatial differences were analyzed by comparing frequency of occurrence (FO) values on a site-by-site basis for each year and all years combined. Breeding-season collection sites were grouped into seven geographic regions based on FO similarities using cluster analysis. Diet diversity was calculated for each of these geographic regions. No significant relationship was found between diet diversity and population trend (P= 0.886). Significant differences in diet composition were found between geographic regions (P < 0.001 for all regions). Significant seasonal differences were also detected at two haul-outs on the Kamchatka Peninsula from which an additional 93 scats were collected during the fall molt (P < 0.001 for both locations).

Waite, J. N., Burkanov, V. N., & Andrews, R. D. (2010, Jul). 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 2010 Annual Meeting. 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 intraand 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. <u>https://doi.org/10.1139/z11-117</u>

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, 416-417*, 41-54. https://doi.org/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 δ 15N and δ 13C 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 δ 15N and δ 13C values between SSL and NFS. Adult female SSL were significantly enriched in both δ 15N and δ 13C 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 δ 13C 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.

Ware, C., Trites, A. W., Rosen, D. A. S., & Potvin, J. (2016). Averaged Propulsive Body Acceleration (Apba)
 Can Be Calculated from Biologging Tags That Incorporate Gyroscopes and Accelerometers to
 Estimate Swimming Speed, Hydrodynamic Drag and Energy Expenditure for Steller Sea Lions.
 PLoS ONE, 11(6) <u>https://doi.org/10.1371/journal.pone.0157326</u>

Forces due to propulsion should approximate forces due to hydrodynamic drag for animals horizontally swimming at a constant speed with negligible buoyancy forces. Propulsive forces should also correlate with energy expenditures associated with locomotion-an important cost of foraging. As such, biologging tags containing accelerometers are being used to generate proxies for animal energy expenditures despite being unable to distinguish rotational movements from linear movements. However, recent miniaturizations of gyroscopes offer the possibility of resolving this shortcoming and obtaining better estimates of body accelerations of swimming animals. We derived accelerations using gyroscope data for swimming Steller sea lions (*Eumetopias jubatus*), and determined how well the measured accelerations correlated with actual swimming speeds and with theoretical drag. We also compared dive

averaged dynamic body acceleration estimates that incorporate gyroscope data, with the widely used Overall Dynamic Body Acceleration (ODBA) metric, which does not use gyroscope data. Four Steller sea lions equipped with biologging tags were trained to swim alongside a boat cruising at steady speeds in the range of 4 to 10 kph. At each speed, and for each dive, we computed a measure called Gyro-Informed Dynamic Acceleration (GIDA) using a method incorporating gyroscope data with accelerometer data. We derived a new metric-Averaged Propulsive Body Acceleration (APBA), which is the average gain in speed per flipper stroke divided by mean stroke cycle duration. Our results show that the gyro-based measure (APBA) is a better predictor of speed than ODBA. We also found that APBA can estimate average thrust production during a single stroke-glide cycle, and can be used to estimate energy expended during swimming. The gyroscope-derived methods we describe should be generally applicable in swimming animals where propulsive accelerations can be clearly identified in the signaland they should also prove useful for dead-reckoning and improving estimates of energy expenditures from locomotion.

Winship, A. J., & Trites, A. W. (2003). Prey Consumption of Steller Sea Lions (*Eumetopias Jubatus*) Off Alaska: How Much Prey Do They Require? *Fishery Bulletin, 101*(1), 147-167. Retrieved from <u>https://spo.NMFS.noaa.gov/content/prey-consumption-steller-sea-lions-eumetopias-jubatusalaska-how-much-prey-do-they-require</u>

The effects of seasonal and regional differences in diet composition on the food requirements of Steller sea lions (*Eumetopias jubatus*) were estimated by using a bioenergetic model. The model considered differences in the energy density of the prey, and differences in digestive efficiency and the heat increment of feeding of different diets. The model predicted that Steller sea lions in southeast Alaska required 45–60% more food per day in early spring (March) than after the breeding season in late summer (August) because of seasonal changes in the energy density of the diets (along with seasonal changes in energy requirements). The southeast Alaska population, at 23,000 (±1660 SD) animals (all ages), consumed an estimated 140,000 (±27,800) t of prey in 1998. In contrast, we estimated that the 51,000 (±3680) animals making up the western Alaska population in the Gulf of Alaska and Aleutian Islands consumed just over twice this amount (303,000 [±57,500] t). In terms of biomass removed in 1998 from Alaskan waters, we estimated that Steller sea lions accounted for about 5% of the natural mortality of gadids (pollock and cod) and up to 75% of the natural mortality of hexagrammids (adult Atka mackerel). These two groups of species were consumed in higher amounts than any other. The predicted average daily food requirement per individual ranged from 16 (± 2.8) to 20 (± 3.6) kg (all ages combined). Per capita food requirements differed by as much as 24% between regions of Alaska depending on the relative amounts of low-energy-density prey (e.g. gadids) versus high-energy-density prey (e.g. forage fish and salmon) consumed. Estimated requirements were highest in regions where Steller sea lions consumed higher proportions of low-energy-density prey and experienced the highest rates of population decline.

Winship, A. J., Trites, A. W., & Rosen, D. A. S. (2002). A Bioenergetic Model for Estimating the Food Requirements of Steller Sea Lions *Eumetopias Jubatus* in Alaska, USA. *Marine Ecology Progress Series, 229*, 291-312. <u>https://doi.org/10.3354/meps229291</u>

A generalized bioenergetic model was used to estimate the food requirements of Steller sea lions *Eumetopias jubatus* in Alaska, USA. Inputs included age- and sex-specific energy requirements by date, population size and composition, and diet composition and energy content. Error in model predictions

was calculated using uncertainty in parameter values and Monte Carlo simulation methods. Our model suggests that energy requirements of individuals were generally lowest in the summer breeding season (June to August) and highest in the winter (December to February) and spring (March to May) mainly due to changes in activity budgets. Predicted relative daily food requirements were highest for young animals (12 +/- 3% SD and 13 +/- 3% of body mass for 1 yr old males and females respectively) and decreased with age (5 +/- 1% and 6 +/- 1% of body mass for 14 yr old males and 22 yr old females respectively), The mean daily food requirement of pregnant females predicted by the model was only marginally greater than the predicted mean daily food requirement of non-pregnant females of the same age. However, the model suggested that the mean daily food requirement of females nursing pups was about 70% greater than females of the same age without pups. Of the 3 sets of model parameters (diet, population, and bioenergetic), uncertainty in diet and bioenergetic parameters resulted in the largest variation in model predictions. The model provides a quantitative estimate of the Steller sea lion population's food requirements and also suggests directions for future research.

Womble, J. N., & Sigler, M. F. (2006). Seasonal Availability of Abundant, Energy-Rich Prey Influences the Abundance and Diet of a Marine Predator, the Steller Sea Lion *Eumetopias Jubatus*. *Marine Ecology Progress Series*, 325, 281-293. <u>https://doi.org/10.3354/meps325281</u>

Steller sea lions Eumetopiasjubatus are central-place foragers that forage in the marine environment while using terrestrial sites to rest and care for young. Some terrestrial sites are used seasonally; however, the reasons for doing so are not fully understood. We addressed the hypothesis that seasonal availability of prey influences seasonal abundance and diet of sea lions. We quantified monthly prey availability and sea lion abundance and quarterly diet composition at Benjamin Island in SE Alaska (2001-2004). Large numbers of sea lions occupied Benjamin Island during the nonbreeding season from October to April when Pacific herring Clupea pallasii biomass was highest. Herring was the most common species in sea lion diet (frequency of occurrence [FO] = 90 %) and comprised over 81 % of the available pelagic prey biomass and 96 % of the energy encountered during pelagic surveys. Walleye pollock Theragra chalcogramma accounted for 19% of the available prey biomass but was only slightly less common in sea lion diet (FO = 88 %) than herring. Herring biomass was correlated with the number of sea lions; in contrast, there was no relationship between pollock biomass and number of sea lions. Several fish species were found in nearshore areas, but were uncommon in sea lion diet. Sea lions consumed the available pelagic prey but little of the available nearshore prey. The FO of herring and pollock in sea lion diet did not differ significantly between seasons; however, the FO of other seasonal prey species differed between seasons. Seasonal occupation of Benjamin Island by sea lions is influenced by seasonally available, densely aggregated, energy-rich prey.

 Womble, J. N., & Sigler, M. F. (2006). Temporal Variation in Steller Sea Lion Diet at a Seasonal Haul-out in Southeast Alaska. In Sea Lions of the World. A.W. Trites, S.K. Atkinson, D.P. DeMaster, L.W. Fritz, T.S. Gelatt, L.D. Rea, and K.M. Wynne (Eds.) Sea Grant Alaska. <u>https://doi.org/10.4027/slw.2006.11</u>

Pinniped diet may vary spatially and temporally and can be influenced by prey availability. Several prey species of Steller sea lions are densely aggregated during the nonbreeding season of sea lions and may be seasonally important because sea lion energetic requirements increase during winter and spring. To assess temporal variation in Steller sea lion diet at Benjamin Island in Lynn Canal, Southeast Alaska, we collected scat samples (n = 787) each February, April, October, and December from 2001 to 2004. Scat

samples were not collected during summer because few sea lions were present at Benjamin Island during that season. Pacific herring (frequency of occurrence [FO] = 90.0%) and walleye pollock (FO = 87.5%) were the two most common prey species in sea lion scat samples, followed by skate, Pacific salmon, Pacific cod, capelin, cephalopods, northern lampfish, sculpins, arrowtooth flounder, eulachon, and Pacific hake. The FO of herring, pollock, skates, Pacific cod, and cephalopods did not differ significantly between seasons; however, the FO of capelin, Pacific salmon, northern lampfish, sculpins, arrowtooth flounder, eulachon, and Pacific hake differed between seasons. Sea lion diet diversity increased in spring and corresponded to the spawning season of several forage fish species. Exploiting salmon in fall, herring during winter, and eulachon, capelin, and northern lampfish in spring likely helps sea lions meet the increased energetic demands that occur during winter and spring.

Womble, J. N., Sigler, M. F., & Willson, M. F. (2009). Linking Seasonal Distribution Patterns with Prey Availability in a Central-Place Forager, the Steller Sea Lion. *Journal of Biogeography*, 36(3), 439-451. <u>https://doi.org/10.1111/j.1365-2699.2007.01873.x</u>

Aim We used a novel approach to infer foraging areas of a central-place forager, the Steller sea lion (Eumetopias jubatus), by assessing changes in the temporal and spatial distribution patterns of sea lions at terrestrial sites. Specifically, our objectives were (1) to classify seasonal distribution patterns of Steller sea lions and (2) to determine to what extent the seasonal distribution of Steller sea lions is explained by seasonal concentrations of prey. Location Southeast Alaska, USA. Methods Steller sea lions of all age classes were counted monthly (2001–04) by aerial surveys at 28 terrestrial sites. Hierarchical cluster analysis and principal components analysis were used to classify seasonal distribution patterns of Steller sea lions at these terrestrial sites. We estimated the proportion of sea lions in the study area that were associated with each seasonal distribution pattern. Results Multivariate ordination techniques revealed four distinct seasonal distributional patterns. During December, 55% of the sea lions in the study area were found at Type 1 sites, located near over-wintering herring aggregations. During May, 56% of sea lions were found at Type 2 sites, near aggregations of spring-spawning forage fish. In July, 78% of sea lions were found at Type 3 sites, near summer migratory corridors of salmon. During September, 44% of sea lions were found at Type 4 sites, near autumn migratory corridors of salmon. Main conclusions Seasonal attendance patterns of sea lions were commonly associated with the seasonal availability of prey species near terrestrial sites and reflected seasonal foraging patterns of Steller sea lions in Southeast Alaska. A reasonable annual foraging strategy for Steller sea lions is to forage on herring (Clupea pallasii) aggregations in winter, spawning aggregations of forage fish in spring, salmon (Oncorhynchus spp.) in summer and autumn, and pollock (Theragra chalcogramma) and Pacific hake (Merluccius productus) throughout the year. The seasonal use of haulouts by sea lions and ultimately haulout-specific foraging patterns of Steller sea lions depend in part upon seasonally available prey species in each region.

Young, B. L., Rosen, D. A. S., Hindle, A. G., Haulena, M., & Trites, A. W. (2011). Dive Behaviour Impacts the Ability of Heart Rate to Predict Oxygen Consumption in Steller Sea Lions (*Eumetopias Jubatus*) Foraging at Depth. *Journal of Experimental Biology, 214*(13), 2267-2275. <u>https://doi.org/10.1242/jeb.047340</u>

The predictive relationship between heart rate (f(H)) and oxygen consumption ((Vover dot)(O2)) has been derived for several species of marine mammals swimming horizontally or diving in tanks to shallow depths. However, it is unclear how dive activity affects the f(H): (Vover dot)(O2) relationship and whether the existing equations apply to animals diving to deeper depths. We investigated these questions by simultaneously measuring the f(H) and (Vover dot)(O2) of Steller sea lions (*Eumetopias jubatus*) under different activity states (surface resting or diving), types of dives (single dives or dive bouts), and depths (10 or 40 m). We examined the relationship over dives only and also over dive cycles (dive + surface interval). We found that f(H) could only predict (Vover dot)(O2) over a complete single dive cycle or dive bout cycle (i.e. surface intervals had to be included). The predictive equation derived for sea lions resting on the surface did not differ from that for single dive cycles. However, the equation derived over dive bout cycles (multiple dives + surface intervals) differed from those for single dive cycles or surface resting, with similar f(H) for multiple dive bout equations yielding higher predicted (Vover dot)(O2) than that for single dive bout cycles (or resting). The f(H): (Vover dot)(O2) relationships were not significantly affected by dive duration, dive depth, water temperature or cumulative food consumed under the conditions tested. Ultimately, our results demonstrate that f(H) can be used to predict activity-specific metabolic rates of diving Steller sea lions, but only over complete dive cycles that include a post-dive surface recovery period.

Section VI: Genetics

Baker, A. R., T.R. Loughlin, V. Burkanov, C.W. Matson, R.G. Trujillo, D.G. Calkins, . . . Bickham, J. W. (2005). Variation of Mitochondrial Control Region Sequences of Steller Sea Lions: The Three-Stock Hypothesis. . *Journal of Mammalogy, 86*, 1075-1084. <u>https://doi.org/10.1644/04-MAMM-A-113R1.1</u>

Sequence variation in the mitochondrial DNA (mtDNA) control region was analyzed from 1,568 individuals representing nearly every rookery (n = 50) at which Steller sea lions (Eumetopias jubatus) are known to breed in significant numbers. Rookeries were grouped into regions and regions into stocks to examine structure at different spatial scales. Haplotype diversity (H = $0.9164 \pm 0.(035)$) was high and nucleotide diversity (n: = 0.00967 ± 0.00586) was moderate. No evidence was observed for significant genetic bottleneck effects. Previous studies of mtDNA recognized 2 stocks (eastern and western) and suggested the presence of 2 groups within the western stock. In this study, significant (P < 0.05) divergence of eastern stock (southeastern Alaska to California) animals from western stock animals was supported in analyses at all spatial scales. Likewise, rookeries and regions from Asia were found to be significantly different from all other western stock rookeries. This was most clearly demonstrated in regional comparisons. The Commander Islands rookery clearly associates with Alaskan western stock rookeries, not with the Asian rookeries. Within each of the 3 stocks there is significant isolation by distance among rookeries. This relationship does not hold for interstock comparisons, indicating that there are important barriers to gene flow among stocks. We recommend that the western stock be partitioned west of the Commander Islands, yielding a western stock that ranges from Prince William Sound west to the Commander Islands, and an Asian stock including rookeries from the Kamchatka Peninsula, Kuril Islands, and Sea of Okhotsk. The eastern stock remains unchanged and includes rookeries from southeastern Alaska through California.

Beklemisheva, V. R., Perelman, P. L., Lemskaya, N. A., Kulemzina, A. I., Proskuryakova, A. A., Burkanov, V.
 N., & Graphodatsky, A. S. (2016). The Ancestral Carnivore Karyotype as Substantiated by
 Comparative Chromosome Painting of Three Pinnipeds, the Walrus, the Steller Sea Lion and the

Baikal Seal (Pinnipedia, Carnivora). *PLoS ONE*, 11(1) https://doi.org/10.1371/journal.pone.0147647

Karyotype evolution in Carnivora is thoroughly studied by classical and molecular cytogenetics and supplemented by reconstructions of Ancestral Carnivora Karyotype (ACK). However chromosome painting information from two pinniped families (Odobenidae and Otariidae) is noticeably missing. We report on the construction of the comparative chromosome map for species from each of the three pinniped families: the walrus (Odobenus rosmarus, Odobenidae-monotypic family), near threatened Steller sea lion (Eumetopias jubatus, Otariidae) and the endemic Baikal seal (Pusa sibirica, Phocidae) using combination of human, domestic dog and stone marten whole-chromosome painting probes. The earliest karyological studies of Pinnipedia showed that pinnipeds were characterized by a pronounced karyological conservatism that is confirmed here with species from Phocidae, Otariidae and Odobenidae sharing same low number of conserved human autosomal segments (32). Chromosome painting in Pinnipedia and comparison with non-pinniped carnivore karyotypes provide strong support for refined structure of ACK with 2n = 38. Constructed comparative chromosome maps show that pinniped karyotype evolution was characterized by few tandem fusions, seemingly absent inversions and slow rate of genome rearrangements (less then one rearrangement per 10 million years). Integrative comparative analyses with published chromosome painting of Phoca vitulina revealed common cytogenetic signature for Phoca/Pusa branch and supports Phocidae and Otaroidea (Otariidae/Odobenidae) as sister groups. We revealed rearrangements specific for walrus karyotype and found the chromosomal signature linking together families Otariidae and Odobenidae. The Steller sea lion karyotype is the most conserved among three studied species and differs from the ACK by single fusion. The study underlined the strikingly slow karyotype evolution of the Pinnipedia in general and the Otariidae in particular.

Berta, A., & Churchill, M. (2012). Pinniped Taxonomy: Review of Currently Recognized Species and Subspecies, and Evidence Used for Their Description. *Mammal Review*, 42(3), 207-234. <u>https://doi.org/10.1111/j.1365-2907.2011.00193.x</u>

1 Pinnipeds are charismatic but difficult to study, and taxonomy is poorly understood. An accurate taxonomic framework is essential for studies of biogeography, ecology and conservation. 2 Morphologic and genetic criteria used to recognize pinniped species and subspecies are evaluated individually for all taxa in the three families: Otariidae (sea lions and fur seals), Odobenidae (walruses) and Phocidae (seals). We advocate a pragmatic approach that, in general, follows the Evolutionary Species Concept and diagnosability criterion for subspecies delimitations. 3 Of the 33 species, all have at least two lines of evidence to distinguish them, and of the 29 subspecies, 24 have at least one line of evidence, but five have inadequate support. We present a composite phylogeny for pinnipeds. 4 We propose that the genus Arctocephalus be limited to Arctocephalus pusillus, and we resurrect the name Arctophoca for at least six species and subspecies. 5 We recommend large sample sizes and broad, random sampling in further research on pinniped taxonomy. Taxa should be described based on robust statistical analysis, not by arbitrary division of characters, and molecular research should include analysis of mtDNA and nuDNA. 6 Finally, we offer suggestions for further taxonomic research (on hybridization in otariids, and to allow consideration of life history data in sampling) in an effort to improve our understanding of pinniped diversity. Even for taxa which are already protected, better understanding of their taxonomy can only enhance their conservation status and facilitate efforts to protect their habitats.

Bickham, J. W., Loughlin, T. R., Calkins, D. G., Wickliffe, J. K., & Patton, J. C. (1998). Genetic Variability and Population Decline in Steller Sea Lions from the Gulf of Alaska. *Journal of Mammalogy*, 79(4), 1390-1395. <u>https://doi.org/10.2307/1383029</u>

The western stock of the Steller sea lion (*Eumetopias jubatus*) was listed as endangered in 1997 due to its decline in numbers since the 1960s. We examined haplotypic diversity using nucleotide-sequence analysis of the control region of the mitochondrial DNA (mtDNA) from animals collected in 1976-1978 from the western and central Gulf of Alaska and compared results to previously published data from animals collected in the 1990s from the same geographic areas. No significant differences were found in frequencies of haplotypes between the two time periods, and genotypic diversity was high for all populations and time periods studied. It is concluded that, despite reduction in numbers, populations in the Gulf of Alaska have not lost appreciable genetic diversity, and if populations are allowed to recover, no long-term change in fitness is expected.

 Bickham, J. W., Loughlin, T. R., Wickliffe, J. K., & Burkanov, V. N. (1998). Geographic Variation in the Mitochondrial DNA of Steller Sea Lions: Haplotype Diversity and Endemism in the Kuril Islands. *Biosphere conservation : for nature, wildlife, and humans, 1*(2), 107-117. https://doi.org/10.20798/biospherecons.1.2 107

Nucleotide sequence analysis of a 238 base-pair segment of the mitochondrial control region for 392 Steller sea lions (*Eumetopias jubatus*) from rookeries across nearly the entire distributional range of the species supports the hypothesis of two genetically differentiated stocks. An eastern stock includes rookeries in California, Oregon, British Columbia, and southeastern Alaska. A western stock includes rookeries in Prince William Sound, the Bering Sea, Central Gulf of Alaska, Western Gulf of Alaska, Eastern Aleutian Islands, Central Aleutian Islands, Russia (Commander Islands and Kamchatka), and the Kuril Islands. The distribution of haplotypes and a phylogenetic analysis of the haplotypes provides evidence for the reconstruction of the evolutionary history of the populations. Steller sea lions diverged genetically as the result of being isolated in at least two, and possibly three, glacial refugia. The data indicate that females have a relatively high level of philopatry and the control region has a rapid rate of evolution, which has resulted in relatively high levels of haplotype endemism in some areas. In particular, the Kuril Islands appear to be highly variable with many low-frequency haplotypes unique to that area.

 Bickham, J. W., Patton, J. C., & Loughlin, T. R. (1996). High Variability for Control-Region Sequences in a Marine Mammal: Implications for Conservation and Biogeography of Steller Sea Lions (*Eumetopias Jubatus*). . Journal of Mammalogy, 77, 95-108. <u>https://doi.org/10.2307/1382712</u>

The Steller sea lion (*Eumetopias jubatus*) is a threatened species that has experienced significant population declines over the past 3 decades. Previous genetic studies indicated low allozymic variability in this monotypic species. However, high levels of variation exist in the mitochondrial control-region, as revealed by a 238 base-pair sequence from 224 specimens taken over most of the range of the species. Patterns of macrogeographic variation indicate the presence of two genetically differentiated populations of Steller sea lions. A western population included rookeries from the Commander Islands in Russia and the Aleutian Islands and Gulf of Alaska in Alaska. An eastern population included rookeries from southeastern Alaska and Oregon. Phenetic analysis of the mitochondrial-DNA (mtDNA) haplotypes indicates that certain haplotype lineages are specific to one or the other populations. Thus, these

populations have been separated for a sufficient amount of time to allow diversification of lineages. However, the two populations are paraphyletic with respect to mtDNA, which indicates that they do not trace their ancestries back to a single maternal ancestor in either case. The populations likely diverged as a result of separation in different glacial refugia.

Bowen, L., Aldridge, B., Beckmen, K., Gelatt, T., Rea, L., Burek, K., . . . Stott, J. L. (2006). Differential Expression of Immune Response Genes in Steller Sea Lions (*Eumetopias Jubatus*): An Indicator of Ecosystem Health? *Ecohealth*, 3(2), 109-113. <u>https://doi.org/10.1007/s10393-006-0021-0</u>

Characterization of the polygenic and polymorphic features of the Steller sea lion major histocompatibility complex (MHC) provides an ideal window for evaluating immunologic vigor of the population and identifying emergence of new genotypes that reflect ecosystem pressures. MHC genotyping can be used to measure the potential immunologic vigor of a population. However, since ecosystem-induced changes to MHC genotype can be slow to emerge, measurement of differential expression of these genes can potentially provide real-time evidence of immunologic perturbations. MHC DRB genes were cloned and sequenced using peripheral blood mononuclear leukocytes derived from 10 Steller sea lions from Southeast Alaska, Prince William Sound, and the Aleutian Islands. Nine unique DRB gene sequences were represented in each of 10 animals. MHC DRB gene expression was measured in a subset of six sea lions. Although DRB in genomic DNA was identical in all individuals, relative levels of expressed DRB mRNA was highly variable. Selective suppression of MHC DRB genes could be indicative of geographically disparate environmental pressures, thereby serving as an immediate and sensitive indicator of population and ecosystem health.

Burek, K. A., Beckmen, K., Gelatt, T., Fraser, W., Bracht, A. J., Smolarek, K. A., & Romero, C. H. (2005). Poxvirus Infection of Steller Sea Lions (*Eumetopias Jubatus*) in Alaska. *Journal of Wildlife Diseases*, 41(4), 745-752. https://doi.org/10.7589/0090-3558-41.4.745

Lesions suggestive of poxvirus infection were observed in two Steller sea lions (Eumetopias jubatus) in Alaska during live capture-and-release studies during 2000 and 2001. Both of these animals, female pups in poor body condition, were from Prince William Sound; this population is part of the declining western stock. Umbilicated, typically ulcerated dermal nodules were present, primarily on the fore flippers in one case, and over most of the body in the second case. Histologically, there were discrete masses in the superficial dermis composed of epithelial cells, some of which contained eosinophilic intracytoplasmic inclusion bodies. Negative staining of skin biopsy homogenates demonstrated the presence of orthopoxvirus-like particles. Total DNA extracted from skin biopsies were analyzed by polymerase chain reaction (PCR) using primers that targeted the DNA polymerase and DNA topoisomerase genes. These primers directed the amplification of fragments 543 base pairs (bp) and 344 bp, respectively, whose deduced amino acid sequences indicated the presence of a novel poxvirus within the Chordopoxvirinae subfamily. Comparison of these amino acid sequences with homologous sequences from members of the Chordopoxvirinae indicated highest identity with orthopoxviruses.

Gelatt, T. S., Trites, A. W., Hastings, K., Jemison, L., Pitcher, K., & O'Corry-Crowe, G. (2007). *Population Trends, Diet, Genetics, and Observations of Steller Sea Lions in Glacier Bay National Park.* Paper presented at the Fourth Glacier Bay Science Symposium. Retrieved from http://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/research_pdfs/population_trend s diet genetics steller lions glacier national park.pdf

We are using demographics, scat analysis, and genetic measurements of Steller sea lions (SSLs)to understand the factors affecting population status throughout Alaska. Steller sea lions are listed as threatened throughout Southeast Alaska including Glacier Bay National Park where they frequent at least five terrestrial sites, including a recently established rookery on Graves Rock. Breeding season counts in GBNP increased at ~6 percent/yr between 1989 and 2002. Brand resighting during 2003 revealed 16 western stock SSLs seen within the park. Survival to two months of age was 90 percent. Fifty pups were branded at Graves Rock in 2002. It is necessary to mark more animals to estimate annual survival rates of juveniles and adults. Sandlance and pollock were top prey items at Graves Rock and South Marble Island. Mitochondrial DNA analysis indicates that the Graves Rock rookery was established in part by females from the western sea lion stock (west of 144° W longitude).

Harlin-Cognato, A., Bickham, J. W., Loughlin, T. R., & Honeycutt, R. L. (2006). Glacial Refugia and the Phylogeography of Steller's Sea Lion (*Eumatopias Jubatus*) in the North Pacific. *Journal of Evolutionary Biology*, 19(3), 955-969. <u>https://doi.org/10.1111/j.1420-9101.2005.01052.x</u>

Mitochondrial DNA sequence data were used to examine the phylogeographic history of Steller's sea lions (*Eumetopias jubatus*) in relation to the presence of Plio-Pleistocene insular refugia. Cytochrome b and control region sequences from 336 Steller's sea lions reveal phylogenetic lineages associated with continental refugia south of the ice sheets in North America and Eurasia. Phylogenetic analysis suggests the genetic structure of E. jubatus is the result of Pleistocene glacial geology, which caused the elimination and subsequent reappearance of suitable rookery habitat during glacial and interglacial periods. The cyclic nature of geological change produced a series of independent population expansions, contractions and isolations that had analogous results on Steller's sea lions and other marine and terrestrial species. Our data show evidence of four glacial refugia in which populations of Steller's sea lions diverged. These events occurred from approximately 60,000 to 180,000 years BP and thus preceded the last glacial maximum.

Hoffman, J. I., Matson, C. W., Amos, W., Loughlin, T. R., & Bickham, J. W. (2006). Deep Genetic Subdivision within a Continuously Distributed and Highly Vagile Marine Mammal, the Steller'S Sea Lion (*Eumetopias Jubatus*). *Molecular Ecology*, 15(10), 2821-2832. <u>https://doi.org/10.1111/j.1365-294x.2006.02991.x</u>

The Steller's sea lion Eumetopias jubatus is an endangered marine mammal that has experienced dramatic population declines over much of its range during the past five decades. Studies using mitochondrial DNA (mtDNA) have shown that an apparently continuous population includes a strong division, yielding two discrete stocks, western and eastern. Based on a weaker split within the western stock, a third Asian stock has also been defined. While these findings indicate strong female philopatry, a recent study using nuclear microsatellite markers found little evidence of any genetic structure, implying extensive paternal gene flow. However, this result was at odds with mark–recapture data, and both sample sizes and genetic resolution were limited. To address these concerns, we increased analytical power by genotyping over 700 individuals from across the species' range at 13 highly polymorphic microsatellite loci. We found a clear phylogenetic break between populations of the eastern stock and those of the western and Asian stocks. However, our data provide little support for

the classification of a separate Asian stock. Our findings show that mtDNA structuring is not due simply to female philopatry, but instead reflects a genuine discontinuity within the range, with implications for both the phylogeography and conservation of this important marine mammal.

Huebinger, R. M., Louis, E. E., Gelatt, T., Rea, L. D., & Bickham, J. W. (2007). Characterization of Eight Microsatellite Loci in Steller Sea Lions (*Eumetopias Jubatus*). *Molecular Ecology Notes*, 7(6), 1097-1099. <u>https://doi.org/10.1111/j.1471-8286.2007.01790.x</u>

Steller sea lions (*Eumetopias jubatus*) are listed as an endangered species in western Alaska and have exhibited a significant population decline throughout their range. Eight microsatellite loci were isolated from genomic DNA libraries. In addition, all these markers were found to be variable in nine individuals of the California sea lion (Zalophus californicus). This panel of markers was developed to analyse population structure in Steller sea lions throughout their range.

Ikehara, T., Eguchi, Y., Kayo, S., & Takei, H. (1996). Amino Acid Sequences of Hemoglobin Beta Chains of Five Species of Pinnipeds: Neophoca Cinerea, Otaria Byronia, *Eumetopias Jubatus*, Pusa Hispida, and Pagophilus Groenlandica. *Journal of Protein Chemistry*, 15(7), 659-665. https://doi.org/10.1007/bf01886748

Pinnipeds (Otariidae, Odobenidae, and Phocidae) in the order Carnivora have one or two types (Hb I and Hb II) of hemoglobin components. These hemoglobins consist of identical beta chains and different alpha chains. We determined the complete amino acid sequences of the hemoglobin beta chain of three species of Otariidae (Australian sea lion, South American sea lion, and northern sea lion) and two species of Phocidae (ringed seal and harp seal) from intact beta chain and chemical cleavage fragments. The sequences are similar to beta chains of the already known sequences of pinnipeds. These sequences were compared with those of other carnivores (Mustelidae, Ursidae, Canidae, and Felidae) and adult human hemoglobin beta chain. Using Artiodactyla (pig) as an outgroup, we find that the tree constructed by means of phylogenetic analysis shows that Odobenidae is closest to Otariidae, and that Otariidae and Odobenidae are closer to Mustelidae than to Phocidae.

 Jemison, L. A., Pendleton, G. W., Fritz, L. W., Hastings, K. K., Maniscalco, J. M., Trites, A. W., & Gelatt, T.
 S. (2013). Inter-Population Movements of Steller Sea Lions in Alaska with Implications for Population Separation. *PLoS ONE*, 8(8). <u>https://doi.org/10.1371/journal.pone.0070167</u>

Genetic studies and differing population trends support the separation of Steller sea lions (*Eumetopias jubatus*) into a western distinct population segment (WDPS) and an eastern DPS (EDPS) with the dividing line between populations at 144 degrees W. Despite little exchange for thousands of years, the gap between the breeding ranges narrowed during the past 15-30 years with the formation of new rookeries near the DPS boundary. We analyzed >22,000 sightings of 4,172 sea lions branded as pups in each DPS from 2000-2010 to estimate probabilities of a sea lion born in one DPS being seen within the range of the other DPS (either 'West' or 'East'). Males from both populations regularly traveled across the DPS boundary; probabilities were highest at ages 2-5 and for males born in Prince William Sound and southern Southeast Alaska. The probability of WDPS females being in the East at age 5 was 0.067 but 0 for EDPS females which rarely traveled to the West. Prince William Sound-born females had high probabilities of being in the East during breeding and non-breeding seasons. We present strong

evidence that WDPS females have permanently emigrated to the East, reproducing at two 'mixing zone' rookeries. We documented breeding bulls that traveled >6,500 km round trip from their natal rookery in southern Alaska to the northern Bering Sea and central Aleutian Islands and back within one year. WDPS animals began moving East in the 1990s, following steep population declines in the central Gulf of Alaska. Results of our study, and others documenting high survival and rapid population growth in northern Southeast Alaska suggest that conditions in this mixing zone region have been optimal for sea lions. It is unclear whether eastward movement across the DPS boundary is due to less-optimal conditions in the West or a reflection of favorable conditions in the East.

Kariya, T., Igarashi, M., Wada, K., Burkanov, V. N., Koyama, S., Hoshino, H., & Oshida, T. (2009). Lack of Sequence Variation of Y Chromosome-Linked Loci in Steller's Sea Lions (*Eumetopias Jubatus*) from lony Island and the Kuril Islands. *Mammal Study*, 34(1), 33-36. https://doi.org/10.3106/041.034.0105

The Y chromosome-linked (Y-linked) genetic markers are important for understanding historical pattern of male dispersal (e.g., Tucker and Lundrigan 1996). Especially, the sex-determining region of the Y gene (SRY) is used as a marker to resolve phylogeography, population structure, and population dynamics of wild mammals (Hurles and Jobling 2001; Petit et al. 2002). For instance, Iwasa and Suzuki (2002) reported that SRY variation in Japanese red-backed moles (Eothenomyce andersonii) showed substantial geographic distribution. Geraldes et al. (2005) found high levels of nucleotide diversity in the SRY of European rabbits (Oryctolagus cuniculus). Moreover, Y-linked introns such as the DEAD/H (Asp-Glu-Ala-Asp/His) box polypeptide of the Y chromosome (DBY) and the histocompatibility Y antigen gene (SmcY) may be effective markers in phylogeographical study (e.g., Underhill et al. 2001).

Koyama, S., Fujita, S., Hirota, T., Satoh, T., Obara, Y., Hoshino, H., . . . Wada, K. (2008). Genetic Structure of Steller Sea Lion (*Eumetopias Jubatus*) Rookeries in the Sea of Okhotsk. *Zoological Studies*, 47(6), 781-787. Retrieved from http://zoolstud.sinica.edu.tw/Journals/47.6/781.pdf

Satoshi Koyama, Shoko Fujita, Tadao Hirota, Toshiyuki Satoh, Yoshiaki Obara, Hiroshi Hoshino, Akihiko Wada, Vladimir N Burkanov, and Kazuo Wada (2008) Genetic structure of Steller sea lion (*Eumetopias jubatus*) rookeries in the Sea of Okhotsk, Zoological Studies 47(6): 781-787. Genetic relationships among 4 Steller sea lion (*Eumetopias jubatus*) rookeries in the Kuril Is. (Brat Chirpoev, Lovushki, Raykoke, and Antsiferov Is.) and 1 at lony I, were evaluated using an inter-simple sequence repeat (ISSR)- polymerase chain reaction assay. An ISSR primer yielded 15 amplification products, almost all of which were polymorphic. An analysis of molecular variance test revealed that 94.4% of the total genetic variation was attributable to differences among individuals within rookeries, and 5.6% was attributable to those among rookeries (Phi(ST) = 0.056). Pairwise Phi(ST) values were relatively high between rookeries of the Kuril Is. and that on lony I., while no significant genetic differentiation was detected among rookeries of the Kuril Is. Since previous research using mitochondrial DNA markers revealed the presence of unique haplotype(s) on each island of the Kuril Is., our results suggest that males, rather than females, contribute to gene flow among the islands.

McClenahan, S. D., Burek, K. A., Beckmen, K. B., Knowles, N. J., Neill, J. D., & Romero, C. H. (2008). Genomic Characterization of Novel Marine Vesiviruses from Steller Sea Lions (*Eumetopias* *Jubatus*) from Alaska. *Virus Research, 138*(1-2), 26-35. <u>https://doi.org/10.1016/j.virusres.2008.08.002</u>

Marine vesiviruses were isolated in cell culture from oral and rectal swabs and vesicular fluid from Alaskan Steller sea lions (SSL; *Eumetopias jubatus*). Further characterization by RT-PCR, complete genomic sequencing, and phylogenetic analyses indicated that these viruses are most closely related to the marine vesiviruses, but are distinct viruses and represent two novel genotypes. The complete genome of these two SSL isolates was sequenced after cloning their viral cDNA. The genomes were found to be 8302 and 8305 nucleotides in length, organized in three open reading frames and contained 5' and 3' untranslated regions (UTR) of 19 and 180 nucleotides, respectively. The complete genomes of both SSL viruses were most closely related to each other and shared 83.0% nucleotide identity. Using the very limited number of complete genomic vesivirus sequences available in the NCBI database, these novel SSL vesiviruses seem most closely related to vesicular exanthema of swine virus-A48 and least related to rabbit vesivirus and walrus calicivirus. Specific antiserum against some evolutionary closer marine vesiviruses did not neutralize these isolates supporting the novel nature of these SSL viruses.

O'Corry-Crowe, G., Gelatt, T., Rea, L., Bonin, C., & Rehberg, M. (2014). Crossing to Safety: Dispersal, Colonization and Mate Choice in Evolutionarily Distinct Populations of Steller Sea Lions, *Eumetopias Jubatus*. *Molecular Ecology*, 23(22), 5415-5434. <u>https://doi.org/10.1111/mec.12944</u>

Population growth typically involves range expansion and establishment of new breeding sites, while the opposite occurs during declines. Although density dependence is widely invoked in theoretical studies of emigration and colonization in expanding populations, few empirical studies have documented the mechanisms. Still fewer have documented the direction and mechanisms of individual transfer in declining populations. Here, we screen large numbers of pups sampled on their natal rookeries for variation in mtDNA (n = 1106) and 16 microsatellite loci (n = 588) and show that new Steller sea lion breeding sites did not follow the typical paradigm and were instead colonized by sea lions from both a declining (Endangered) population and an increasing population. Dispersing individuals colonized rookeries in the distributional hiatus between two evolutionarily distinct (Phi (st) = 0.222, R (st) = 0.053, K = 2) metapopulations recently described as separate subspecies. Hardy-Weinberg, mixed-stock and relatedness analysis revealed levels of interbreeding on the new rookeries that exclude (i) assortative mating among eastern and western forms, and (ii) inbreeding avoidance as primary motivations for dispersal. Positive and negative density dependence is implicated in both cases of individual transfer. Migration distance limits, and conspecific attraction and performance likely influenced the sequence of rookery colonizations. This study demonstrates that resource limitation may trigger an exodus of breeding animals from declining populations, with substantial impacts on distribution and patterns of genetic variation. It also revealed that this event is rare because colonists dispersed across an evolutionary boundary, suggesting that the causative factors behind recent declines are unusual or of larger magnitude than normally occur.

O'Corry-Crowe, G., Taylor, B. L., Gelatt, T., Loughlin, T. R., Bickham, J., Basterretche, M., . . . DeMaster, D. P. (2006). Demographic Independence Along Ecosystem Boundaries in Steller Sea Lions Revealed by Mtdna Analysis: Implications for Management of an Endangered Species. *Canadian Journal of Zoology*, *84*(12), 1796-1809. <u>https://doi.org/10.1139/z06-167</u>

Previous genetic studies indicate Steller sea lions (*Eumetopias jubatus* (Schreber, 1776)) comprise three phylogeographically distinct populations. However, differences in population trends and ecology and the limited extent of recorded dispersal suggest structure may be present at smaller scales. We examined sequence variation within a longer segment (531 bp) of the mtDNA control region in greater numbers (n = 1654) ofsea lions from across Alaska than earlier investigations to investigate fine-scale dispersal patterns in Steller sea lions. We detected high levels of haplotypic diversity (h = 0.934) and confirmed phylogeographic differentiation between southeastern and western Alaska (Ost = 0.23, P < 0.0001), but also found significant differentiation at regional and local scales. Rookeries in the GulfofAlaska, eastern Bering Sea, and eastern Aleutians were distinct from rookeries in the central and western Aleutians (Fst = 0.021, P < 0.0001; st = 0.017, P < 0.0001). The location of this split coincides with an oceanographic divergence between continental shelf and ocean basin waters and with differences in sea lion foraging ecology and population trends. A number of rookeries were also significantly differentiated from nearby rookeries (Fst = 0.02–0.025, P < 0.05), signifying substantial female-mediated philopatry, in some cases, at local scales. These findings have important implications for understanding the ecology of Steller sea lions in relation to marine ecosystems and the causes of population declines, and they provide guidance for management, including the identification of management stocks.

O'Corry-Crowe, G. The Molecular Ecology and Management of Steller Sea Lions. In: National Marine Fisheries Service Southwest Fisheries Science Center.

Presentation slides from a talk on Steller sea lion genetics.

Palacios, G., Wellehan, J. F. X., Raverty, S., Bussetti, A. V., Hui, J., Savji, N., . . . Lipkin, W. I. (2011).
 Discovery of an Orthoreovirus in the Aborted Fetus of a Steller Sea Lion (*Eumetopias Jubatus*).
 Journal of General Virology, 92(11), 2558-2565. <u>https://doi.org/10.1099/vir.0.032649-0</u>

An aborted mid-gestational male Steller sea lion fetus with an attached placenta was recovered on the floor of an open floating capture trap located off Norris Rock near Denman Island, British Columbia. Viral culture of the placenta demonstrated cytopathic effect. Although no specific signal was obtained in microarray experiments using RNA obtained from viral culture, elution and sequence analysis revealed the presence of a reovirus. Complete genome pyrosequencing led to the identification of an orthoreovirus that we have tentatively named Steller sea lion reovirus (SSRV). Phylogenetic analysis revealed similarities between SSRV and orthoreoviruses of birds, bats and other mammals that suggests potential for interspecies transmission.

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 <u>https://doi.org/10.1038/s41598-018-34758-0</u>

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.

Phillips, C. D. (2009). Systematics, Molecular Evolution, and Phylogeography of Steller Sea Lions, Eumetopias Jubatus. Purdue University. Retrieved from <u>https://search.proquest.com/asfa/docview/923192985/E9EA5EC90DCB4BAAPQ/1?accountid=2</u> 8258

Exploring intraspecific diversity and divergences and testing hypotheses which endeavor to explain these observed levels of diversity within and among populations is a key component of evolutionary biology. By describing the variation of characters over a species distribution and testing these patterns in light of information on biotic and abiotic processes, we should gain insight into the origin and maintenance of observed patterns. In this dissertation data on Steller sea lions, *Eumetopias jubatus*, is presented with this intent. A survey on patterns of morphological variation in conjunction with genetic and demographic data is used to provide a clear taxonomic description of E. jubatus. An investigation about the molecular evolution of a commonly used genetic locus is also presented to characterize substitution processes at this locus that when unchecked can lead to inaccurate interpretations of population structure. In addition, the phylogeographic history of E. jubatus is described in which major patterns of population structure are explainable by the role climate change over the last 400,000 years has had in continually modifying the distribution of available habitat. Collectively, these results provide an accurate depiction of the evolutionary history and current population structure of E. jubatus.

Phillips, C. D., Bickham, J. W., Patton, J. C., & Gelatt, T. S. (2009). Systematics of Steller Sea Lions (Eumetopias Jubatus): Subspecies Recognition Based on Concordance of Genetics and Morphometrics. M. o. T. T. University Number 283. Retrieved from http://www.nsrl.ttu.edu/publications/opapers/ops/OP283.pdf

Previous studies have revealed discontinuities in the distribution of genetic markers that led to the recognition of eastern, western, and Asian stocks of Steller sea lions (*Eumetopias jubatus*). The most profound break separates the eastern and western stocks and is based upon both nuclear and mitochondrial genetic markers. Here, a morphometric analysis of skulls was used to re-evaluate geographic variation in light of the genetics data and to possibly identify characters to distinguish between the eastern and western stocks. For males, three variables were used in stock assignment to correctly identify 88.13% and 86.59% of individuals from the eastern and western stocks, respectively. Through the same method the correct identification in stock assignment using five selected variables for female eastern and western stock individuals was 86.27% and 88.1%, respectively. Furthermore, plots from canonical discriminant analyses clearly separate individuals into stocks with very minimal overlap. Based on the observed morphological differences between these genetically differentiated stocks, we recognize two subspecies of E. jubatus; one includes the Asian and western stocks, and the other the eastern stock. The vernacular name Loughlin's northern sea lion is used to signalize the eastern subspecies.

Phillips, C. D., Gelatt, T. S., Patton, J. C., & Bickham, J. W. (2011). Phylogeography of Steller Sea Lions: Relationships among Climate Change, Effective Population Size, and Genetic Diversity. *Journal of Mammalogy*, 92(5):1091–1104. <u>https://doi.org/10.1644/10-MAMM-A-305.1</u>

The biology of the Steller sea lion (*Eumetopias jubatus*) has been the subject of intense scientific investigation. This is primarily due to the rapid decline of population size in the western part of the species' range since the 1970s and the subsequent Threatened and Endangered species listings that had direct impact on the management of one of the world's largest fisheries. The Steller sea lion has emerged as an indicator species representing the environmental health of the North Pacific Ocean and Bering Sea. In this study, to better understand the historical processes that have culminated in the extant populations of E. jubatus, a large genetic data set consisting of 3 mitochondrial regions for .1,000 individuals was analyzed from multiple phylogeographic and demographic perspectives. The results describe the role of climate change in shaping the population structure of E. jubatus. Climatically associated historical processes apparently involved differential demographic responses to ice ages (and putative glacial vicariance) dependent on population size. Ice ages during times of small effective population size promoted restricted gene flow and fragmentation, and ice ages occurring during times of large population size promoted gene flow and dispersal. These results illustrate that effective population size has a profound effect on how species respond to climate change, an observation with obvious implications for large mammals and endangered species under the present conditions of imminent anthropogenically caused climate change. In addition, the results confirm previous observations of strongly biased historic and contemporary gene flow involving dispersal from west to east. Furthermore, phylogenetic patterns in combination with available fossil data suggest the potential of an Asian origin of E. jubatus. The results of this study provide a detailed scenario for the history that has shaped contemporary populations of E. jubatus.

Phillips, C. D., Trujillo, R. G., Gelatt, T. S., Smolen, M. J., Matson, C. W., Honeycutt, R. L., . . . Bickham, J. W. (2009). Assessing Substitution Patterns, Rates and Homoplasy at Hvri of Steller Sea Lions, *Eumetopias Jubatus. Molecular Ecology*, *18*(16), 3379-3393. <u>https://doi.org/10.1111/j.1365-294x.2009.04283.x</u>

Despite the widely recognized incidence of homoplasy characterizing this region, the hypervariable region I (HVRI) of the mitochondrial control region is one of the most frequently used genetic markers for population genetic and phylogeographic studies. We present an evolutionary analysis of HVRI and cytochrome b sequences from a range-wide survey of 1031 Steller sea lions, *Eumetopias jubatus*, to quantify homoplasy and substitution rate at HVRI. Variation in HVRI was distributed across 41 variable sites in the 238-bp segment examined. All variants at HVR1 were found to be transitions. However, our analyses suggest that a minimum of 101 changes have actually occurred within HVRI with as many as 18 substitutions occurring at a single site. By including this hidden variation into our analyses, several instances of apparent long-range dispersal were resolved to be homoplasies and 8.5–12% of observed HVRI haplotypes were found to have geographic distributions descriptive of convergent molecular evolution rather than identity by descent. We estimate the rate of substitution at HVRI in Steller sea lions to be ~24 times that of cytochrome b with an absolute rate of HVRI substitution estimated at 27.45% per million years. These findings have direct implications regarding the utility of HVRI data to generate a variety of evolutionary genetic hypotheses. [ABSTRACT FROM AUTHOR]

Ream, R. R. (2002). Molecular Ecology of North Pacific Otariids: Genetic Assessment of Northern Fur Seal and Steller Sea Lion Distributions. University of Washington. Retrieved from <u>https://search.proquest.com/asfa/docview/18604166/870362056EC4020PQ/1?accountid=2825</u> <u>8</u>

Using different classes of molecular markers, I conducted three independent studies to examine distributions of northern fur seals (Callorhinus ursinus) and Steller sea lions (Eumetopias jubatus). Molecular techniques were developed and applied to studies of population distribution, seasonal distribution, and gender distribution among sites and seasons. I used eight microsatellites to examine the genetic variability and to test for population differentiation among breeding islands across the range of the northern fur seal. Genetic variation was high, and significant differences in allele frequencies were observed over all loci and populations. However, there was little evidence of heterogeneity of allele frequencies at individual loci across populations, or in single or multilocus pairwise comparisons of populations. Estimates of F[sub]ST and R[sub]ST were low for all comparisons (F[sub]ST [le] 0.0043; R[sub]ST [le] 0.0373), and were not significant. Tests of isolation by distance revealed no correlation between geographic and genetic distance. Despite high levels of philopatry associated with both male and female northern fur seals, and extensive variation at the microsatellite loci, I found little evidence of genetic differentiation among breeding islands. Using mtDNA haplotypes determined from fecal samples collected non-invasively during the winter, I explored the seasonal distribution and migration patterns of Steller sea lions. I compared the observed winter haplotype composition to the known summer stock distribution and found evidence of few seasonal migrants between stocks. A mixed-stock analysis supported these findings, indicating that during winter 98.6% of the animals residing in the geographic region of the western stock originated from that stock. The results substantiate current management policies for the two sea lion stocks. Finally, using fecal samples and sex chromosome markers, I examined seasonal gender distribution, and composition, of Steller sea lions at rookery and haul-out sites. Females were the predominate gender identified from summer (72.5%) and winter (61.2%) samples. Within winter collections, the percentage of samples assigned to females at rookery and haulout sites was similar. The results indicate that terrestrial sites may be more important for females. Seasonal movement by females among sites, at least locally, is extensive and possibly reflects changes in prey availability or environmental conditions.

Richmond, J. P., Rea, L. D., & Zinn, S. A. (2010, Jul). *Steller Sea Lion (Eumetopias Jubatus) Leptin Cdna Sequence Homology.* Paper presented at the Integrative and Comparative Biology. Retrieved from <u>http://www.sicb.org/meetings/2010/schedule/abstractdetails.php3?id=523</u>

Increased circulating concentrations of leptin are observed with increased adiposity in most mammalian species, but this relationship is not clear in pinnipeds. This suggests that either leptin may be differentially regulated in pinnipeds or that contrasting results may be due to reduced sensitivity of multi-species assays used to quantify hormone concentrations. Either hypothesis necessitates an understanding of the sequence homology of leptin for experimentation. The objective of this research was to sequence leptin cDNA in Steller sea lions and determine the homology among various mammalian species. Adipose tissue was collected from free-ranging Steller sea lions (n=3). Total RNA was isolated from adipose tissue (Promega SV Total RNA Isolation), and quantified by spectrophotometric (NanoDrop 1000) and electrophoretic methods (Experion RNA StdSens Analysis). RNA was reverse transcribed to cDNA (Promega RT System) and amplified with canine leptin primers using standard PCR methods. The cDNA product was sequenced using 3130XL Genetic Analyzer. The cDNA sequence of Steller sea lions is 92% homologous with dog, but shares only 84% homology with

mouse. This difference in cDNA results in an inferred Steller sea lion protein sequence that shares approximately 89% and 74% homology with dog and mouse, respectively. Due to the differences in cDNA sequence between mouse and sea lions careful interpretation of results from studies that have used mouse based immunoassays must be employed. Results using mouse based immunoassays may be inaccurate due to variability in protein structure resulting in poor assay accuracy. Based on inferred protein structure, if heterologous assays must be used, antisera to canine leptin may have better potential for accurate assessment of sea lion leptin.

Ryu, J.-S., Jang, K. H., Choi, E. H., Kim, S. K., Ryu, S. H., Kim, Y.-J., . . . Hwang, U. W. (2010). Complete Mitochondrial Genome of a Steller Sea Lion *Eumetopias Jubatus* (Carnivora, Otariidae). *Mitochondrial DNA: The Journal of DNA Mapping, Sequencing & Analysis, 21*(2), 54-56. https://doi.org/10.3109/19401731003681111

The article offers information on the complete mitochondrial genome, *Eumetopias jubatus* of a Steller sea lion. As stated it is the second complete mitochondrial genome sequenced from this species. The complete mitochondrial genome consists of 13 protein coding, 22 tRNA, and 2 rRNA genes. A table is also presented showing the mitochondrial genome characteristics of *Eumetopias jubatus*.

Spitz, J., Becquet, V., Rosen, D. A. S., & Trites, A. W. (2015). A Nutrigenomic Approach to Detect Nutritional Stress from Gene Expression in Blood Samples Drawn from Steller Sea Lions. *Comparative Biochemistry and Physiology Part A Molecular & Integrative Physiology, 187*, 214-223. <u>https://doi.org/10.1016/j.cbpa.2015.02.006</u>

Gene expression profiles are increasingly being used as biomarkers to detect the physiological responses of a number of species to disease, nutrition, and other stressors. However, little attention has been given to using gene expression to assess the stressors and physiological status of marine mammals. We sought to develop and validate a nutrigenomic approach to quantify nutritional stress in Steller sea lions (*Eumetopias jubatus*). We subjected 4 female Steller sea lions to 3 feeding regimes over 70-day trials (unrestricted food intake, acute nutritional stress, and chronic nutritional stress), and drew blood samples from each animal at the end of each feeding regime. We then extracted the RNA of white blood cells and measured the response of 8 genes known to react to diet restriction in terrestrial mammals. Overall, we found that the genomic response of Steller sea lions experiencing nutritional stress was consistent with how terrestrial mammals respond to dietary restrictions. Our nutritionally stressed sea lions down-regulated some cellular processes involved in immune response and oxidative stress, and upregulated pro-inflammatory responses and metabolic processes. Nutrigenomics appears to be a promising means to monitor nutritional status and contribute to mitigation measures needed to assist in the recovery of Steller sea lions and other at-risk species of marine mammals.

Trujillo, R. G., Loughlin, T. R., Gemmell, N. J., Patton, J. C., & Bickham, J. W. (2004). Variation in Microsatellites and Mtdna across the Range of the Steller Sea Lion, *Eumetopias Jubatus. Journal* of Mammalogy, 85(2), 338-346. <u>https://doi.org/10.1644/1545-</u> <u>1542(2004)085<0338:VIMAMA>2.0.CO;2</u> Genetic variation at 6 nuclear microsatellite loci with biparental inheritance and the maternally inherited mitochondrial DNA (mtDNA) was studied at 3 geographic scales (rookeries, regions, and stocks) in Steller sea lions (*Eumetopias jubatus*). Genetic variation was high in both nuclear and mtDNA markers as revealed by a near range-wide survey of 21 rookeries. However, population structure was not well defined, and there was no obvious phylogeographic pattern to the distribution of microsatellite alleles. This contrasts with a clear phylogeographic pattern revealed by control-region sequences of mtDNA in which 2 well-differentiated stocks, eastern and western, are defined as well as 2 distinct groups, Asian and central, in the western stock. Effective migration estimates are consistently higher for the nuclear loci than for mtDNA. The difference in patterns between the biparentally and maternally inherited genetic markers can be explained by relatively high male dispersal rates and female philopatry, or else there has been insufficient time since populations have been isolated for the nuclear loci to have diverged. It is recommended that the presently accepted stock structure be retained for management purposes and that further studies be carried out to test the male dispersal hypothesis.

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. <u>https://doi.org/10.1111/j.1755-0998.2010.02874.x</u>

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.

Section VII: Habitat and Critical Habitat

Ban, S., & Trites, A. W. (2007). Quantification of Terrestrial Haul-out and Rookery Characteristics of Steller Sea Lions. *Marine Mammal Science*, 23(3), 496-507. <u>https://doi.org/10.1111/j.1748-7692.2007.00130.x</u>

Steller sea lions (*Eumetopias jubatus*) are known to have occupied the same terrestrial haul-out and rookery sites across the North Pacific Rim for centuries, but it is not known why they choose and stay at these locations, or what defines their preferred habitat. Classifying and comparing the shoreline type of haul-outs and rookeries against sites not used by Steller sea lions showed that they preferentially locate their haul-outs and rookeries on exposed rocky shorelines and wave-cut platforms. However, no preference was found for selecting rookeries on sheltered shore types. Shoreline types used less frequently by sea lions included fine-to-medium-grained sand beaches, mixed sand and gravel beaches, gravel beaches, and sheltered rocky shores. Quantifying the shoreline types used by sea lions confirms

anecdotal reports of habitat preferences and may prove useful in identifying and protecting sea lion terrestrial habitat, or in forecasting how climate change might affect the distribution of sea lions.

Ban, S. S. (2005). Modelling and Characterization of Steller Sea Lion Haulouts and Rookeries Using Oceanographic and Shoreline Type Data. University of British Columbia, Retrieved from http://www.marinemammal.org/wp-content/pdfs/Ban_2005.pdf

Steller sea lions range across the Pacific rim from Southern California in the east to northern Japan in the west, where they have continuously occupied terrestrial resting sites (haulouts) and breeding sites (rookeries) for hundreds of years, if not longer. Why they choose (and stay) at these locations, and what their preferred habitat is, remains unknown. Thus, two aspects of the Steller sea lion's habitat usage were examined—the oceanographic and the terrestrial. For the oceanographic aspect, spatial models were constructed to determine which oceanographic factors are associated with haulouts and rookeries, and how conditions near sites might differ from conditions elsewhere. The two modelling techniques employed (logistic regression and supervised classification) were evaluated using the kappa statistic (Kno), and receiver-operating characteristic (ROC) plots. Supervised classification was found to produce better-fitting models than logistic regression.

Call, K. A., & Loughlin, T. R. (2005). An Ecological Classification of Alaskan Steller Sea Lion (*Eumetopias Jubatus*) Rookeries: A Tool for Conservation/Management. *Fisheries Oceanography*, 14, 212-222. <u>https://doi.org/10.1111/j.1365-2419.2005.00370.x</u>

As the western stock of Steller sea lions continues to decline, government managers may place additional controls on commercial fisheries as protective measures. Currently, management decisions regarding rookeries are based largely on the geographic location of a site, and little effort has been made to describe sea lion rookeries in an ecosystem context. We provide a broad ecological characterization of rookeries for the western stock of Steller sea lions, which can be used in making management decisions to facilitate their recovery. We gathered data on habitat (bathymetry, sea surface temperature, substrate type, and orientation), diet and population trends from available literature and National Marine Fisheries Service databases (1990-98), and we used a Geographic Information System to group sea lion rookeries into ecologically related regions. Ecological attributes were assigned to rookeries within a 10-nm radius of land. Regions were determined using cluster analysis. Five distinct classes of rookeries (i.e. potential management regions) were identified based on their relatedness to the ecological factors we defined. Several of the regional breaks occur at major oceanic passes including Amchitka, Samalga, and Unimak Passes and are associated with ocean currents.

 Fritz, L. W. (1993). Estimated Catches of Walleye Pollock, Atka Mackerel and Pacific Cod within Critical Habitat of the Steller Sea Lion in the Bering Sea, Aleutian Islands and Gulf of Alaska from 1977-92. National Marine Fisheries Service Alaska Fisheries Science Center. AFSC Processed Report 93-13. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/11959</u>

This report contains annual and first quarter catch estimates of warleye pollock, Pacific cod and Atka rnackerel by foreign, joint-venture, and domestic fisheries within designated critical habitat of the Steller sea lion (59 FR 17181) in the Bering sea and Aleutian Islands (BSAI) and Gulf of Alaska (GOA) from 1977-92. Data are plotted as both species catch estimates and percent of regional (BSAI and GOA)

species catch taken from the three types of critical habitat (within 20 nautical miles of rookeries and haulouts, and within aquatic foraging areas) each year and first quarter. Trends in removals from critical habitat from 1977-92 are described in light of the changes in the composition and management of the region's groundfish fisheries.

 Fritz, L. W. (1993). Observed Catches of Groundfish and Selected Bycatch Species within Critical Habitat of the Steller Sea Lion in the Bering Sea, Aleutian Islands, and Gulf of Alaska from 1977-92.
 National Marine Fisheries Service Alaska Fisheries Science Center. AFSC Processed Report 93-07 Retrieved from <u>https://repository.library.noaa.gov/view/noaa/11958</u>

This report contains tables of observed catches of groundfish and selected bycatch species by foreign joint venture, and domestic fisheries within designated critical habitat of the Steller sea lion (58 FR L7181) in the Bering sea and Aleutian Islands (BSAI; INPFC areas 5L-55) and Gulf of Alaska (GOA; INPFC areas 61-64).

Gregr, E. J., Ban, S., Coatta, R., & Trites, A. W. (2005, Sep 2005). *Ecological Characterization of Steller Sea Lion Rookeries and Haulouts in the North Pacific.* Paper presented at the North Pacific Marine Science Organization 14th Annual Meeting. Retrieved from http://www.pices.int/meetings/annual/PICES14/BookOfAbstracts/Abstracts S3.doc

Steller sea lions (Eumetopias jubatus) range across the North Pacific rim, from Southern California in the east, to Russia and northern Japan in the west. They are consistently found at a few select terrestrial resting (haulouts) and breeding (rookeries) sites, which appear to have been continuously occupied for hundreds of years. We characterized the oceanographic habitat surrounding these sites in Canada, the United States, Russia and Japan to investigate how conditions at these sites might differ from conditions near sites in the North Pacific where sea lions did not occur. Environmental variables included depth, slope, monthly sea surface height, and monthly winds. We used supervised classification to identify the combination of oceanographic variables that were most closely associated with the sites in the eastern North Pacific. We then predicted where terrestrial sites might be in the western North Pacific, and tested our classification-based predictions using a randomization test. We tested for significant differences between haulouts and rookeries, and between the eastern and western North Pacific. Preliminary results indicate that sea lions show preferences for terrestrial sites located near shallow waters and less-steep bottom slopes. Conditions closer to the terrestrial sites (1-5 km) provided a better characterization of occupied sea lion sites than conditions further away (over 10 km). No significant differences were found between sites in the eastern vs. western North Pacific, or between haulouts and rookeries.

 Harington, C. R., Ross, R. L. M., Mathewes, R. W., Stewart, K. M., & Beattie, O. (2004). A Late Pleistocene Steller Sea Lion (*Eumetopias Jubatus*) from Courtenay, British Columbia: Its Death, Associated Biota, and Paleoenvironment. *Canadian Journal of Earth Sciences*, 41(11), 1285-1297. https://doi.org/10.1139/e04-061

A partial juvenile Steller sea lion (*Eumetopias jubatus*) skeleton from nearshore marine sands at Courtenay, Vancouver Island, British Columbia has been radiocarbon dated to 12570+/-70 BR This date is supported by both stratigraphic and regional sea-level emergence data and is similar to radiocarbon

dates on a Steller sea lion humerus from Bowen Island, just north of Vancouver. The juvenile apparently died from a blow to the braincase, most likely caused by a Steller sea lion bull. The Courtenay specimen is significant since very few Pleistocene otariid fossils are complete enough to be assigned to modern taxa. Associated mollusk remains indicate that the marine paleoclimate of the fossil locality was considerably colder than now-close to that along the northern reaches of Cook Inlet and Prince William Sound, Alaska. Pollen and plant macrofossils collected from the Courtenay site clearly demonstrate the presence of lodgepole pine (Pinus contorta) forests nearby during this early late-glacial interval. Fish remains (mainly Pacific cod and walleye pollock, with some salmon) from this site probably reflect selection by adult sea lions at a rookery.

Himes Boor, G. K., & Small, R. J. (2012). Steller Sea Lion Spatial-Use Patterns Derived from a Bayesian Model of Opportunistic Observations. *Marine Mammal Science, 28*(4), E375-E403. https://doi.org/10.1111/j.1748-7692.2011.00541.x

Abstract Despite acquisition of a substantial catalog of telemetry data from Steller sea lions (*Eumetopias jubatus*) over the past two decades, scientists still lack comprehensive regionally explicit knowledge about Steller sea lion habitat use. The Platforms of Opportunity data contain records of Steller sea lion sightings throughout the species' entire range and have potential to fill gaps in knowledge about their spatial use; however, the data have not previously been used because effort (e.g., time spent surveying or area sampled) was not recorded when sightings were obtained. For this study a novel approach was used to overcome the lack of effort data through development of an effort index and a Bayesian negative binomial model. The model quantified Steller sea lion encounter rates and associated uncertainty within 15×15 km2 grid cells across the species' entire range. Year-round, as well as breeding and nonbreeding season encounter rates were estimated. The results of this analysis identify several previously undocumented areas of high use by Steller sea lions, indicate that only 37% of Steller sea lion high-use areas fall within designated critical habitat, and demonstrate that use of depth and distance from shore as indicators of Steller sea lion habitat is contraindicated.

Hollowed, A. B., Logerwell, E., Isquith, R., & Wilson, C. (2006). The Impact of Regime Shifts on the Oceanography of the Northern Gulf of Alaska and Its Influence on the Species Interactions between Walleye Pollock, Capelin, and Steller Sea Lions. Slides presented at PICES 15 Annual Meeting. Retrieved from

https://pices.int/publications/presentations/PICES_15/Ann15_CCCC_paper/CCCC_Hollowed.pdf

Recent studies of the oceanography of the eastside of Kodiak Island have revealed a complex system of pelagic ocean habitats. Acoustic surveys reveal that these habitats serve to partition marine fishes across the shelf. We hypothesize that the ocean conditions prior to the 1976/77 regime shift differed from the present resulting in a more diverse mix of forage species across the shelf. To test this hypothesis, we reconstructed the pre-regime shift ocean conditions using data collected during oceanographic surveys conducted in the region in 1961, 1973 and 1974 and compare the system to present day conditions. We reconstructed the distribution of walleye pollock in over the central GOA shelf from NMFS stock assessment surveys and other field research efforts. Physical oceanographic data were used to describe surface and subsurface temperature fields and ocean currents from current moorings placed in the region in the early 1970s and early 2000s. Results of this paper provide new insight into the impact of the regime shift on the availability and diversity of prey to top trophic level

consumers. Our work also provides a baseline for understanding the processes controlling competition, resource partitioning, and other species interactions among forage species in the region.

Lander, M. E. (2008). Population Dynamics and Behaviors of Juvenile Steller Sea Lions (Eumetopias Jubatus) with Respect to Environmental Heterogeneity: Finding the Links. University of Washington. Retrieved from <u>https://search.proquest.com/asfa/docview/20223211/28B397C06AD640F3PQ/1?accountid=282</u> 58

Among many other factors, the decline of the western stock of Steller sea lions (Eumetopias jubatus) in Alaska has been attributed to changes in the distribution or abundance of prey due to large scale environmental perturbations. It is necessary, therefore, to assess how Steller sea lions alter their distribution or foraging strategies in response to spatial and temporal changes of local oceanographic processes, which ultimately affect the distribution of prey. The overall goal of my dissertation was to use a multi-scale approach to examine the spatial patterns of juvenile Steller sea lions with respect to the composition and configuration of environmental heterogeneity. Habitat use and spatially explicit diving behaviors were assessed by deploying satellite transmitters on juvenile Steller sea lions (n=76) from 2000-2004 within areas of the Aleutian Islands and Gulf of Alaska. A hierarchical approach was used to examine the population dynamics, distribution, and behavior of juvenile Steller sea lions in response to quantitative metrics used to characterize patterns of environmental variables (sea surface temperature (SST), chlorophyll-a, and bathymetry) related to habitat use. At larger spatial and temporal scales, intermediate spatial heterogeneity of chlorophyll-a and maximum spatial heterogeneity coupled with minimal temporal variability of SST appeared to promote population increase. At intermediate spatial scales, point pattern distributions of Steller sea lions at sea displayed scale invariant fractal properties, but were not significantly related to SST patchiness or bathymetric measurements of fractal dimension. At smaller spatial and temporal scales, multivariate analyses indicated that fractal dimension, edge density, and patch area of SST habitat were statistically significant factors for predicting different aspects of foraging effort (mean trip duration, maximum trip duration, and percentage of time spent diving). Furthermore, a combination of many short trip durations and infrequent long trip durations conforming to a power law relationship suggested that sea lions perform Levy walks, an optimal search strategy for resources that are scarce or distributed with a fractal pattern. The mechanisms underlying Steller sea lion and environmental patterns remain uncertain; hence, future studies on small-scale features will ultimately be important for understanding the biogeography of this species and developing additional conservation strategies.

Lander, M. E., Fritz, L. W., Johnson, D. S., & Logsdon, M. G. (2013). Population Trends of Steller Sea Lions (*Eumetopias Jubatus*) with Respect to Remote Sensing Measures of Chlorophyll-a in Critical Habitat. *Marine Biology*, 160(1), 195-209. <u>https://doi.org/10.1007/s00227-012-2077-4</u>

The recovery plan for Steller sea lions (SSL; *Eumetopias jubatus*) suggests critical habitat should be enhanced to incorporate the spatio-temporal variation in dynamic oceanographic features that influence the prey and survival of SSL. It is necessary, therefore, to determine which features affect SSL. Demographics for sub-regions of the endangered, western stock of SSL were examined with respect to corresponding average, maximum, and variance of chlorophyll-a data (SeaWIFS), a proxy for primary productivity. Overall, SSL trends (2000-2008) and pup productivity (1999-2009) were related to maximum values of chl-a in critical habitat. Additionally, conditions in critical habitat appeared worse in areas of decline (i.e., dispersed patterns of chl-a hotspots and greater distances from SSL sites to productive areas). Although there may be a low feasibility of mitigating the effects of dynamic features on the recovery of SSL, the interactive effects of primary productivity and other stressors should be investigated for safeguarding their prey.

Lander, M. E., Loughlin, T. R., Logsdon, M. G., VanBlaricom, G. R., Fadely, B. S., & Fritz, L. W. (2009). Regional Differences in the Spatial and Temporal Heterogeneity of Oceanographic Habitat Used by Steller Sea Lions. *Ecological Applications* 19(6), 1645-1659. <u>https://doi.org/10.1890/08-0159.1</u>

Over the past three decades, the decline and altered spatial distribution of the western stock of Steller sea lions (Eumetopias jubatus) in Alaska have been attributed to changes in the distribution or abundance of their prey due to the cumulative effects of fisheries and environmental perturbations. During this period, dietary prey occurrence and diet diversity were related to population decline within metapopulation regions of the western stock of Steller sea lions, suggesting that environmental conditions may be variable among regions. The objective of this study, therefore, was to examine regional differences in the spatial and temporal heterogeneity of oceanographic habitat used by Steller sea lions within the context of recent measures of diet diversity and population trajectories. Habitat use was assessed by deploying satellite-depth recorders and satellite relay data loggers on juvenile Steller sea lions (n = 45) over a five-year period (2000-2004) within four regions of the western stock, including the western, central, and eastern Aleutian Islands, and central Gulf of Alaska. Areas used by sea lions during summer months (June, July, and August) were demarcated using satellite telemetry data and characterized by environmental variables (sea surface temperature [SST] and chlorophyll a [chl a]), which possibly serve as proxies for environmental processes or prey. Spatial patterns of SST diversity and Steller sea lion population trends among regions were fairly consistent with trends reported for diet studies, possibly indicating a link between environmental diversity, prey diversity, and distribution or abundance of Steller sea lions. Overall, maximum spatial heterogeneity coupled with minimal temporal variability of SST appeared to be beneficial for Steller sea lions. In contrast, these patterns were not consistent for chl a, and there appeared to be an ecological threshold. Understanding how Steller sea lions respond to measures of environmental heterogeneity will ultimately be useful for implementing ecosystem management approaches and developing additional conservation strategies.

Lander, M. E., Loughlin, T. R., Logsdon, M. G., VanBlaricom, G. R., & Fadely, B. S. (2010). Foraging Effort of Juvenile Steller Sea Lions *Eumetopias Jubatus* with Respect to Heterogeneity of Sea Surface Temperature. *Endangered Species Research*, 10, 145-158. <u>https://doi.org/10.3354/esr00260</u>

Among many other factors, the decline of the western distinct population segment of Steller sea lions *Eumetopias jubatus* in Alaska (USA) has been attributed to changes in the distribution or abundance of prey due to the cumulative effects of fisheries and large-scale climate change. However, the depletion of localized prey resources due to small-scale environmental variability and perturbations may be impeding recovery, resulting in the need to understand how the environment currently affects this species on smaller spatial and temporal scales. The objective of this study, therefore, was to assess how Steller sea lions respond to changes in localized environmental features. Satellite-relayed data loggers were deployed on juvenile Steller sea lions (n = 24) from July 2002 to May 2004 in the Aleutian Islands and Gulf of Alaska. Weekly indices of foraging effort (mean and maximum trip duration, diving activity) of Steller sea lions were examined with respect to corresponding patterns of sea surface temperature (SST)

data obtained from the moderate resolution imaging spectroradiometer. An assortment of landscape metrics was used to characterize the heterogeneity of frontal features derived from SST gradients because it has been suggested that Steller sea lions depend on prey patches associated with these features. Multivariate analyses indicated that fractal dimension and patch density of frontal features were significant factors for predicting different aspects of foraging effort (p < 0.05; n = 6 models). Overall, results suggested that aggregated frontal features associated with small-scale temperature gradients were probably conducive to foraging effort of Steller sea lions, but additional mechanisms should be investigated further.

National Marine Fisheries Service. (1993). Environmental Assessment of a National Marine Fisheries Service Action to Designate Critical Habitat for Steller Sea Lions. Retrieved from https://repository.library.noaa.gov/view/noaa/17334

This environmental assessment (EA) was prepared to analyze the environmental and economic effects of designating critical habitat for the Stellar sea lion, a species listed as threatened under the Endangered Species Act (ESA). The National Marine Fisheries sarvico (NMFS) is proposing to designate (1) all Steller sea lion rookeries and major haulouts (i.e. >200 Steller aea lions) located within state and federally managed waters off Alaska, including a zone that extends 3,000 feet (0.9 km) landward and vertical of each rookery and major haulout boundary and that extends either 3,000 feet (0.9 km) seaward from rookaries and major haulouts in Alaska located east of 144 W. longitude, ·or 20-nm seaward from rookeries and major haulout sites west of 144 W. longitude; (2) all Steller sea lion rookeries in state And federally managed waters off Washington, Oregon and California, including the zone that extends 3,000 feet (0.9 km) vertical and seaward from each rookery; and (3) three aquatic foraging habitats within the core ot the Steller sea lion's geographic range, one aquatic zone located exclusively in the Gulf of Alaska (GOA), and two aquatic zones in the Bering Sea/Aleutian Islands area (BSAI). No adverse environmental or economic effects are e.xpected to result from the proposed critical habitat designation.

 Schaufler, L., Logerwell, E., & Vollenweider, J. (2006). Geographical Variation in Steller Sea Lion Prey Quality in Alaska. In Sea Lions of the World. A.W. Trites, S.K. Atkinson, D.P. DeMaster, L.W. Fritz, T.S. Gelatt, L.D. Rea, and K.M. Wynne (Eds.) Sea Grant Alaska. <u>https://doi.org/10.4027/slw.2006.09</u>

Nutritional stress is one of the leading hypotheses explaining the decline in Steller sea lion populations of the western stock. Central to this hypothesis is the possibility that western stock sea lions encounter prey of significantly lower quality than those from the eastern stock. We collected and analyzed over 1,200 whole fish representing species identified as sea lion prey items from the Aleutian Islands and southeastern Alaska, including species that reside in both regions. We present proximate composition and calculated mean energy densities based on the lipid and protein contents for the sampled fish. Initial comparisons of the proximate compositions and energy densities between the Aleutian Islands and southeastern Alaska fish on a species basis revealed significant differences in prey energetic content in the two regions for the sampled prey. Overall, the mean energy density for 22 forage species from southeastern Alaska (1.62 +/- 0.02 kcal per g on a wet weight basis) was greater than that of 15 species from the Aleutians (1.44 +/- 0.03 kcal per g), but these variations could be attributed to size differences among the fish sampled from the two regions as well as species composition and collection season differences. For example, Pacific cod sampled from the Aleutians were significantly larger (p < 0.001)

than those from southeastern Alaska and had a higher energy density (p < 0.001). However, controlling for size revealed no difference in energy density between the two populations of cod (p > 0.5). Similarly accounting for size, no difference was found in the energy density of walleye pollock or arrowtooth flounder from the two locations. In contrast, squid and sandfish from southeastern Alaska had higher energy densities (p < 0.01) while Aleutian rockfish had higher energy densities than those from southeastern Alaska (p < 0.001), though these may represent seasonal and species composition differences. These data reveal the importance of considering size, season, and species when making energy density comparisons of the available prey between geographical regions.

Stewart, B. S., Antonelis, G. A., Baker, J. D., & Yochem, P. K. (2006). Foraging Biogeography of Hawaiian Monk Seals in the Northwestern Hawaiian Islands. *Atoll Research Bulletin* Retrieved from https://www.pifsc.noaa.gov/library/pubs/StewartARB543_Final.pdf

The extant population of Hawaiian monk seal (Monachus schauinslandi) numbers around 1, 00 distributed among six island atolls in the remote Northwestern Hawaiian Islands (NWHI) and at several small, emerging colonies on the Main Hawaiian Islands. Demographic studies have identified poor juvenile survival as the ultimate primary cause of substantial declines at all colonies and of slow recent recovery at some. Variable foraging success may be a key proximate effect, but the knowledge of habitat needs of foraging monk seals has not been adequate to test that hypothesis nor to provide management with the necessary information to address resource conservation issues. We documented the geographic and vertical foraging patterns of 1 Hawaiian monk seals from all six NWHI breeding colonies from 1 through 00 to describe the marine habitats that may be key to the species' viability. We found that seals foraged extensively within barrier reefs of the atolls and on the leeward slopes of reefs and islands at all colony sites. They also ranged away from these sites along the Hawaiian Islands Archipelago submarine ridge to most nearby seamounts and submerged reefs and banks. Most dives were less than 10 m deep, though dives of some seals exceeded 0 m. Suitable foraging habitat may be a resource limiting the population of monk seals in the NWHI. Moreover, the foraging biogeography of Hawaiian monk seals may vary spatially and temporally with variation in the extent of physical substrate, prey community composition and species' abundance, and demographic composition of seal colonies.

Stricker, C. A., Christ, A. M., Wunder, M. B., Doll, A. C., Farley, S. D., Rea, L. D., . . . Tollit, D. J. (2015). Stable Carbon and Nitrogen Isotope Trophic Enrichment Factors for Steller Sea Lion Vibrissae Relative to Milk and Fish/Invertebrate Diets. *Marine Ecology Progress Series, 523*, 255-266. <u>https://doi.org/10.3354/meps11205</u>

Nutritional constraints have been proposed as a contributor to population declines in the endangered Steller sea lion *Eumetopias jubatus* in some regions of the North Pacific. Isotopic analysis of vibrissae (whiskers) is a potentially useful approach to resolving the nutritional ecology of this species because long-term (up to 8 yr) dietary information is sequentially recorded and metabolically inert once formed. Additionally, vibrissae are grown in utero, potentially offering indirect inference on maternal diet. However, diet reconstruction using isotopic techniques requires a priori knowledge of trophic enrichment factors (TEFs), which can vary relative to diet quality and among animal species. In this study, we provide new TEF estimates for (1) maternal relative to pup vibrissae during both gestation and nursing and (2) adult vibrissae relative to a complex diet. Further, we refine vibrissa-milk TEFs based on an additional 76 animals with an age distribution ranging from 1 to 20 mo. Mother-pup vibrissae TEF values during gestation and nursing were near zero for delta C-13 and averaged 0.8 and 1.6%,
respectively, for delta N-15. In contrast, vibrissa-fish/invertebrate TEFs averaged 3.3 (+/- 0.3 SD) and 3.7% (+/- 0.3) for lipid-free delta C-13 and delta N-15, respectively. Average lipid-free d(13)C and d(15)N vibrissa-milk TEFs were 2.5 (+/- 0.9) and 1.8% (+/- 0.8), respectively, and did not differ among metapopulations. Empirically determined TEFs are critical for accurate retrospective diet modeling, particularly for evaluating the hypothesis of nutritional deficiency contributing to the lack of Steller sea lion population recovery in some regions of Alaska.

Thedinga, J. F., Johnson, S. W., & Csepp, D. J. (2006). *Nearshore Fish Assemblages in the Vicinity of Two Steller Sea Lion Haul-Outs in Southeastern Alaska*. <u>https://doi.org/10.4027/slw.2006.19</u>

To better understand Steller sea lion foraging ecology, information is needed on the species composition, abundance, and seasonality of prey species, especially in nearshore waters adjacent to rookeries and haul-outs. From 2001 to 2004, we examined nearshore fish assemblages in summer and winter in the vicinity of two Steller sea lion haul-outs, Benjamin Island and The Brothers Islands, in southeastern Alaska. Fish were captured in nearshore waters (< 115 m deep, < 350 m from shore) by beach seining and hand-jigging; we also observed fish assemblages with a remotely operated vehicle (ROV). Total catch by seining and jigging for all sampling periods was 201,331 fish and 559 fish; 58 species were identified in summer and 44 species in winter. Seine catches were dominated by young-ofthe-year walleye pollock, Pacific herring, and Pacific sand lance in summer, and salmon fry, armorhead sculpin, and rock sole in winter. Jig catches were dominated by armorhead sculpin, Pacific cod, and two rockfish species in summer and winter. Twenty-seven. species were observed with the ROV; seven of these species were not captured by seining or jigging. Catch and number of fish species were greater in summer than in winter and greater at The Brothers Islands than at Benjamin Island. Most fish captured by seining were too small (median fork length [FL] < 81 mm) to be consumed by Steller sea lions, whereas most fish captured by jigging or observed with the ROV were large enough (median FL > 248 mm) to be consumed by Steller sea lions. Inclusive of all sampling methods, 34 of the species inventoried have been identified in Steller sea lion scat collected at either haul-out. Although the extent of Steller sea lion foraging in nearshore waters surrounding Benjamin Island and The Brothers Islands is unclear, a diverse fish assemblage is present at both locations and may be an important prey field for Steller sea lions.

Section VIII: Movements and Distribution

Bishop, A., Brown, C., Rehberg, M., Torres, L., & Horning, M. (2018). Juvenile Steller Sea Lion (*Eumetopias Jubatus*) Utilization Distributions in the Gulf of Alaska. *Movement Ecology, 6* <u>https://doi.org/10.1186/s40462-018-0124-6</u>

Background: A utilization distribution quantifies the temporal and spatial probability of space use for individuals or populations. These patterns in movement arise from individuals' internal state and from their response to the external environment, and thus can provide insights for assessing factors associated with the management of threatened populations. The Western Distinct Population Segment of the Steller sea lion (*Eumetopias jubatus*) has declined to approximately 20% of levels encountered 40 years ago. At the height of the decline, juvenile survival appeared to be depressed and currently there is evidence that juvenile mortality due to predation may be constraining recovery in some regions.

Therefore, our objectives were to identify what spaces are biologically important to juvenile Steller sea lions in the Kenai Fjords and Prince William Sound regions of the Gulf of Alaska. Methods: We examined geospatial location data from juvenile sea lions tagged between 2000 and 2014 (n = 84) and derived individual and pooled-population utilization distributions (UDs) from their movements. Core areas were defined from the UDs using an individual-based approach; this quantitatively confirmed that all individuals in our sample exhibited concentrated use within their home range (95% UD). Finally, we explored if variation in UD characteristics were associated with sex, season, age, or region. Results: We found evidence that individual juvenile home ranges were region and sex-specific, with males having larger home ranges on average. Core space characteristics were also sex-specific, and exhibited seasonal patterns of reduced size, increased proximity to haulouts, and increased intensity of use in the summer, but only in the Kenai Fjords-Gulf of Alaska region. Conclusions: This study highlights the areas of biological importance during this vulnerable life history stage, and the demographic, seasonal, and spatial factors associated with variation in movement patterns for a marine mesopredator. This can be useful information for promoting species recovery, and for future efforts to understand ecological patterns such as predator-prey interactions.

Boeskorov, G. G., Davydov, S. P., Kochnev, A. A., & Lang, E. M. (2011). Penetration of the Steller's Sea Lion (*Eumetopias Jubatus*) into Waters of the Chukchi and East-Siberian Seas. *Zoologichesky Zhurnal*, 90(1), 123-128. Retrieved from

http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch &qid=15&SID=8AKBSJ5RixL6hagr5Wp&page=1&doc=1

The penetration of Steller's sea lions into the waters of the Chukchi and East-Siberian seas to the west from Bering Strait, beyond the limits of the northern part of their main area are discussed. The information collected by the authors during their own investigations and inquiry of local people and officers of different services, showed that at the end of the 1970s-1980s, Steller's sea lions started to penetrate regularly into the waters of the Chukchi and East-Siberian seas. They appeared to the west of the Kolyma river mouth and in the mouth of other rivers, especially frequently in the 2000s. Such far penetrations of the Steller's sea lions in the western direction may be connected with the phenomenon of global warming that resulted in the decrease of the ice cover in the Chukchi and East-Siberian Seas and rise of water temperature. The northern seas investigated appeared to become more attractive for these seals normally inhabiting warmer seas. Probably, the first stage of the colonization of new territories by the Steller's sea lions was revealed.

Burkanov, V. N., & Loughlin, T. R. (2005). Distribution and Abundance of Steller Sea Lions, *Eumetopias Jubatus*, on the Asian Coast, 1720's-2005. *Marine Fisheries Review*, 67(2), 1-62. Retrieved from https://spo.NMFS.noaa.gov/mfr672/mfr6721.pdf

We analyzed published and archived records for the past 250 years to assess changes in distribution and abundance of Steller sea lions, *Eumetopias jubatus*, along the Asian coast from the Bering Strait to the Korean Peninsula. We found that the northern extent of Steller sea lion distribution has not changed but that the southern limit has moved north by some 500–900 km (~300–500 n.mi.) over the past 50 years. Additionally, the number of animals and their distribution has changed on the Commander Islands, Kuril Islands, and Kamchatka Peninsula. We found no changes in the number of rookeries in the northern Sea of Okhotsk, but a new rookery was established at Tuleny Island on the eastern coast of Sakhalin Island. We estimate that the total abundance of Steller sea lions along the Asian coast in the late 19th century

was about 115,000 animals; during the 1960's, the total estimate was about 27,000 (including pups), most of which were in the Kuril Islands. The fewest number of Steller sea lions occurred in the northwestern Pacific in the late 1980's-early 1990's when only about 13,000 individuals (including pups) were estimated in the entire region. During the 1990's, and especially in early 2000, an increasing trend in abundance occurred in most areas. Present estimated abundance of Steller sea lions in Asia is about 16,000 individuals (including about 5,000 pups), about half of which occur in the Kuril Islands. Changes in abundance occurred during all time periods but varied by site and period. Specifically, over the past 150 years Steller sea lion abundance at most sites has changed. There were no rookeries on the Commander Islands between 1850 and 1960 and abundance was low, but by 1977, abundance increased to 4,800 individuals and a rookery was established in the mid 1980's; abundance there has declined since the early 1980's and in 2004 only 895 individuals (including 221 pups) were counted during the breeding season. Between 1940 and 2004, abundance along the eastern coast of Kamchatka declined from ~7,000 to ~600 individuals, an overall reduction of 90%. Steller sea lion abundance on the Kuril Islands declined by >90% from the 1800's to 2005; the most severe decline there occurred during 1969–1981. Steller sea lion numbers in the northern part of the Sea of Okhotsk declined during 1930–2002 from 7,200 to 3,100 individuals. Numbers at Tuleny Island have increased since establishment of a rookery there during 1983–2005 and by immigration from other sites.

Byrd, G. V. (1997). Wildlife Observations at Walrus Island, Pribilof Islands, Alaska, July 24, 1997. United States Fish and Wildlife Service. AMNWR 97/14. Retrieved from https://www.arlis.org/docs/vol1/76878637.pdf

On July 20, 2006, a team of biologists from Alaska Maritime National Wildlife Refuge with support from National Marine Fisheries Service and International Pacific Halibut Commission volunteers, conducted a survey of wildlife on Walrus Island, Pribilof Islands, Alaska. Walrus Island is designated an "intermittent" monitoring site on the Refuge, meaning that it should be surveyed at least every 10 years. The primary breeding species in 2006 were red-faced cormorant (68 birds and 7 nests), common murre (679 birds), black-legged kittiwake (154 birds and 20 nests), and Steller sea lion (159 adults and 27 pups). Results of this survey show continued decrease in numbers of common and thick-billed murres, but more black-legged kittiwakes were counted in 2006 than in previous surveys (1987 and 1997). In addition, the number of northern fur seals recorded by the Refuge on the island has risen sharply (1 in 1987, 15 in 1997, and 120 in 2006).

Calkins, D. G., & Pitcher, K. W. (1982). *Population Assessment, Ecology and Trophic Relationships of Steller Sea Lions in the Gulf of Alaska.* Outer Continental Shelf Environmental Assessment Program, U. S. Department of the Interior Final Report: Research Unit 243. ACE 8094521. Retrieved from <u>https://www.boem.gov/ESPIS/0/310.pdf</u>

This report discusses distribution and abundance, rookery structure and composition, movements, food habits, reproduction, and population characteristics of Steller sea lions in the Gulf of Alaska.

Ceballos, G., Pompa, S., Espinoza, E., & García, A. (2010). Extralimital Distribution of Galapagos (Zalophus Wollebaeki) and Northern (*Eumetopias Jubatus*) Sea Lions in Mexico. *Aquatic Mammals*, *36*(2), 188-194. <u>https://doi.org/10.1578/AM.36.2.2010.188</u>

Global pinniped distribution is greatly determined by changes in sea surface temperature. El Niño events also have been reported to directly influence pinniped distribution. These events have increased in frequency and intensity changing the foraging ecology of the two pinniped species analyzed. In this paper, we present new extralimital records of distribution of two species rarely found in Mexican waters: the Galapagos (Zalophus wollebaeki) and the Northern (*Eumetopias jubatus*) sea lions. Three adult Z. wollebaeki were found in Chiapas, and one E. jubatus was recorded off the coasts of Colimaboth exceeding the maximum reported extralimital distance. These new records increase the number of marine mammal species recorded in Mexico and add evidence to the fact that large-scale climatic variation and possible effects of global warming shift the distribution of marine mammals.

Chumbley, K. (1998). *Winter Steller Sea Lion Prey and Foraging Studies, (Cruise SMMOCI 98I) 4-25 March 1998.* National Marine Fisheries Service Alaska Fisheries Science Center AFSC Processed Report 98-10. Retrieved from https://www.afsc.noaa.gov/Publications/ProcRpt/PR1998-10.pdf

Beginning in 1991, the National Marine Mammal Laboratory G has been partiallyfunded by the National Marine Fisheries Service's (NÀÆS) Office ofProtected Resources to determine the abundance of selected species in U. S. waters of the eastern North Pacific Ocean. 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 had regulated fisheries-related incidental takes since 1988. The 1994 MMPA amendments continue NMFS' responsibility to carry out population studies to determine the abundance, distribution and stock identification of marine mammal species that might be impacted by human-related or natural causes. The following report, containing 18 papers, is a compilation of studies carried out with fiscal year 1997 (FY97) funding as part of the NMFS MMPAÆSA Implementation Program. The report contains information regarding studies conducted on beluga whales, Dall's porpoise, harbor porpoise, harbor seals, humpback whales, northern fur seals, and Steller sea lions.

Edgell, T. C., & Demarchi, M. W. (2012). California and Steller Sea Lion Use of a Major Winter Haulout in the Salish Sea over 45 Years. *Marine Ecology Progress Series, 467,* 253-262. <u>https://doi.org/10.3354/meps09911</u>

Populations of California sea lions Zalophus californianus and Steller sea lions *Eumetopias jubatus* in much of the eastern North Pacific Ocean have experienced significant growth since being protected in the early 1970s (by the US Marine Mammal Protection Act and Canada's Fisheries Act) from commercial harvests and fisheries-related culls. However, there remains substantial and unexplained variance in the annual number of sea lions using a major winter haulout at the entrance to the Salish Sea. We used linear regression on principal components to show maximum annual sea lion counts, adjusted for population growth, varied as a function of herring biomass and not local sea surface temperatures or precipitation. Results suggest that Race Rocks, British Columbia, Canada, is used as a stopover for an increasing number of sea lions approaching southern Vancouver Island to feed during the nonbreeding season. Reports of resource-driven movements of sea lions are not new, but this is the first study to use a multidecade data set to show resource-driven movements can underlie long-term patterns of population growth. Finally, we found an unexplained change in the seasonal use of Race Rocks affecting both species. Arrival at Race Rocks has occurred in late summer since 1965, but up to 1979 departure had occurred the following spring; since as late as 1997, departure has occurred mid winter. This study

highlights the complexities of enacting conservation plans for species with latitudinal distributions and undergoing long-term population change.

Fadely, B., & Lander, M. (2012). Satellite Tracking of Adult Female Steller Sea Lions in the Western-Central Aleutian Islands Reveals Diverse Foraging Behaviors. National Marine Fisheries Service Alaska Fisheries Science Center. Retrieved from <u>https://www.afsc.noaa.gov/quarterly/ond2012/divrptsNMML1.htm</u>

Very little is understood about adult female Steller sea lion (*Eumetopias jubatus*) foraging behavior in the Aleutian 170°0'0"E Alaska Bering Sea Semisopochnoi North Pacific Ocean 55°0'0"N Amchitka Alaid Islands, particularly during winter for the western and central Aleutian Islands area. Understanding where marine mammals forage to obtain energy needed for growth and reproduction is necessary to evaluate the potential for competition with other predators (including humans) for resources, and gathering this information is especially crucial in the western and central Aleutian Islands where controversial large-scale commercial fisheries restrictions were enacted (see 2010 NOAA News Release). However, attaching satellite-telemetry instruments capable of recording diving behavior and tracking locations requires the safe capture and restraint of sea lions that may weigh more than 350 kilograms. Thus, to develop suitable techniques, a team from the National Marine Mammal Laboratory's (NMML) Alaska Ecosystems Program (AEP), Alaska Department of Fish and Game Steller Sea Lion Program, and Vancouver Aquarium conducted a pilot project to test capture and handling methods in the more logistically tractable area of Southeast Alaska in November 2010. As reported in a previous AFSC Quarterly Report, October-December 2010, that effort resulted in three successful captures and the subsequent tracking of Steller sea lion movements for up to 253 days, longer than any previous satellitetelemetry instrument deployments on adult females. Based on that success, captures were next attempted in the western and central Aleutian Islands in November 2011, but the effort was confounded by weather and ocean conditions. The successful capture of one adult female (identified as "=24") on Ulak Island in the central Aleutian Islands resulted in the subsequent tracking of her movements for a period of 175 days. During this time, "=24" spent most of her time foraging north of Semisopochnoi Island over the southern portion of Petrel Bank, where the potential prey field was described by a concurrent AFSC Fisheries Interaction Team Atka mackerel study (see AFSC Quarterly Report April-June 2012).

Hastings, K. K., Jemison, L. A., Pendleton, G. W., Raum-Suryan, K. L., & Pitcher, K. W. (2017). Natal and Breeding Philopatry of Female Steller Sea Lions in Southeastern Alaska. *PLoS ONE*, *12*(6). <u>https://doi.org/10.1371/journal.pone.0176840</u>

Information on drivers of dispersal is critical for wildlife conservation but is rare for long-lived marine mammal species with large geographic ranges. We fit multi-state mark-recapture models to resighting data of 369 known-aged Steller sea lion (*Eumetopias jubatus*) females marked as pups on their natal rookeries in southeastern Alaska from 1994-2005 and monitored from 2001-15. We estimated probabilities of females being first observed parous at their natal site (natal philopatry), and of not moving breeding sites among years (breeding philopatry) at large (> 400 km, all five rookeries in southeastern Alaska) and small (< 4 km, all islands within the largest rookery, Forrester Island Complex, F) spatial scales. At the rookery scale, natal philopatry was moderately high (0.776-0.859) for most rookeries and breeding philopatry was nearly 1, with < 3% of females switching breeding rookeries between years. At more populous islands at F, natal philopatry was 0.500-0.684 versus 0.295-0.437 at

less populous islands, and breeding philopatry was 0.919-0.926 versus 0.604-0.858. At both spatial scales, the probability of pupping at a non-natal site increased with population size of, and declined with distance from, the destination site. Natal philopatry of < 1 would increase gene flow, improve population resilience, and promote population recovery after decline in a heterogeneous environment. Very high breeding philopatry suggests that familiarity with neighboring females and knowledge of the breeding site (the topography of pupping sites and nearby foraging locations) may be a critical component to reproductive strategies of sea lions.

Hattori, K., Isono, T., Wada, A., & Yamamura, O. (2009). The Distribution of Steller Sea Lions (*Eumetopias Jubatus*) in the Sea of Japan Off Hokkaido, Japan: A Preliminary Report. *Marine Mammal Science*, 25(4), 949-954. <u>https://doi.org/10.1111/j.1748-7692.2009.00335.x</u>

The article focuses on the winter distribution of Steller sea lions (SSLs) in Hokkaido, Japan. It states that the sea lions come together at the Russian rookeries and haul-outs during the breeding season, and are most found in the northern and central areas of Hokkaido. It mentions that an aerial survey was conducted, and a twine-engine aircraft was used to determine the population of SSLs in the country.

Himes Boor, G. K. (2010). A Poisson Bayesian Analysis of Opportunistic Steller Sea Lion at-Sea Observations from the Platform of Opportunity Dataset. Montana State University.

Identifying the habitat needs of a species is essential to understanding its ecology, and critical for its management and protection. Accurately delineating habitat for an entire species requires knowledge of range-wide foraging patterns by all classes of individuals. The time-scale over which habitat use is assessed should also be broad enough to encompass the natural variability of the species of interest as well as the natural variability of the resources upon which it relies. Unfortunately, for many species of conservation concern, movement and habitat use data meeting these high standards are not available. Such has been the case with Steller sea lions (SSL). To date, information about SSL at-sea spatial use has been derived almost exclusively from satellite telemetry data, but these data have provided only summarized metrics of at-sea movement from a relatively small sample of individuals. These limited data are not sufficient to adequately address questions of range-wide habitat use. An alternative source of information that has thus far been overlooked as a source for habitat use information for Steller sea lions or any other marine mammal is the Platforms of Opportunity (POP) data collected by the National Marine Fisheries Service. The POP dataset contains opportunistic at-sea marine mammal observations throughout the entire Pacific basin. I have developed a methodology for deriving spatially-explicit quantitative estimates of Steller sea lion patterns of occurrence across their entire range from the POP data. A novel approach to correcting for the lack of associated sighting effort records was utilized to estimate Steller sea lion encounter rates in the north Pacific and Bering Sea at a resolution of 15 kilometers.

Hoshino, H., Isono, T., Takayama, T., Ishinazaka, T., Wada, A., & Sakurai, Y. (2006). Distribution of the Steller Sea Lion *Eumetopias Jubatus* During Winter in the Northern Sea of Japan, Along the West Coast of Hokkaido, Based on Aerial and Land Sighting Surveys. *Fisheries Science*, 72(5), 922-931. https://doi.org/10.1111/j.1444-2906.2006.01239.x Aerial and land-based sighting surveys were conducted to clarify the distribution of Steller sea lions during winter in the northern Sea of Japan, along the west coast of Hokkaido, from 2001 to 2003. Aerial surveys revealed that sea lions gathered around the Rishiri-Rebun Islands in March 2002 and 2003, and between Iwanai and Cape Obana in February 2003. Higher numbers of sea lions were also confirmed at Cape Ofuyu and Cape Kamui on the central-west coast compared to that at the haul-out sites in the 1980s on the upper-west coast in March 2002 and 2003. Additionally, fisherman observed sea lions along the coast of the Tsugaru Strait from February to May 2003, where the presence of sea lions was not reported in the 1980s. These facts suggest that sea lions have recently expanded their distribution southward. Land-based surveys at the recent haul-out sites indicated that sea lions in the central-west coast were composed mainly of adult and subadult males (average: Cape Ofuyu 75.2%, Cape Kamui 69.5%), which stayed from November 2002 to May 2003. In this area, sea lions arrived earlier and stayed longer than in the 1980s.

The two stocks of Steller sea lions (Eumetopias jubatus) in Alaska include an endangered western stock, recently recovering in parts of its range following decades of decline, and an eastern stock which was removed from the U.S. Endangered Species List in 2013 following increasing numbers since the 1970s. Information on overlapping distributions of eastern and western sea lions is needed for management considerations. We analyzed >30,000 sightings collected from 2000-2014 of 2,385 sea lions that were branded as pups at 10 Alaskan rookeries to examine mesoscale (mostly <500km) spatial distribution, geographic range, and geographic population structure based on natal rookery, sex, and age during breeding and non-breeding seasons. Analyses of summary movement measures (e.g., natal rookery, sex, and age-class differences in spatial distribution and geographic range) indicate wide variation in rookeryspecific movement patterns. Correlations between movement measures and population dynamics suggested movement patterns could be a function of density dependence. Animals from larger rookeries, and rookeries with slower population growth and lower survival, had wider dispersion than animals from smaller rookeries, or rookeries with high growth and survival. Sea lions from the largest rookery, Forrester Island, where survival and population trends are lowest, were the most widely distributed. Analysis of geographic population structure indicated that animals born in the eastern Aleutian Islands had the most distinct movements and had little overlap with other western sea lions. Northern Southeast Alaska, within the eastern stock, is the area of greatest overlap between stocks, and is important to western animals, especially those born in Prince William Sound. Detailed knowledge of distribution and movements of western sea lions is useful for defining recovery and population trend analysis regions that better reflect dispersion and population structure and provides valuable information to managers as critical habitat is re-evaluated and the location of the stock boundary reconsidered

Jemison, L. A., & Pendleton, G. W. Inter-Stock Movements of Steller Sea Lions in Alaska. Alaska Department of Fish and Game Wildlife Conservation.

Steller sea lions (*Eumetopias jubatus*) have been permanently marked (branded) in Alaska allowing recognition of individuals throughout their lives. Resightings of branded animals allow us to estimate vital rates and evaluate distribution and movement patterns. Of particular interest are movements

Jemison, L., Pendleton, G. W., Hastings, K. K., Maniscalco, J. M., & Fritz, L. (*In Review*). Spatial Distribution, Movements, and Geographic Range of Steller Sea Lions (*Eumetopias Jubatus*) in Alaska. *PLOS One*. <u>https://doi.org/10.1371/journal.pone.0208093</u>

across the geographic boundary of 144°W, delineating the western (endangered) and eastern (threatened) populations, and whether these movements are temporary or permanent.

Kastelein, R. A., & Weltz, F. C. (1991). Distribution and Behaviour of Steller Sea Lions (*Eumetopias Jubatus*) in Prince William Sound, Alaska, June 1989. *Aquatic Mammals*, 17(2), 91-97. Retrieved from https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=40

https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=40 https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=40 https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=40

The distribution and behaviour of Steller sea lions (*Eumetopias jubatus*) on their rookeries and haul-out areas in Prince William Sound, Alaska were studied in June 1989. An aerial count at low tide showed more animals hauled out than a similar survey, flown 9 days later at high tide. In this geographical area, and in this period of the year, the haul-out pattern of Steller sea lions seems influenced by the tide in varying degrees depending on the colony. A larger number of Steller sea lions were counted in the colonies in 1989 than in a similar study during the same period of the previous year. One colony was only used as a haul-out in 1988, but was used on a small scale as a rookery in 1989.

Keiper, C. A., Ainley, D. G., Allen, S. G., & Harvey, J. T. (2005). Marine Mammal Occurrence and Ocean Climate Off Central California, 1986 to 1994 and 1997 to 1999. *Marine Ecology Progress Series*, 289, 285-306. <u>https://doi.org/10.3354/meps289285</u>

The California Current System (CCS), a highly variable eastern boundary system, supports a rich marine mammal fauna. Variation in local coastal upwelling, coupled with larger scale processes (El Nino/La Nina) affects the productivity and distribution of marine species at all trophic levels. Herein, we present an analysis of the occurrence patterns of marine mammals in the central CCS and relate these patterns to changing ocean climate and prey availability. Data on marine mammal distributions, ocean conditions, and prey availability were collected in waters overlying the continental shelf and slope from Bodega to Monterey Bays, from 1986 to 1994 and 1997 to 1999. Occurrence patterns were investigated using geographical information system (GIS), percent similarity index (PSI), multiple logistic regression, and principal component analyses. Spatial patterns of the most frequently sighted species (California sea lion Zalophus californianus, northern fur seal Callorhinus ursinus, Pacific white-sided dolphin Lagenorhyncus obliquidens, Dall's porpoise Phocoenoides dalli, harbor porpoise Phocoena phocoena, and humpback whale Megaptera novaeangliae) were related to bathymetry and changing ocean climate, and were likely to have been mediated by changes in prey availability. Temporal changes were related to migration and significant differences in ocean structure resulting from both local and large-scale processes.

Kurle, C. M., & Gudmundson, C. J. (2007). Regional Differences in Foraging of Young-of-the-Year Steller Sea Lions *Eumetopias Jubatus* in Alaska: Stable Carbon and Nitrogen Isotope Ratios in Blood. *Marine Ecology Progress Series, 342*, 303-310. <u>https://doi.org/10.3354/meps342303</u>

Stable nitrogen and carbon isotope ratios were measured from red blood cell (RBC) and serum components from 9 mo old Steller sea lions *Eumetopias jubatus* captured during February and March 2000 and 2001 from the Gulf of Alaska (GOA; Region 1, n = 11), the eastern Aleutian Islands (Region 3, n = 5), and the central Aleutian Islands (Region 4, n = 5) to assess their foraging ecology. Isotope ratios

from sea lions were compared with those from probable prey species and results were compared with those from a study demonstrating regional differences in the diets of juvenile and adult sea lions through the use of scat analysis. Discriminant analyses using the delta N-15 and delta C-13 values of each blood component as the discriminant functions accurately classified sea lions to the appropriate foraging regions as predicted by a previous study employing scat analysis with an accuracy of 90 % for serum and 95 % for RBCs. The delta N-15 values reflect a decrease in sea lion trophic position moving east to west that is probably driven by changes in sea lion diet. The delta C-13 values demonstrated clear distinctions between foraging locations that are likely driven by known geographic carbon isotope patterns observed in the GOA and along the Aleutian archipelago. Our data present further evidence that, in the marine environment, delta C-13 values do not covary with delta N-15 values as a result of trophic enrichment, and are better determinants of foraging location than trophic position.

Lander, M., Johnson, D., Fadely, B., & Gelatt, T. (2013). At-Sea Distribution of Steller Sea Lions in the Western-Central Aleutian Islands. Memo Submitted to Alaska Science Center.

[NO ABSTRACT AVAILABLE]

Lander, M. E., Johnson, D. S., Sterling, J. T., Gelatt, T. S., & Fadely, B. S. (2011). Diving Behaviors and Movements of Juvenile Steller Sea Lions (Eumetopias Jubatus) Captured in the Central Aleutian Islands, April 2005. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC 218. Retrieved from https://repository.library.noaa.gov/view/noaa/3790

Population counts and pup production for Steller sea lions (Eumetopias jubatus) in the central Aleutian Islands (CAI) of the western distinct population segment (wDPS) continue to decline for unknown reasons. Due to paucity of telemetry data for this region, satellite-linked depth recorders were deployed on 16 juvenile Steller sea lions from 19 April to 2 May 2005 to gain a better understanding of their diving behaviors and habitat use. Overall, depths of dives (n = 89,993, x = 11.8 m, SD = 12.6, med = 8.0, and range = 5.0 to 255.0), durations of dives (n = 155,620, x = 0.8 min, SD = 0.6, med = 0.5, and range = 0.5 to > 13.0), trip durations (n = 553, x = 14.0 hours, SD = 19.6, med = 10.7, and range = 0.3 to 280.0), and shore durations (n = 589, x = 10.5 hours, SD = 7.1, med = 10.7, and range = 1.0 to 58.7) were similar to findings for Steller sea lions previously tagged in the CAI. Diel behaviors, ontogenetic trends, and movements displayed by juvenile Steller sea lions also were similar to past accounts. Relative to data reported for Steller sea lions from the eastern DPS, however, trip durations of sea lions reported herein were longer, whereas depths of dives were shallower and durations of dives were shorter.A continuous-time correlated random walk model that was applied to the telemetry data was used to examine areas of predicted diving activity with respect to Steller sea lion designated critical habitat. Overall, the proportions of predicted locations associated with diving to > 4 m within zones of critical habitat appeared to reflect the proportions of Argos data well and results were similar to other reports. Additional models will be useful for examining sea lion movements and diving behaviors among regions and with respect to spatial management measures and environmental features.

 Lowry, M. S., Nehasil, S. E., & Jaime, E. M. (2017). Distribution of California Sea Lions, Northern Elephant Seals, Pacific Harbor Seals, and Steller Sea Lions at the Channel Islands During July 2011-2015. National Marine Fisheries Service Southwest Fisheries Science Center. NMFS-SWFSC-578. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/14442</u> Aerial photographic surveys targeting California sea lions conducted during July 2011- 2015 were used to describe inter-island and intra-island distributions of California sea lions, northern elephant seals, Pacific harbor seals, and Steller sea lions within the Channel Islands. Age/sex class counts were made for California sea lions, Steller sea lions, and northern elephant seals, but not for Pacific harbor seals. Each island was subdivided into areas to document intraisland distribution of each species. California sea lions were found at all of the Channel Islands. However, San Miguel Island, San Nicolas Island, Santa Barbara Island, and San Clemente Island accounted for 99.8% to 99.9% of California sea lion pups counted, with San Miguel Island and San Nicolas Island having the most pups and non-pups of those four islands. In July 2015, when all islands were surveyed for elephant seals, 2790 elephant seals (61.3% of Channel Islands total) were at San Miguel Island, 932 (20.5% of total) at San Nicolas Island, and 816 (17.9% of total) at Santa Rosa Island. There were 1367 Pacific harbor seals counted at the Channel Islands in July 2015, and a single Steller sea lion was counted at San Nicolas Island in 2013.

Moss, M. L., Yang, D. Y., Newsome, S. D., Speller, C. F., McKechnie, 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. <u>https://doi.org/10.1080/15564890600934129</u>

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 (δ 13C) and nitrogen (δ 15N) isotopes to investigate whether northern fur seal remains from these archaeological sites originated with migratory Pribilof Islands populations. For sites located in Oregon andpoints 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.

Raum-Suryan, K. L., Pitcher, K. W., Calkins, D. G., Sease, J. L., & Loughlin, T. R. (2002). Dispersal, Rookery Fidelity, and Metapopulation Structure of Steller Sea Lions (*Eumetopias Jubatus*) in an Increasing and a Decreasing Population in Alaska. *Marine Mammal Science*, 18(3), 746-764. https://doi.org/10.1111/j.1748-7692.2002.tb01071.x

Over the past 24 yr, 8,596 Steller sea lion (*Eumetopias jubatus*) pups were branded on their natal rookeries throughout Alaska with the objectives of determining survival rates, recruitment, movements, and site fidelity. Our objectives here were to examine the extent of dispersal of Steller sea lions away from their natal rookeries, movements between stocks, and degree of natal rookery fidelity. Pups (<1 yr old) usually remained within 500 km of their natal rookery. Branded juveniles dispersed widely and were resighted at distances up to 1,785 km from their natal rookeries. Adults generally remained within 500 km of their natal rookeries. Adults generally remained within 500 km of their natal rookeries. No interchange of breeding animals between the ES (eastern stock) and WS (western stock) was observed. Although natal rookery fidelity was prevalent, 33% of the 12 observations of females branded in the WS during 1987-1988 and 19% of the 29 observations of females branded in

the ES during 1994-1995 were observed with newly born pups at sites other than their natal rookeries. Steller sea lions generally conformed to the metapopulation concept as depicted by Hanski and Simberloff (1 997), with local breeding populations (rookeries) and movements among these local populations having the potential of affecting local dynamics.

Raum-Suryan, K. L., Rehberg, M. J., Pendleton, G. W., Pitcher, K. W., & Gelatt, T. S. (2004). Development of Dispersal, Movement Patterns, and Haul-out Use by Pup and Juvenile Steller Sea Lions (*Eumetopias Jubatus*) in Alaska. *Marine Mammal Science*, 20(4), 823-850. https://doi.org/doi.org/10.1111/j.1748-7692.2004.tb01195.x

Population declines of Steller sea lions (*Eumetopias jubatus*) in western Alaska (west of 144degreesW) may be a result of reduced juvenile Survival. We used satellite telemetry to study the at-sea distribution and movement patterns of pup (1.6-11.9 mo) and juvenile (12.0-35.1 mo) Steller sea lions. We studied trip distance, duration, and interhaul-out movements of sea lions in relation to age, sex, and month of year in the decreasing western population (WP; Prince William Sound, Kodiak, Aleutian Islands, Alaska) and the increasing eastern Population (EP; Southeast Alaska). We deployed 103 satellite transmitters (29 WP; 74 EP) on sea lions between 1998 and 2001. Round trip distance and duration increased with age, trip distance was greater in the WP than the EP, trip duration was greater for females than males, and haul-out use was clustered. Changes in round trip distance and duration occurred from April to June for all age classes studied indicating that the annual timing of weaning may be less variable than the age of weaning. Overall, 90% of round trips were less than or equal to 15 km from haul-outs and 84% were < 20 h, indicating nearshore areas adjacent to haul-outs are critical to the developing juvenile.

Rehberg, M., Jemison, L., Womble, J. N., & O'Corry-Crowe, G. (2018). Winter Movements and Long-Term Dispersal of Steller Sea Lions in the Glacier Bay Region of Southeast Alaska. *Endangered Species Research*, *37*, 11-24. https://doi.org/10.3354/esr00909

Steller sea lions *Eumetopias jubatus* in the Glacier Bay region of northern Southeast Alaska experience greater survival and more rapid population growth than sea lions elsewhere in this region. To better understand demographics of sea lions in the region, and to describe the origins and behavior of sea lions and relate these descriptions to previous studies, we studied genetic origins, residency, foraging range, diving behavior, and dispersal of immature sea lions (≤24 mo of age) captured in Glacier Bay. Fifty-two percent of individuals had maternal origins in the distant (550 km) endangered western population rather than in the local recovered eastern population. During winter, 5 mo old pups, dependent on their dams for nutrition, remained within Glacier Bay, diving to shallow depths (≤108 m) mainly during daylight, whereas older (17 mo old) juveniles ranged more widely to areas of known seasonal prey aggregations, performing deep (≥241 m) nocturnal dives. Both pups and juveniles remained within the northern portion of Southeast Alaska, in contrast to farther-ranging pup and juvenile sea lions captured elsewhere in Southeast Alaska. Over the long term, females from Glacier Bay remained within this northern area through maturity and were sighted breeding in this area only. Restricted ranging patterns and natal and breeding philopatry by Steller sea lions of both eastern and western distinct population segment origin in the Glacier Bay region reveal that optimal foraging and breeding conditions likely prevail and help explain the recent colonization, increased survival, and rapid population growth of this species in the region.

Sinclair, E. H., Moore, S. E., Friday, N. A., Zeppelin, T. K., & Waite, J. M. (2005). Do Patterns of Steller Sea Lion (*Eumetopias Jubatus*) Diet, Population Trend and Cetacean Occurrence Reflect Oceanographic Domains from the Alaska Peninsula to the Central Aleutian Islands? *Fisheries* Oceanography, 14, 223-242. <u>https://doi.org/10.1111/j.1365-2419.2005.00375.x</u>

Shipboard surveys were conducted along the Aleutian Islands in 2001 and 2002 to assess the influence of a suite of biophysical parameters on regional patterns in the distribution of cetaceans and Steller sea lions (SSL; Eumetopias jubatus). Distributions of four large whale species: fin (Balaenoptera physalus), humpback (Megaptera novaeangliae), minke (B. acutorostrata) and sperm (Physeter macrocephalus) aligned with proposed metapopulation breaks in diet and population trend of SSLs. Dall's porpoise (Phocoenoides dalli) and killer whales (Orcinus orca) were widely distributed throughout the study area, and killer whales were particularly prevalent along the north Aleutian Island coastlines between Unimak Pass and Samalga Pass. Biopsies determined that most killer whales (92%) were of the piscivorous (resident) ecotype as opposed to the mammal-eating (transient) ecotype observed in 2002 only. Generalized additive models (GAMs) were used to explore relationships between these multispecies patterns in distribution, oceanographic variables (salinity, temperature, fluorescence and depth) and proximity to six Aleutian passes. The GAMs indicated the best-fit models and most significant correlations as determined by the Akaike function and Cp-statistics were: depth and proximity to the nearest measured pass for SSLs and all cetaceans, respectively; frequencies of herring and salmon in SSL diet with population trend; fluorescence in the top 50 m with occurrence of humpback, minke, and killer whales; and surface temperature with occurrence of humpback, killer, and sperm whales. Results of the GAM analyses suggest foci for future investigation of relationships between physical variables and interspecific patterns of marine mammal distribution.

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. <u>https://doi.org/10.1515/mammalia-2012-0098</u>

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.

Winter, A., Foy, R. J., & Wynne, K. (2009). Seasonal Differences in Prey Availability around a Steller Sea Lion Haulout and Rookery in the Gulf of Alaska. *Aquatic Mammals, 35*(2), 145-162. <u>https://doi.org/10.1578/AM.35.2.2009.145</u>

Abundance and distribution of fish biomass were surveyed around a Steller sea lion (*Eumetopias jubatus*) haulout (nonbreeding) and rookery (breeding) site in the Gulf of Alaska to test the hypothesis that seasonal occupation of either site was related to the availability of prey. The haulout and rookery are located 30 nmi (55.56 km) apart at Long Island and Marmot Island in the Central Gulf of Alaska

region where the Steller sea lion population is slowly recovering from a severe decline. Surveys conducted in May and November of 2002 (just before and after the breeding season) showed significantly higher prey energy density (total fish biomass density x energy content; kJ nmi-2) around the Long Island haulout than around the Marmot Island rookery. A survey conducted in July of 2002 (during breeding season) showed prey energy densities that were not significantly different between Long Island and Marmot Island but that were more concentrated in a single area by Marmot Island. Major prey species groups in all surveys were arrow tooth flounder, walleye pollock, cod, and soles; all are known prey of Steller sea lions in this area. Steller sea lion counts at Long Island during nonbreeding seasons from 2000 to 2004 correlated significantly with midwater prey energy densities. Steller sea lion counts at Marmot Island over the same period did not correlate with midwater prey energy densities in either breeding or nonbreeding seasons. The results of the study indicate that prey availability may be an important factor in the choice of haulout sites by Steller sea lions, and the higher prey availability at rookery sites provides some advantage.

Womble, J. N., Willson, M. F., Sigler, M. F., Kelley, B. P., & VanBlaricom, G. R. (2005). Distribution of Steller Sea Lion *Eumetopias Jubatus* in Relation to Spring-Spawning Fish in Se Alaska. *Marine Ecology Progress Series, 294*, 271-282. https://doi.org/10.3354/meps294271

Energetic demands are high for Steller sea lions *Eumetopias jubatus* during spring, when females are pregnant and lactating and males are preparing for extended fasts on breeding territories. Therefore, we predicted that the distribution of sea lions in SE Alaska in spring would be influenced by the distribution of spring spawning aggregations of high-energy prey species (Pacific herring Clupea pallasii and eulachon Thaleichthys pacificus). The spatial distribution of sea lions during spring reflected the distribution of spawning eulachon in northern Southeast Alaska, particularly in Lynn Canal and along the Yakutat forelands. Haulouts with peak numbers of sea lions in spring were located significantly closer to eulachon spawning sites than haulouts that peaked at other times of year. Some haulouts were occupied only during the eulachon spawning period. The maximum number of sea lions at haulouts in spring was inversely correlated with the distance to the closest eulachon aggregation and was positively associated with the number of eulachon within 20 km. Aerial surveys conducted every 7 to 10 d during March through May in 2002 and 2003 revealed large numbers of sea lions in the water at herring spawning sites in 2002 and 2003; however, there were no significant relationships between the number of herring spawning sites and number of sea lions (except at distances >60 km). The number of sea lions was greater at herring spawning sites in 2003, corresponding to higher herring biomass. Seasonally aggregated, high-energy prey species influence the seasonal distribution of sea lions and may be critical to their reproductive success.

Section IX: News Articles (Bites)

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Section X: Physiology

Amatuli, K. C., Rosen, D. A. S., & Richmond, J. P. (2014). Seasonality of Metabolic Hormones in a Seasonal Carnivore, the Steller Sea Lion Eumetopias Jubatus. Paper presented at the Annual Meeting of the Society for Integrative and Comparative Biology. Retrieved from <u>http://www.sicb.org/meetings/2014/schedule/abstractdetails.php?id=110</u>

Seasonal changes in body mass, nutrient partitioning, and food intake are strongly influenced by metabolic hormones. As a part of normal life history patterns, Steller sea lions (SSL) exhibit dynamic seasonal changes in intake during the summer breeding season. Previous research found seasonality of metabolic hormones in males but not female SSL likely due to the artificially consistent feeding regime during the study. The current study investigates seasonal patterns of growth hormone (GH), insulin-like growth factor (IGF)-I, and ghrelin in adult female SSL, fed a diet reflective of normal life history patterns. Specifically, SSL were fed ad libitum during most of the year, but intake was reduced in early summer. Following increased intake in fall and winter (74575±2101kJ; p<0.01), mass was greatest in winter and spring (159.5±1.9kg; p<0.01). Known to stimulate GH release, ghrelin was positively correlated to GH (p<0.01) in the spring; however, exhibited a negative correlation in winter and fall. Ghrelin stimulates appetite, especially during periods of fasting. SSL ghrelin was negatively correlated with intake (p<0.01) in winter and spring, but positively correlated in summer and fall. IGF-I concentrations were positively correlated (p<0.01) with intake independent of season. The inverse relationship between GH and ghrelin during the breeding season likely suppresses the urge to feed (reduced ghrelin) during these extended periods of restricted intake and facilitates use of adipose for energy (increased GH). Increased ghrelin with reduced GH in the winter is likely a mechanism to facilitate winter fattening. Dynamic seasonality in metabolic hormones was observed in female SSL suggesting seasonal change in nutrient partitioning priorities.

Ando-Mizobata, N., Sakai, M., & Sakurai, Y. (2006). Trace-Element Analysis of Steller Sea Lion (*Eumetopias Jubatus*) Teeth Using a Scanning X-Ray Analytical Microscope. *Mammal Study*, 31(1), 65-68. <u>https://doi.org/10.3106/1348-6160(2006)31[65:TAOSSL]2.0.CO;2</u>

Marine mammals are top predators in marine ecosystems and bioaccumulate various trace elements that pass through the food web (Miles and Hills 1994; Wagemann and Stewart 1994; Dietz et al. 1996). Trace elements include both essential and non-essential metals. Iron (Fe) and zinc (Zn) are essential metals that occur widely and abundantly in living organs. The concentrations at which they occur in an animal are affected not only by the diet, age, nutritional stress but also health status of the animal. In mammals, it is possible to examine element accumulation using their teeth. During dentine formation, trace elements are removed from dietary and environmental sources, and incorporated into the crystalline apatite structure of the teeth. Here, unlike in bones, they are not subject to reabsorption or remodeling, so they can be used to examine an animal's life history. Ando et al. (2005) found significant long-term differences in Zn/calcium (Ca) and Fe/Ca ratios from 1968 to 1999 by particle-induced X-ray emission analysis (PIXE). And Zn/Ca and Fe/Ca ratios were higher in younger males than older males, but showed no trend with age in females. There are question about fluctuation of these metals within each animal. In this study, we examined the canine teeth of Steller sea lions (*Eumetopias jubatus*) to assess their action and the fluctuation of essential metals of that occur in the teeth with their each life history.

Barlough, J. E., Berry, E. S., Skilling, D. E., & Smith, A. W. (1988). Prevalence and Distribution of Serum Neutralizing Antibodies to San-Miguel Sea Lion Virus Type-6 and Type-7 in Selected Populations of Marine Mammals. *Diseases of Aquatic Organisms*, 5(2), 75-80. <u>https://doi.org/10.3354/da0005075</u>

Neutralizing antibodies to San M~guel sea lion virus (SMSV) types 6 and/or 7 were found in sera collected from California sea l~ons Zalophus c californianus in 1977 and 1983 and in sera collected from Steller sea lions *Eumetopias jubatus* in 1976 and 1985 The combined prevalence rates of SMSV antibodies in these 2 species were SMSV-6 19/228 = 8.3 %, and SMSV-7, 4/228 = 1 7 '10 Titers ranged from 1 20 to 1 320 by standard microtiter neutralization assay Seropositive sea lions were dispersed along the eastern Pacific rim from Alaska to the southern California Channel Islands Antibodies to either agent were not found In sera collected from northern fur seals Callorhinus ursinus, Pacific walruses Odobenus rosmarus divergens seals of the family Phocidae, or several cetacean species Both SMSV-6 and SMSV-7 have been isolated from opaleye Girella nigricans an ocean fish found primarily In the southern California coastal zone, the presence of antibody-positive sea lions in more northern waters indicates that these piscine-ongin SMSV types may have a wider distribution in nature than has been previously supposed

Bishop, D. H., & Morado, J. F. (1995). Results on Blood Cell Morphology and Differential Blood Cell Counts from Seventeen Steller Sea Lion *Eumetopias Jubatus* Pups. *Diseases of Aquatic Organisms*, 23(1), 1-6. <u>https://doi.org/10.3354/da0023001</u>

During summer 1991, blood was collected and blood smears were prepared from 17 Steller sea lion *Eumetopias jubatus* pups. Of the sampled pups 8 were from 3 Southeast Alaska rookeries (Forrester Island, N = 3; White Sisters, N = 4; Hazy Island, N = 1) and 9 were from 2 Gulf of Alaska rookeries (Seal Rocks, N = 5; Outer Island, N = 4). The total number of white blood cells (WBC) per ul was estimated, and differential counts were performed on each smear. Red blood cell (RBC) anomalies were identified and quantified. Only the values from the Hazy Island pup sample appeared remarkable as the levels of banded neutrophils, monocytes, and total WBC counts were greater than 1 standard deviation from the total average values. Poikilocytes and target cells were the most frequently encountered RBC anomalies occurring in all (100%) and 15 of 17 (88%) sampled pups, respectively. No clear differences were observed between pups from the 2 regions, but total WBC counts from Southeast Alaska pups appeared depressed when compared with Gulf of Alaska values. RBC data indicated that target cells were markedly elevated in Gulf of Alaska pups over Southeast Alaska pups and that poikilocyte levels were higher in Southeast Alaska pups than Gulf of Alaska pups. The results suggest anemia, but given the wide range of reported values from captive, stranded, and wild sea lions, the exact condition of the sampled Steller sea lion pups could not be determined.

Blomquist, C. H., Lima, P. H., & Atkinson, S. (2005). Activity of Steroidogenic Enzymes in Placenta and in Lung, Fat and Skin of the Steller Sea Lion Pup (Eumetopias Jubatus). Paper presented at the Annual Meeting of the Society for Integrative and Comparative Biology. <u>http://www.sicb.org/meetings/2006/schedule/abstractdetails.php3?id=111</u>

Steroidogenic enzymes that regulate levels of estrogens and androgens in mammalian tissues may be targets for endocrine disruptors. As a basis for assessing their role in regulating hormone levels and their potential as biomarkers of endocrine disruption in the Steller sea lion, 17&beta-hydroxysteroid

dehydrogenase (17&beta-HSD), 3&beta-hydroxysteroid dehydrogenase/5-ene-3-ketosteroid isomerase (3&beta-HSD) and 3&alpha-hydroxysteroid dehydrogenase (3&alpha-HSD) were assayed in homogenates of placenta (n=13) as well as lung, subcutaneous fat and skin from one female and five male pups (1-4 weeks). 17&beta-HSD activity with estradiol (E2) and testosterone (T) was detected in the placenta samples as was 3&alpha-HSD activity with 5&alpha-DHT. 3&beta-HSD activity with DHEA was not detected. With regard to 17&beta-HSD activity in pup tissues, lung samples had the lowest activity and skin the highest. The ratio of 17&beta-HSD activity with E2 and T varied from 0.1 to 1.1 for skin and 0.1 to 2.3 for fat. For male pup skin samples, the 17&beta-HSD/3&alpha-HSD activity ratio varied from 0.27 to 7.2. For subcutaneous fat the range was 0.16-5.1. No 3&alpha-HSD activity was detected in the female pup skin sample. The marked variations in activity levels and ratios are consistent with the presence of multiple isoforms of 17&beta-HSD. They are also suggestive of differential regulation of 17&beta-HSD, 3&alpha-HSD and 3&beta-HSD in skin and fat, tissues in which the levels of these enzymes are known to be regulated in other species by gonadal steroids. Although the basis for the marked differences between samples remains to be clarified, our findings suggest activity patterns and ratios may be sensitive markers of endocrine status and endocrine disruption in sea lion pups.

Brandon, E. A. A., Calkins, D. G., Loughlin, T. R., & Davis, R. W. (2005). Neonatal Growth of Steller Sea Lion (*Eumetopias Jubatus*) Pups in Alaska. *Fishery Bulletin, 103*(2), 246-257. Retrieved from <u>http://aquaticcommons.org/9611/</u>

The growth rate of Steller sea lion (*Eumetopias jubatus*) pups was studied in southeast Alaska, the Gulf of Alaska, and the Aleutian Islands during the first six weeks after birth. The Steller sea lion population is currently stable in southeast Alaska but is declining in the Aleutian Islands and parts of the Gulf of Alaska. Male pups (22.6 kg [+/- 2.21 SD]) were significantly heavier than female pups (19.6 kg [+/- 80 SD]) at 1-5 days of age, but there were no significant differences among rookeries. Male and female pups grew (in mass, standard length, and axillary girth) at the same rate. Body mass and standard length increased at a faster rate for pups in the Aleutian Islands and the western Gulf of Alaska (0.45-0.48 kg/day and 0.47-0.53 cm/day, respectively) than in southeast Alaska (0.23 kg/day and 0.20 cm/day). Additionally, axillary girth increased at a faster rate for pups in the Aleutian Islands a greater maternal investment in male pups during gestation, but not during early lactation. Although differences in pup growth rate occurred among rookeries, there was no evidence that female sea lions and their pups were nutritionally stressed in the area of population decline.

Brunner, S. (2002). Geographic Variation in Skull Morphology of Adult Steller Sea Lions (*Eumetopias Jubatus*). *Marine Mammal Science*, 18(1), 206-222. <u>https://doi.org/10.1111/j.1748-7692.2002.tb01029.x</u>

Data from cranial specimens of adult E. jubatus were analyzed to compare intra-specific morphology of skulls, Males and females were grouped separately to avoid bias from sexual dimorphism. Geographic variation was observed in adult male E. jubatus, indicating the potential presence of three morphologically disparate groups: those from Alaska, those from California, and those from Japan and Russia, Although sample sizes were small, results from cluster and discriminant function analyses indicated that specimens from eastern and western Alaska were morphologically similar, and that the most divergent specimens for the species appeared to be those from Japan. Skulls from Alaska

possessed a typically longer, less robust skull, whereas those from Japan appeared smaller, yet most robust. Skulls from California were intermediate.

Burns, J. M., Clark, C. A., & Richmond, J. P. (2004). The Impact of Lactation Strategy on Physiological Development of Juvenile Marine Mammals: Implications for the Transition to Independent Foraging. In Animals and Environments. S. Morris & A. Vosloo (Eds.), (Vol. 1275, pp. 341-350) https://doi.org/10.1016/j.ics.2004.09.032

Lactating marine mammals provision their offspring either by providing large amounts of lipid-rich milk over a short period during which females fast (capital provisioning), or smaller amounts of less energetically dense milk over an extended period during which females forage (income provisioning). While it has long been recognized that these two strategies carry different costs for the female, the effect of these two strategies on the physiological status of newly weaned pups has rarely been considered. Recent comparative studies on the development of diving capacity, as assessed by measuring total body oxygen stores, have demonstrated that the provisioning strategy does affect pup development. Phocid pups, which grow rapidly during their brief nursing period undergo a strong postparturition anemia and are weaned with relatively immature oxygen stores, possibly due to limited iron intake. Otariid pups, which grow at a slower pace over a longer period, are weaned with body oxygen stores that are significantly more mature. This suggests that newly independent phocid pups must quickly develop foraging skills in order to acquire the nutrients necessary to mature physiologically. In contrast, newly weaned otariids have more mature oxygen stores, and may have previous foraging experience, which may allow for increased behavioral flexibility.

Calkins, D. G., Becker, E. F., & Pitcher, K. W. (1998). Reduced Body Size of Female Steller Sea Lions from a Declining Population in the Gulf of Alaska. *Marine Mammal Science*, *14*(2), 232-244. https://doi.org/10.1111/j.1748-7692.1998.tb00713.x

Nutritional stress is a leading hypothesis behind the decline in numbers of Steller sea lions in the Gulf of Alaska, the Aleutian Islands, and the Bering Sea. To evaluate this hypothesis we compared body growth of female Steller sea lions 1.0-13.9 yr of age collected in the Gulf of Alaska during two time periods, 1975-1978 just prior co or early in the decline and 1985-1986 when the decline was well establishe. We found that growth, as measured by standard length, axillary girth, and mass, was reduced during the 1980s, supporting the undernutrition hypothesis. We also found a suggestion of reduced growth in our 1970s and 1980s samples when compared to a collection of Steller sea lions obtained from the Gulf of Alaska in 1958. However, no direct link has been demonstrated between undernutrition and the actual decline in numbers.

Castellini, M. A., & Calkins, D. G. (1993). Mass Estimates Using Body Morphology in Steller Sea Lions. Marine Mammal Science, 9(1), 48-54. <u>https://doi.org/10.1111/j.1748-7692.1993.tb00425.x</u>

Analytical procedures developed from studies on phocids for relating body morphometrics (length and girth) to mass were applied to 390 Steller sea lions from the Gulf of Alaska and the Bering Sea. The equations relating body volume to mass were significant and had very high correlation coefficients for animals from about 60 to over 900 kg with a standard error of +/-0.6% in fitted mass. There was a

significant difference in these relationships for female sea lions studied in the 1970s and those examined in the 1980s. The latter sea lions were smaller and/or leaner than those collected in the 1970s.

Locomotion in early ontogenesis of the born in captivity pups of the sea lion *Eumetopias jubatus* was studied by observation and description of their behavior as well as by ethogram recording with subsequent computer processing of the obtained data. The composed list of elements of the locomotional behavior of the animals in the process of development included locomotional acts, such as crawling, walking, sliding, climbing up onto a steep surface ("rock") and a descent from it, jumping from the coast into the water, swimming, "dolphing, " diving and surfacing, jumping from the water to the land, and postures, such as sitting, lying on the abdomen, on the side, on the back, and position of standing on the posterior flappers. The first locomotion elements in ontogenesis were climbing and swimming, and the first postures--sitting and lying on the abdomen. Formation of all the locomotor postures characteristic of this animal species occurred step-by-step, in the process of improvements of the available elements, of the appearance of new elements, and of their complication. After the entire repertoire of the species-specific locomotor behavior had been formed, predominant in the process of further development were walking and swimming, while most comforting, playing, and explorative actions were performed in the sitting posture.

Cheneval, O. (2005). *Biomechanics of Turning Manoeuvres in Steller Sea Lions (Eumetopias Jubatus).* University of British Columbia, Retrieved from <u>http://www.marinemammal.org/wp-content/pdfs/Cheneval_2005.pdf</u>

Otariids such as the Steller sea lion (*Eumetopias* jubatus) are among the most manoeuvrable of marine mammals (expressed as a minimum turning radius and speed during manoeuvres). They evolved in terrestrial and aquatic environments that are structurally complex, and feed on prey that are an order of magnitude smaller than themselves. Compared to other aquatic organisms, Steller sea lions have an unstable body design and are presumed to invoke swimming techniques that reflect their need to be highly manoeuvrable. Detailed information was experimentally obtained about the turning techniques employed by otariids through jointly analysing kinematic and kinetic parameters measured from video recordings of three captive Steller sea lions. Centripetal force and thrust production were determined by examining body movements throughout a series of turns. Overall, the turning sequence of the Steller sea lion was found to be very consistent, and their manoeuvrability was found to come from their ability to vary the duration and intensity of movements within the turning sequence.

Cheneval, O., Blake, R. W., Trites, A. W., & Chan, K. H. S. (2007). Turning Maneuvers in Steller Sea Lions (Eumatopias Jubatus). *Marine Mammal Science*, 23(1), 94-109. <u>https://doi.org/10.1111/j.1748-7692.2006.00094.x</u>

Steller sea lions are highly maneuverable marine mammals (expressed as minimum turning radius). Video recordings of turns (n = 195) are analyzed from kinematic measurements for three captive

Chechina, O. N., Kovalenko, Y., Kulagina, O. A., & Mikhailenko, A. A. (2004). Development of Locomotion in Sea Lions *Eumetopias Jubatus* in Early Ontogenesis. *Journal of Evolutionary Biochemistry and Physiology*, 40(1), 66-71. https://doi.org/http://dx.doi.org/10.1023/B:JOEY.0000031007.59709.6f

animals. Speed-time plots of 180 degrees turns have a typical "V-shape." The sea lions decelerated during the first half of the turn, reached a minimum speed in the middle of the curved trajectory and reaccelerated by adduction of the pectoral flippers. The initial deceleration was greater than that for passive gliding due to pectoral flipper braking and/or change in body contour from a stiff, straight streamlined form. Centripetal force and thrust were determined from the body acceleration. Most thrust was produced during the power phase of the pectoral flipper stroke cycle. Contrary to previous findings on otariids, little or no thrust was generated during initial abduction of the pectoral flippers and during the final drag-based paddling phase of the stroke cycle. Peak thrust force at the center of gravity occurs halfway through the power phase and the centripetal force is maximal at the beginning of the power stroke. Performance is modulated by changes in the duration and intensity of movements without changing their sequence. Turning radius, maximum velocity, maximum acceleration and turning duration were 0.3 body lengths, 3.5 m/s, 5 m/s(2), and 1.6 s, respectively. The relative maneuverability based on velocity and length specific minimum turning radius is comparable to other otariids, superior to cetaceans but inferior to many fish.

Crawford, S. G., L.D. Rea, & Coker., R. H. (2017). *Fasting Status of Steller Sea Lion Pups as an Index of Potential Nutritional Stress in Decreasing and Increasing Metapopulations.* Paper presented at the 22nd Biennial Conference on the Biology of Marine Mammals. Retrieved from <u>http://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/research_pdfs/fasting_status_ste</u> <u>ller_sea_lion_pups_nutritional_stress_metapopulations.pdf</u>

Steller sea lion (SSL; Eumetopius jubatus) pups routinely alternate between feeding and fasting, corresponding to dams' absence during foraging trips. Prior research suggests dams extend foraging trips when prey resources are limited. We propose that comparing proportions of recently fed pups sampled on rookeries over a broad spatiotemporal range can provide information regarding variation in the dams' foraging duration and identify localities where the potential for nutritional stress exists. We applied published metabolite thresholds derived during experimental fasts on captive SSL pups to concentrations of blood urea nitrogen and β -hydroxybutyrate in plasma of free-ranging SSL pups (n = 1,600, collected 1990-2016) to categorize fasting phases: recently fed, Phase II fasting (utilizing predominantly lipid stores), transitioning Phases II–III, and Phase III (reversion to catabolizing protein). Using a cross-sectional approach, we compared proportions of recently fed pups on 41 rookeries in 11 metapopulations from western Russia to southeastern Alaska. The overall mean proportion of recently fed pups was 0.71 +/- 0.03. Two metapopulations had significantly lower proportions of recently fed pups: 1) western Aleutian islands (mean: 0.49 +/- 0.11, p = 0.03) and 2) southern southeastern Alaska (mean: 0.55 + - 0.05, p < 0.01). The western distinct population segment (DPS), including the western Aleutian Islands, underwent a precipitous decline (~80% decline) from the 1970s–1990s. The eastern DPS, including southeastern Alaska rookeries, however, has been increasing at ~3% annually since the 1970s. Additionally, we found a significant difference in the proportion of recently fed pups between newly-established rookeries (established 1990-2002) within the northern extent of the eastern DPS and the historical rookeries of the southern portion (means: 0.79 + - 0.04 and 0.54 + - 0.06, respectively; p = 0.04). We suggest that the southern southeastern Alaskan metapopulation may be experiencing nutritional stress due to intraspecific competition resulting from continued population growth, while the western Aleutian SSLs are responding to a different ecological pressure as that population has not yet recovered.

Davis, R. W., Williams, T. M., Loughlin, T. R., & Castellini, M. A. (1993). Blood Chemistries and Body Condition of Steller Sea Lion Pups at Marmot Island, Alaska. *Marine Mammal Science*, 9(2), 202. Retrieved from

https://williams.eeb.ucsc.edu/wp-content/uploads/2015/09/StellarPups_CastelliniEtAl1993.pdf

This work is part of a large project focused on assessing the blood chemistry and body condition of pinnipeds in and around Alaskan waters. We have utilized a series of blood indices that reflect hydration state, blood oxygen transport, and protein, lipid and carbohydrate metabolism. In addition to total mass, animals are also examined for blubber thickness at several locations around the body.

du Dot, T. J., Rosen, D. A. S., Richmond, J. P., Kitaysky, A. S., Zinn, S. A., & Trites, A. W. (2009). Changes in Glucocorticoids, Igf-I and Thyroid Hormones as Indicators of Nutritional Stress and Subsequent Refeeding in Steller Sea Lions (*Eumetopias Jubatus*). *Comparative Biochemistry and Physiology A- Molecular & Integrative Physiology*, 152(4), 524-534. https://doi.org/10.1016/j.cbpa.2008.12.010

Physiological responses to changes in energy balance are tightly regulated by the endocrine system through glucocorticoids, IGF-I and thyroid hormones. Changes in these hormones were studied in eight captive female Steller sea lions that experienced changes in food intake, body mass, body composition, and blood metabolites during summer and winter. During a period of energy restriction, one group of sea lions was fed reduced amounts of Pacific herring and another was fed an isocaloric diet of walleye pollock, after which both groups returned to their pre-experimental diets of herring. Cortisol was negatively and IGF-I was positively associated with changes in body mass during periods of energy restriction (mass loss associated with increase in cortisol and decrease in IGF-I) and refeeding (body mass maintenance associated with stable hormone concentrations in summer and compensatory growth linked to decrease in cortisol and increase in IGF-I in winter). Cortisol and IGF-I were also correlated with changes in lipid and lean mass, respectively. Consequently, these two hormones likely make adequate biomarkers for nutritional stress in sea lions, and when combined provide indication of the energetic strategy (lipid vs lean mass catabolism) animals adopt to cope with changes in nutrient intake. Unlike type of diet fed to the sea lions, age of the animals also impacted hormonal responses, with younger animals showing more intense hormonal changes to nutritional stress. Thyroid hormones, however, were not linked to any physiological changes observed in this study.

du Dot, T. J., Rosen, D. A. S., & Trites, A. W. (2009). Energy Reallocation During and after Periods of Nutritional Stress in Steller Sea Lions: Low-Quality Diet Reduces Capacity for Physiological Adjustments. *Physiological and Biochemical Zoology*, 82(5), 516-530. <u>https://doi.org/10.1086/603637</u>

Two groups of female Steller sea lions (groups H and P) were subjected to periods of energy restriction and subsequent re-feeding during winter and summer to determine changes in energy partitioning among principal physiological functions and the potential consequences to their fitness. Both sea lion groups consumed high-quality fish (herring) before and after the energy restrictions. During restrictions, group H was fed a lower quantity of herring and group P a caloric equivalent of low-quality fish (pollock). Quantitative estimates of maintenance and production energies and qualitative estimates of thermoregulation, activity, and basal metabolic rate were measured. During summer, all animals compensated for the imposed energy deficit by releasing stored energy (production energy). Group H also optimized the energy allocation to seasonal conditions by increasing activity during summer, when fish are naturally abundant (foraging effort), and by decreasing thermoregulation capacity when waters are warmer. During winter, both groups decreased the energy allocated to overall maintenance functions (basal metabolic rate, thermoregulation, and activity together) in addition to releasing stored energy, but they preserved thermoregulatory capacity. Group H also decreased activity levels in winter, when foraging in the wild is less efficient, unlike group P. Overall, sea lions fed pollock did not change energy allocation to suit environmental conditions as readily as those fed herring. This implies that a low energy-density diet may further reduce fitness of animals in the wild during periods of nutritional stress.

Fahlman, A., Hastie, G. D., Rosen, D. A. S., & Trites, A. W. (2007). The Influence of Buoyancy on Diving Metabolism of Steller Sea Lions (*Eumetopias Jubatus*). *FASEB Journal*, *21*(5), A593-A594. Retrieved from <u>http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch_&qid=17&SID=8AKBSJ5RixL6hagr5Wp&page=1&doc=1</u>

Resting (RMR) and diving metabolic rates (DMR, I O2 \cdot min-1) were measured in 3 female Steller sea lions (body masses, Mb): 135.0, 168.8 and 213.1 kg) in water with and without adjustment in buoyancy to determine if seasonal fluctuations in subcutaneous adipose tissue affect DMR. Total body water was used to assess percent body fat (body condition) and buoyancy for the control condition (B, range: -86N to 51N). Buoyancy was adjusted either positively (B+, range:-62N to -33 N) or negatively (B-, -101N to 64N) from the control condition to investigate the full range of body conditions experienced in the wild (12*27% body fat). Mean RMR ranged between 1.65 to 1.12 I O2 \cdot min-1 and was positively correlated with Mb (P < 0.01). DMR was corrected for Mb (sDMR) using a mass exponent of 0.6 (McPhee et al., J Exp Biol 2002). sDMR was found to decline exponentially with dive duration (DD, min), although significant differences were observed in slope and intercept (P < 0.01) between animals (r² = 0.51, ANCOVA). The best mixed model ANOVA, including animal as a random factor, was: sDMR = 0.130 -0.102 \cdot [1-e(-DD))] + 6.48 \cdot 10-4. Depth Consequently, sDMR was unaffected by changes in buoyancy but increased with depth and decreased with DD.

 Fahlman, A., Moore, M. J., Trites, A. W., Rosen, D. A. S., Haulena, M., Waller, N., . . . Thom, S. R. (2016). Dive, Food, and Exercise Effects on Blood Microparticles in Steller Sea Lions (*Eumetopias Jubatus*): Exploring a Biomarker for Decompression Sickness. *American Journal of Physiology-Regulatory Integrative and Comparative Physiology, 310*(7), R596-R601. https://doi.org/10.1152/ajpregu.00512.2015

Recent studies of stranded marine mammals indicate that exposure to underwater military sonar may induce pathophysiological responses consistent with decompression sickness (DCS). However, DCS has been difficult to diagnose in marine mammals. We investigated whether blood microparticles (MPs, measured as number/mu l plasma), which increase in response to decompression stress in terrestrial mammals, are a suitable biomarker for DCS in marine mammals. We obtained blood samples from trained Steller sea lions (*Eumetopias jubatus*, 4 adult females) wearing time-depth recorders that dove to predetermined depths (either 5 or 50 meters). We hypothesized that MPs would be positively related to decompression stress (depth and duration underwater). We also tested the effect of feeding and exercise in isolation on MPs using the same blood sampling protocol. We found that feeding and exercise had no effect on blood MP levels, but that diving caused MPs to increase. However, blood MP

levels did not correlate with diving depth, relative time underwater, and presumed decompression stress, possibly indicating acclimation following repeated exposure to depth.

Fahlman, A., Svard, C., Rosen, D. A. S., Wilson, R. P., & Trites, A. W. (2013). Activity as a Proxy to Estimate Metabolic Rate and to Partition the Metabolic Cost of Diving Vs. Breathing in Pre- and Post-Fasted Steller Sea Lions. *Aquatic Biology*, 18(2), 175-184. <u>https://doi.org/10.3354/ab00500</u>

Three Steller sea lions *Eumetopias jubatus*, trained to dive voluntarily to depths ranging from 10 to 50 m, were used to determine whether the relationship between activity and metabolic rate during a diving interval (MRDI, dive + surface interval) was affected by fasting (9 d) during the breeding season (spring through summer). We subsequently used the relationship between activity and MRDI to partition the metabolic costs between underwater breath-holding activity and surface breathing activities. We estimated activity from overall dynamic body acceleration (ODBA) measured using a 3-axis accelerometer, and measured MRDI using flow-through respirometry. The relationship between ODBA-based activity and MRDI was not affected by fasting period, suggesting that ODBA can be used to predict energy expenditure regardless of nutritional state in the spring and summer. However, the relationship between ODBA and dive metabolic rate differs from the relationship between ODBA and the surface wersus swimming underwater suggests that the metabolic cost of iremaining at the surface versus swimming underwater suggests that the surface. ODBA appears to be a reasonable proxy to estimate metabolic rate in marine mammals, but more detailed behavioral data may be required to accurately apply the method in the field.

Fahlman, A., Wilson, R., Svard, C., Rosen, D. A. S., & Trites, A. W. (2008). Activity and Diving Metabolism Correlate in Steller Sea Lion *Eumetopias Jubatus*. *Aquatic Biology*, 2(1), 75-84. <u>https://doi.org/10.3354/ab00039</u>

Three Steller sea lions *Eumetopias jubatus* were trained to participate in free-swimming, open-ocean experiments designed to determine if activity can be used to estimate the energetic cost of finding prey at depth. Sea lions were trained to dive to fixed depths of 10 to 50 m, and to re-surface inside a floating dome to measure energy expenditure via gas exchange. A 3-axis accelerometer was attached to the sea lions during foraging. Acceleration data were used to determine the overall dynamic body acceleration (ODBA), a proxy for activity. Results showed that ODBA correlated well with the diving metabolic rate (dive + surface interval) and that the variability in the relationship (r(2) = 0.47, linear regression including Sea lion as a random factor) was similar to that reported for other studies that used heart rate to estimate metabolic rate for sea lions swimming underwater in a 2 m deep water channel. A multivariate analysis suggested that both ODBA and dive duration were important for predicting diving metabolic cost, but ODBA alone predicted foraging cost to within 7% between animals. Consequently, collecting 3-dimensional acceleration data is a simple technique to estimate field metabolic rate of wild Steller sea lions and other diving mammals and birds.

Gerlinsky, C. D., Haulena, M., Trites, A. W., & Rosen, D. A. S. (2018). Reference Ranges and Age-Related and Diving Exercise Effects on Hematology and Serum Chemistry of Female Steller Sea Lions (*Eumetopias Jubatus*). *Journal of Zoo and Wildlife Medicine, 49*(1), 18-29. https://doi.org/10.1638/2017-0072R.1 Decreased health may have lowered the birth and survival rates of Steller sea lions (*Eumetopias jubatus*) in the Gulf of Alaska and Aleutian Islands over the past 30 yr. Reference ranges for clinical hematology and serum chemistry parameters needed to assess the health of wild sea lion populations are limited. Here, blood parameters were serially measured in 12 captive female Steller sea lions ranging in age from 3 wk to 16 yr to establish baseline values and investigate age-related changes. Whether diving activity affects hematology parameters in animals swimming in the ocean compared with animals in a traditional aquarium setting was also examined. Almost all blood parameters measured exhibited significant changes with age. Many of the age-related changes reflected developmental life history changes, including a change in diet during weaning, an improvement of diving capacity, and the maturity of the immune system. Mean corpuscular hemoglobin and mean corpuscular volume were also higher in the ocean diving group compared with the aquarium group, likely reflecting responses to increased exercise regimes. These data provide ranges of hematology and serum chemistry values needed to evaluate and compare the health and nutritional status of captive and wild Steller sea lions.

Gerlinsky, C. D., Rosen, D. A. S., & Trites, A. W. (2013). High Diving Metabolism Results in a Short Aerobic Dive Limit for Steller Sea Lions (*Eumetopias Jubatus*). *Journal of Comparative Physiology B-Biochemical Systemic and Environmental Physiology*, 183(5), 699-708. https://doi.org/10.1007/s00360-013-0742-7

The diving capacity of marine mammals is typically defined by the aerobic dive limit (ADL) which, in lieu of direct measurements, can be calculated (cADL) from total body oxygen stores (TBO) and diving metabolic rate (DMR). To estimate cADL, we measured blood oxygen stores, and combined this with diving oxygen consumption rates (VO2) recorded from 4 trained Steller sea lions diving in the open ocean to depths of 10 or 40 m. We also examined the effect of diving exercise on O-2 stores by comparing blood O-2 stores of our diving animals to non-diving individuals at an aquarium. Mass-specific blood volume of the non-diving individuals was higher in the winter than in summer, but there was no overall difference in blood O-2 stores between the diving and non-diving groups. Estimated TBO (35.9 ml O-2 kg(-1)) was slightly lower than previously reported for Steller sea lions and other Otariids. Calculated ADL was 3.0 min (based on an average DMR of 2.24 L O-2 min(-1)) and was significantly shorter than the average 4.4 min dives our study animals performed when making single long dives-but was similar to the times recorded during diving bouts (a series of 4 dives followed by a recovery period on the surface), as well as the dive times of wild animals. Our study is the first to estimate cADL based on direct measures of VO2 and blood oxygen stores for an Otariid and indicates they have a much shorter ADL than previously thought.

Gerlinsky, C. D., Trites, A. W., & Rosen, D. A. S. (2014). Steller Sea Lions (*Eumetopias Jubatus*) Have Greater Blood Volumes, Higher Diving Metabolic Rates and a Longer Aerobic Dive Limit When Nutritionally Stressed. *Journal of Experimental Biology*, 217(5), 769-778. <u>https://doi.org/10.1242/jeb.089599</u>

Marine mammal foraging behaviour inherently depends on diving ability. Declining populations of Steller sea lions may be facing nutritional stress that could affect their diving ability through changes in body composition or metabolism. Our objective was to determine whether nutritional stress (restricted food intake resulting in a 10% decrease in body mass) altered the calculated aerobic dive limit (cADL) of four captive sea lions diving in the open ocean, and how this related to changes in observed dive

behaviour. We measured diving metabolic rate (DMR), blood O-2 stores, body composition and dive behaviour prior to and while under nutritional restriction. We found that nutritionally stressed sea lions increased the duration of their single long dives, and the proportion of time they spent at the surface during a cycle of four dives. Nutritionally stressed sea lions lost both lipid and lean mass, resulting in potentially lower muscle O-2 stores. However, total body O-2 stores increased due to rises in blood O-2 stores associated with having higher blood volumes. Nutritionally stressed sea lions also had higher mass-specific metabolic rates. The greater rise in O-2 stores relative to the increase in mass-specific DMR resulted in the sea lions having a longer cADL when nutritionally stressed. We conclude that there was no negative effect of nutritional stress on the diving ability of sea lions. However, nutritional stress did lower foraging efficiency and require more foraging time to meet energy requirements due to increases in diving metabolic rates and surface recovery times.

Goundie, E. T., Rosen, D. A. S., & Trites, A. W. (2015). Dive Behaviour Can Predict Metabolic Expenditure in Steller Sea Lions. *Conservation Physiology*, 3 <u>https://doi.org/10.1093/conphys/cov052</u>

Quantification of costs associated with foraging contributes to understanding the energetic impact that changes in prey availability have on the energy balance of an animal and the fitness of populations. However, estimating the costs of foraging is difficult for breath-hold divers, such as Steller sea lions, that feed underwater. We developed models parameterized with data from free-diving captive Steller sea lions to estimate the costs incurred by wild animals while foraging. We measured diving metabolic rate of trained sea lions performing four types of dives to 10 and 40 m in the open ocean and estimated the separate costs of different dive components: surface time; bottom time; and transiting to and from depth. We found that the sea lions' diving metabolic rates were higher while transiting (20.5 +/- 13.0 ml $O-2 \min(-1) \text{ kg}(-1)$) than while swimming at depth (13.5 +/- 4.1 ml O-2 min(-1) kg(-1)), and both were higher than metabolism at the surface (9.2 +/- 1.6 ml O-2 min(-1) kg(-1)). These values were incorporated into an energetic model that accurately predicted oxygen consumption for dives only (within 9.5%) and dive cycles (within 7.7%), although it consistently overestimated costs by 5.9% for dives and 21.8% for dive cycles. Differences in the costs of individual components of dives also explained differences in the efficiency of different dive strategies. Single dives were energetically less costly than bout dives; however, sea lions were more efficient at replenishing oxygen stores after bout dives and could therefore spend a greater portion of their time foraging than when undertaking single dives. The metabolic rates we measured for the different behavioural components of diving can be applied to timedepth recordings from wild Steller sea lions to estimate the energy expended while foraging. In turn, this can be used to understand how changes in prey availability affect energy balance and the health of individuals in declining populations.

Harmon, H., & Castellini, M. (1999). The Reproductive Physiology and Endocrinology of Steller Sea Lions. *Biology of Reproduction, 60*, 239-239. Retrieved from <u>http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch_</u> &qid=18&SID=8AKBSJ5RixL6hagr5Wp&page=1&doc=1

We examined the reproductive performance of female Steller sea lions (*Eumetopias jubatus*) in order to evaluate the hypothesis that low pup production was associated with nutritional stress and to assess whether reduced birth rates could have been a factor in a recent large-scale decline in numbers. Nearly all (97%) sexually mature females were pregnant during early gestation. However, by late gestation, pregnancy rates had declined to 67 and 55% in the 1970s and 1980s, respectively, owing to reproductive

failures. We found that body condition, as depicted by mass index and blubber index, had a positive effect on the probability that a female would be pregnant during late gestation. Age, age2, and lactation were also associated with pregnancy status during late gestation. These findings support the hypotheses that reproductive failures were associated with lowered nutritional status and that the resulting low birth rates were a proximate factor in the decline. We speculate that abortion is a part of the reproductive strategy of the female Steller sea lion that enhances overall reproductive performance during times of suboptimal nutrition. A major shift in oceanic regime occurred in the Gulf of Alaska during the late 1970s that resulted in a reduction of about 50% in the overall biomass of fishes and a shift in species composition. Prey resources may not have been adequate to successfully support the Steller sea lions' "energetically expensive" reproductive/foraging strategy during the period of our study.

Harmon, H. L., Castellini, M. A., Rowell, J., & Atkinson, S. (2000). The Use of Saliva, Vaginal Cytology and Testicular Size to Determine Reproductive Status in Steller Sea Lions. *FASEB Journal*, *14*(4), A46-A46. Retrieved from

http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch &qid=19&SID=8AKBSJ5RixL6hagr5Wp&page=1&doc=1

The goal of this ongoing project is to describe the reproductive endocrinology and physiology of Steller sea lions (SSLs). Some Alaskan populations are declining for unknown reasons and recently there has been interest in determining if hormone balance or changes in reproductive rates are related to this decline. The objectives are to validate alternative methods for determining peripheral hormone concentrations using saliva, provide anatomical verification of reproductive status and to describe the annual cycles of repro ductive hormones. Three adult captive SSLs housed at the ASLC are being used for this project.-Plasma was collected monthly and-saliva sam-ples were collected twice weekly and frozen. Progesterone (P 4)1 estrone {E1} and testosterone {T} concentrations in plasma and saliva were measured by RIA and were compared. Vaginal swabs were taken twice weekly to determine percent cornifica.tion of epithelial cells, which may indicate the state of estrus. Testicle lengths and girths were measured monthly. The correlation coefficient between plasma and saliva for both P 4 and T was 0.94. These results indicate that saliva is a valid alternative to plasma for determining P 4 and T concentrations for SSLs. However, the correlation coefficient between plasma and saliva for E1 was only 0.34. Therefore, salivary E1 can not be reliably used for the determination of reproductive status for SSLs. Vaginal cytology was found to be useful in determining reproductive status. Both T and testicle size increased with the onset of the breeding season.

Hastie, G. D., Rosen, D. A. S., & Trites, A. W. (2006). The Influence of Depth on a Breath-Hold Diver: Predicting the Diving Metabolism of Steller Sea Lions (*Eumetopias Jubatus*). Journal of Experimental Marine Biology and Ecology, 336(2), 163-170. <u>https://doi.org/10.1016/j.jembe.2006.05.004</u>

Diving animals must endeavor to increase their dive depths and prolong the time they spend exploiting resources at depth. Results from captive and wild studies suggest that many diving animals extend their foraging bouts by decreasing their metabolisms while submerged. We measured metabolic rates of Steller sea lions (*Eumetopias jubatus*) trained to dive to depth in the open ocean to investigate the relationships between diving behaviour and the energetic costs of diving. We also constructed a general linear model to predict the oxygen consumption of sea lions diving in the wild. The resultant model suggests that swimming distance and depth of dives significantly influence the oxygen consumption of

diving Steller sea lions. The predictive power of the model was tested using a cross-validation approach, whereby models reconstructed using data from pairs of sea lions were found to accurately predict the oxygen consumption of the third diving animal. Predicted oxygen consumption during dives to depth ranged from 3.37 L min(-1) at 10 m, to 1.40 L min(-1) at 300 m over a standardized swimming distance of 600 m. This equated to an estimated metabolic rate of 97.54 and 40.52 MJ day(-1), and an estimated daily feeding requirement of 18.92 and 7.96 kg day(-1) for dives between 10 and 300 m, respectively. The model thereby provides information on the potential energetic consequences that alterations in foraging strategies due to changes in prey availability could have on wild populations of sea lions.

Hastie, G. D., Rosen, D. A. S., & Trites, A. W. (2006). *Studying Diving Energetics of Trained Steller Sea Lions in the Open Sea*. Retrieved from <u>https://seagrant.uaf.edu/bookstore/pubs/item.php?id=11180</u>

The costs associated with diving are a central component of a sea lion's energy budget. Accurate estimates of diving costs are needed to assess energetic and physiological constraints on foraging behavior, including the potential effects of changes in prey distribution or density. However, information on sea lion diving physiology is limited to relatively few species of pinnipeds, and there is currently no information for Steller sea lions. Information on diving energetics of pinnipeds has traditionally been gathered using either wild or captive animals. Studies with wild animals are logistically challenging and are limited by the opportunistic nature of data collection, while studies in captivity have been constrained by the physical restrictions of the holding facility. To circumvent some of these limitations, we combined the best aspects of both techniques by conducting diving metabolism studies with trained Steller sea lions in an open ocean environment. Two captive-reared Steller sea lions were housed in a holding pen and transported by boat to a diving trial area. The animals were trained to dive to predetermined depths for controlled periods of time using an underwater light targeting system and a video system to monitor behavior. At the end of each dive the sea lions returned to a respirometry dome on the surface where oxygen consumption was measured to estimate diving metabolism. This paper describes the experimental setup used to evaluate diving metabolism, discusses the logistical challenges of the study and the advantages of using such an approach to carry out physiological experiments with sea lions, and provides preliminary data on the diving energetics of Steller sea lions.

Hastie, G. D., Rosen, D. A. S., & Trites, A. W. (2007). Reductions in Oxygen Consumption During Dives and Estimated Submergence Limitations of Steller Sea Lions (*Eumetopias Jubatus*). *Marine Mammal Science*, *23*(2), 272-286. <u>https://doi.org/10.1111/j.1748-7692.2007.00118.x</u>

Accurate estimates of diving metabolic rate are central to assessing the energy needs of marine mammals. To circumvent some of the limitations inherent with conducting energy studies in both the wild and captivity, we measured diving oxygen consumption of two trained Steller sea lions (*Eumetopias jubatus*) in the open ocean. The animals dived to predetermined depths (5-30 m) for controlled periods of time (50-200 s). Rates of oxygen consumption were measured using open-circuit respirometry before and after each dive. Mean resting rates of oxygen consumption prior to the dives were 1.34 (+/- 0.18) and 1.95 (+/- 0.19) liter/min for individual sea lions. Mean rates of oxygen consumption during the dives were 0.71 (+/- 0.24) and 1.10 (+/- 0.39) liter/min, respectively. Overall, rates of oxygen consumption during dives were significantly lower (45% and 41176) than the corresponding rates measured before dives. These results provide the first estimates of diving oxygen consumption rate for Steller sea lions and show that this species can exhibit a marked decrease in oxygen consumption relative to surface

rates while submerged. This has important consequences in the evaluation of physiological limitations associated with diving such as dive duration and subsequent interpretations of diving behavior in the wild.

Hastings, K. K., & Jemison, L. A. (2016). Age-Specific Variation in Timing of Parturition in Steller Sea Lions at Forrester Island Complex, Alaska. *Marine Mammal Science*, *32*(2), 777-785. <u>https://doi.org/10.1111/mms.12288</u>

The article presents a study that determined whether parturition date varies with age in Stellar sea lion (SSL) at the Forrester Island Complex in Alaska. The study involved a large sample of marked females observed from late May to beginning July for a decade, surveyed the reproductive status of mature known-aged females from late May to mid-July from 2007 to 2014, and revealed that later parturition dates for younger SSL suggests physiological constraints on timing of gestation length.

Hindle, A. G., Rosen, D. A. S., & Trites, A. W. (2010). Swimming Depth and Ocean Currents Affect Transit Costs in Steller Sea Lions *Eumetopias Jubatus*. *Aquatic Biology*, *10*(2), 139-148. <u>https://doi.org/10.3354/ab00279</u>

Transit costs associated with commuting between resting sites ashore and foraging areas at sea constitute an appreciable portion of foraging expenditures in pinnipeds. We examined transit swimming in 3 Steller sea lions *Eumetopias* jubatus trained to follow a moving boat at different speeds and depths. We measured dive behavior (duration) and focused specifically on activity measures (fore-flipper stroking and overall dynamic body acceleration [ODBA], an overall measure of body motion), which may be proxies for metabolic expenditure. Sea lions appeared to increase efficiency while transiting at depths that approached 3 times their body diameters (mean depth = 151 + - 1 cm SEM, n = 87). Although the response was not uniform for all tested scenarios, all of the observed significant adjustments to dive behavior and swimming mechanics supported an increased efficiency at this depth. An increase in transit speed (4.5 versus 3.5 knots [kn] surface speed) was associated with elevated flipper stroke frequencies (+5 %) and stroke output (ODBA stroke(-1), +48 %). Sea lions transiting against the flow of a tidal current had reduced dive durations (-10 %), while total ODBA was consistently elevated (+8% overall). This response to tidal flow was accompanied either by elevated ODBA stroke(-1) (3.5 kn) or a parallel increase in stroking (4.5 kn). Our data demonstrate that small changes in the physical environment affect transiting in Steller sea lions, and imply that altered prey fields or changing ocean conditions can carry energetic consequences.

Hindle, A. G., Young, B. L., Rosen, D. A. S., Haulena, M., & Trites, A. W. (2010). Dive Response Differs between Shallow- and Deep-Diving Steller Sea Lions (*Eumetopias Jubatus*). Journal of *Experimental Marine Biology and Ecology, 394*(1-2), 141-148. <u>https://doi.org/10.1016/j.jembe.2010.08.006</u>

Muscle exercise correlates with oxygen use, tissue perfusion and heart rate (f(H)) in terrestrial animals, but the relationship between these physiological processes is less clear in diving animals. We found the mean heart rate of Steller sea lions trained to voluntarily dive to depths up to 40 m dropped by 40% while diving, and noted that mean bradycardia was 9% greater during shallow (10 m) compared to deep (40 m) dives. Longer dives resulted in lower heart rates, but only when they were shallow; on the other

hand, minimum instantaneous f(H) decreased consistently with dive duration. In general, instantaneous f(H) did not reflect activity over short timescales. Our data suggest that our sea lions invoked a different dive response depending on whether they dove to shallow or deep depths. During shallow (10 m) dives only, the correlation between activity and f(H) was indicative of vascular compromise between diving and exercise. However, during deep dives (40 m), there was no such correlation, suggesting that locomotory activity was uncoupled from dive bradycardia, which was possibly mediated by an absence of blood flow to active muscle. For both diving scenarios, surface f(H) correlated with dive activity, suggesting that some underwater locomotory costs were deferred to the post-dive surface interval. Ultimately, our data support the speculation that Steller sea lion locomotory muscles become hypoxic during diving, regardless of dive depth.

Hirons, A. C., Schell, D. M., & St Aubin, D. J. (2001). Growth Rates of Vibrissae of Harbor Seals (Phoca Vitulina) and Steller Sea Lions (*Eumetopias Jubatus*). *Canadian Journal of Zoology*, 79(6), 1053-1061. <u>https://doi.org/10.1139/z01-055</u>

Growth rates of vibrissae (whiskers), which act as a temporal record of feeding in harbor seals (Phoca vitulina) and Steller sea lions (*Eumetopias jubatus*), were estimated using C-13- and N-15-labeled glycine followed by stable-isotope analysis. The labeled glycine was incorporated into keratin and served as a temporal marker for growth-rate calculation. One captive harbor seal received two doses 147 days apart, while a second seal received one dose; vibrissae were analyzed after 86 and 154 days. The peak positions indicated that growth began in the fall, continued into spring, but ceased in June, with active growth rates of 0.33 mm/day. Two adult captive Steller sea lions each received two labeled doses during a 308-day period. After 427 days vibrissae in both sea lions showed two peaks corresponding to the markers; growth rates were calculated as 0.05-0.07 mm/day. Growth rates in captive juvenile and wild adult Steller sea lions, 0.10-0.17 mm/day, supported the assumption that major isotopic oscillations in vibrissae of wild sea lions were annual. The multiyear records imply that Steller sea lions retain their vibrissae; harbor seal vibrissae, in contrast, have periods of rapid growth and appear to be shed, at least in part, annually.

Hoopes, L. A. (2007). *Metabolic and Thermoregulatory Capabilities of Juvenile Steller Sea Lions, Eumetopias Jubatus*. Texas A&M University. Retrieved from <u>https://search.proquest.com/asfa/docview/1272686080/44CBADD671469FPQ/1?accountid=28</u> 258

Maintaining thermal balance is essential for all homeotherms but can be especially challenging for pinnipeds which must regulate over a variety of ambient temperatures and habitats as part of their life history. Young pinnipeds, with their immature physiology and inexperience, have the additional expense of needing to allocate energy for growth while still dealing with a thermally stressful aquatic environment. With the immense environmental and physiological pressures acting on juvenile age-classes, declines in prey resources would be particularly detrimental to survival. The goal of the present study was to examine the metabolic and thermoregulatory capabilities of juvenile Steller sea lions to better understand how changing prey resources indirectly impact juvenile age classes. Data collected from captive Steller sea lions suggest that changes in body mass and body composition influence the thermoregulatory capabilities of smaller sea lions in stationary and flowing water. Serial thermal images taken of sea lions after emergence from the water show vasoconstriction of the flippers compared to the body trunk to help minimize heat loss. Despite this ability to vasoconstrict, sea lions in poor body

condition displayed a reduced tolerance for colder water temperatures, suggesting that decreases in prey availability which affect insulation may limit survival in younger sea lions. If reductions in prey availability (i.e., nutritional stress) were impacting western Alaskan populations, a reduction in energetic expenditures would be expected in these animals to cope. Measures of resting metabolism in juvenile free-ranging Steller sea lions across Alaska showed no differences between eastern and western capture locations, suggesting no evidence of metabolic depression in declining western stocks of sea lions. Finally, thermal costs predicted by a thermal balance model were compared to actual costs measured in the present study. Model output reliably predicted thermoregulatory costs for juvenile Steller sea lions under certain environmental conditions. Basic physiological measurements combined with the predictive power of modeling will allow for greater exploration of the environmental constraints on juvenile Steller sea lions and identify directions of future study.

Hoopes, L. A., Rea, L. D., & Worthy, G. A. J. (2005, Dec). Born Free: Resting Metabolic Rate in Free-Ranging Steller Sea Lions (Eumetopias Jubatus). Paper presented at the Annual Meeting of the Society for Integrative and Comparative Biology. Retrieved from http://www.sicb.org/meetings/2006/schedule/abstractdetails.php3?id=471

The prevalent hypothesis for the >80% decline of Steller sea lions (SSLs) in western Alaska is that changing prey quality and/or quantity have prevented sea lions from meeting their energetic demands, thus creating a deficit, or nutritional stress. This may be particularly true in younger animals which experience the high energetic demands associated with growth. When energy intake is insufficient to meet daily energetic demands, some animals are able to compensate by limiting their energy expenditures. The most common physiological response to limited food intake is a lowering of resting metabolic rate (RMR) known as metabolic depression. Given observed reductions in RMR in captive SSLs fed a low energy diet, the potential significance of metabolic depression in juvenile free-ranging SSLs was examined via open flow respirometry. Free-ranging animals were captured from western stocks in Prince William Sound (PWS, n =30) and the Central Aleutian Islands (AL, n=16) and from the eastern stock in Southeast Alaska (SE, n=43). RMR was measured in animals aged 2, 5, 8, 11, 14, 20 and 26 months at ambient air temperatures (-6-18 °C). Standard morphometrics, blubber depth, and total body fat stores were measured for an estimate of body condition at each location. Mean RMR ranged from 11.0 to 32.3 MJ d-1 across all aged animals, and as expected, increased with increasing body mass. Although air temperatures varied between capture sites, similar temperatures existed between PWS and SE locations, allowing direct comparisons of RMR, blubber depth, and total body fat stores between similarly aged animals. Our data indicate no evidence of metabolic depression in western stock animals.

 Jono, M., Kobayashi, Y., Asanuma, T., Tsubota, T., & Sakurai, Y. (2012). Allometric Growth and Morphology of Steller Sea Lion Fetuses. *Bulletin of fisheries sciences, Hokkaido University, 62*(1), 1-7. Retrieved from <u>http://hdl.handle.net/2115/49086</u>

In precocial species, fetuses often show adaptation to their particular environments. We investigated growth and morphology of 11 fetuses of Steller sea lion (*Eumetopias jubatus*), a highly precocial animal. The specimens were collected around Hokkaido, Japan in 2006-2008. Body length was found to increase gradually with gestational period, while body weight rapidly increased after the middle period (81-160 days) of gestation. Positive allometric growth indicating tachyauxesis was found only in the four limbs. This noteworthy limb development may indicate adaptation to postnatal movements on shore and in the water. The fur, which developed fully by birth, confirmed the importance of thermoregulation. MRI

images suggested a progressive status of ossification, leading us to surmise that bone development occurs during the early (<80 days) and middle periods of gestation. We presume that shapes of internal organs are determined for the most part during early gestation, although the period will vary from one organ to another.

Kastelein, R. A., van Schie, R., Verboom, W. C., & de Haan, D. (2005). Underwater Hearing Sensitivity of a Male and a Female Steller Sea Lion (*Eumetopias Jubatus*). *Journal of the Acoustical Society of America*, 118(3), 1820-1829. <u>https://doi.org/10.1121/1.1992650</u>

The unmasked underwater hearing sensitivities of an 8-year-old male and a 7-year-old female Steller sea lion were measured in a pool, by using behavioral psychophysics, The animals were trained with positive reinforcement to respond when they detected an acoustic signal and not to respond when they did not. The signals were narrow-band, frequency-modulated stimuli with a duration of 600 ms and center frequencies ranging from 0.5 to 32 kHz for the male and from 4 to 32 kHz for the female. Detection thresholds at each frequency were measured by varying signal amplitude according to the up-down staircase method. The resulting underwater audiogram (50% detection thresholds) for the male Steller sea lion showed the typical mammalian U-shape, His maximum sensitivity (77 dB re: 1 mu Pa, rms) occurred at I kHz. The range of best hearing (10 dB from the maximum sensitivity) was from I to 16 kHz (4 octaves). Higher hearing thresholds (indicating poorer sensitivity) were observed below I kHz and above 16 kHz. The maximum sensitivity of the female (73 dB re: 1 mu Pa, rms) occurred at 25 kHz. Higher hearing thresholds (indicating poorer sensitivity) were observed for signals below 16 kHz and above 25 kHz. At frequencies for which both subjects were tested, hearing thresholds of the male were significantly higher than those of the female. The hearing sensitivity differences between the male and female Steller sea lion in this study may be due to individual differences in sensitivity between the subjects or due to sexual dimorphism in hearing.

 Kennedy, S. N., Castellini, J. M., Hayden, A. B., Fadely, B. S., Burkanov, V. N., Dajles, A., . . . Rea, L. D. (2019). Regional and Age-Related Variations in Haptoglobin Concentrations in Steller Sea Lions (*Eumetopias Jubatus*) from Alaska, USA. *Journal of Wildlife Diseases, 55*(1), 91-104, 114. Retrieved from <u>https://doi.org/10.7589/2017-10-257</u>

Varying concentrations of the highly conserved acute phase response protein, haptoglobin, can indicate changes to the health and disease status of mammals, including the Steller sea lion (SSL; *Eumetopias jubatus*). To better understand factors relating to acute phase response in SSLs, circulating haptoglobin concentrations (Hp) were quantified in plasma collected from 1,272 individuals sampled near rookeries and haulouts off the coast of Alaska, US. We compared Hp in SSLs between sexes and among different age classes (young pups, young-of-the-year, yearlings, subadults, and adults) sampled within distinct regions in Alaska (Aleutian Islands, Gulf of Alaska, Southeast Alaska). Regional and agerelated differences were observed, particularly in younger SSLs. No sex-related differences were detected. We identified weakly significant relationships between Hp and hematology measurements including white blood cell counts and hematocrit in young pups from the Aleutian Islands and Southeast Alaska. No relationship between Hp and body condition was found. Lastly, a nonlinear relationship of plasma Hp and whole blood total mercury concentrations (THg) was observed in SSLs from the endangered western distinct population segment in Alaska. These results demonstrated that regional variation in Hp, especially in younger SSLs, may reflect regional differences in health and circulating THg.

Keogh, M. J., Atkinson, S., & Maniscalco, J. M. (2013). Body Condition and Endocrine Profiles of Steller Sea Lion (Eumetopias Jubatus) Pups During the Early Postnatal Period. General and Comparative Endocrinology, 184, 42-50. https://doi.org/10.1016/j.ygcen.2012.12.016

Body condition indices have been useful in assessing the health of domestic and free ranging populations of terrestrial mammals. Given the high energy demand and rapid growth during the postnatal period of Steller sea lion (Eumetopias jubatus) (SSL) pups, body condition was expected to be related to concentrations of a suite of hormones (cortisol, aldosterone, thyroxine, triiodothyronine, leptin) previously associated with changes in body mass and composition in developing pinnipeds. Blood samples were collected from free ranging SSL pups of known ages and sex. A body condition index (BCI) previously developed for SSL pups based on a mass and length relationship was applied to 61 SSL pups ranging in age from 5 to 38 days old. BCI was not related to pup age. Overall, male pups were larger than females and older pups were larger than younger pups. Aldosterone was negatively correlated with BCI only in female pups, whereas no relationship was observed between aldosterone and BCI in males. Further, male pups had higher aldosterone concentrations than females. Concentrations of cortisol, total and free thyroxine (T-4), and total triiodothyronine (T-3) decreased when regressed against the elapsed time between researchers' arrival on the rookery and removal of pup from the holding corral for blood collection. While the overall variation attributed to the rookery disturbance was low (r(2) < 0.293), it may be of significance for future studies on free ranging pinnipeds. This study adds to the current knowledge of the postnatal changes in free ranging SSL pups by providing ranges of the BCI and several hormone concentrations from an apparently stable population.

Kitaysky, A., & Springer, A. (2004). When, Where and Why Steller Sea Lions Experience Physiological Stress - Evidence from Stress Hormones and Diet Quality. Slides presented at PICES 13 Annual Meeting. Retrieved from

https://pices.int/publications/presentations/PICES 13/PICES 13 S2/Kitaysky S2.pdf

Following a rapid decline, population counts of the western stock of Steller sea lions leveled off in the mid-1990s. Whether numbers finally stabilized to match the carrying capacity of the ecosystems, or the population has been stripped to the last cohorts prior to disappearance, is not known. One of the basic problems is that we have not been able to determine which breeding populations are currently stressed. We know even less about the severity of physiological stress required to interfere with reproductive function in affected sea lions. Our objectives were to: (A) To determine which rookeries currently experience physiological stress; (B) To examine whether this level of physiological stress might affect reproductive function; (C) To determine whether poor diet quality could be a major factor causing physiological stress (the "nutritional stress" hypothesis). We used fecal samples to assess hormone levels and diet composition. Inter-seasonal and inter-rookery comparisons suggest that physiological stress is contributing to the continuing decline of Steller sea lions, probably via its effects on reproductive function. In support of the nutritional stress hypothesis, we found that the diet quality was lowest in the areas of highest physiological stress and population declines. However, on the scale of specific rookeries this pattern didn't hold. Thus, although physiological stress and its negative effects on reproductive function of individuals in the western stock of the Steller sea lion are evident, the causal factors remain to be shown. The nutritional stress hypothesis can be neither accepted nor rejected based on the results of our study.

Kumagai, S., Rosen, D. A. S., & Trites, A. W. (2006). Body Mass and Composition Responses to Short-Term Low Energy Intake Are Seasonally Dependent in Steller Sea Lions (*Eumetopias Jubatus*). *Journal of Comparative Physiology B-Biochemical Systemic and Environmental Physiology*, 176(6), 589-598. https://doi.org/10.1007/s00360-006-0082-y

Steller sea lions (*Eumetopias jubatus*) were fed restricted iso-caloric amounts of Pacific herring (Clupea pallasi) or walleye pollock (Theragra chalcogramma) for 8-9 days, four times over the course of a year to investigate effects of season and prey composition on sea lion physiology. At these levels, the sea lions lost body mass at a significantly higher rate during winter (1.6 +/- 0.14 kg day(-1)), and at a lower rate during summer (1.2 +/- 0.32 kg day(-1)). Decreases in body fat mass and standard metabolic rates during the trials were similar throughout the seasons and for both diet types. The majority of the body mass that was lost when eating pollock derived from decreases in lipid mass, while a greater proportion of the mass lost when eating herring derived from decreases in lean tissue, except in the summer when the pattern was reversed. Metabolic depression was not observed during all trials despite the constant loss of body mass. Our study supports the hypothesis that restricted energy intake may be more critical to Steller sea lions in the winter months, and that the type of prey consumed (e.g., herring or pollock) may have seasonally specific effects on body mass and composition.

Lander, M. E., Fadely, B. S., Gelatt, T. S., Rea, L. D., & Loughlin, T. R. (2013). Serum Chemistry Reference Ranges for Steller Sea Lion (*Eumetopias Jubatus*) Pups from Alaska: Stock Differentiation and Comparisons within a North Pacific Sentinel Species. *Ecohealth*, 10(4), 376-393. https://doi.org/10.1007/s10393-013-0891-x

Blood chemistry and hematologic reference ranges are useful for population health assessment and establishing a baseline for future comparisons in the event of ecosystem changes due to natural or anthropogenic factors. The objectives of this study were to determine if there was any population spatial structure for blood variables of Steller sea lion (*Eumetopias jubatus*), an established sentinel species, and to report reference ranges for appropriate populations using standardized analyses. In addition to comparing reference ranges between populations with contrasting abundance trends, data were examined for evidence of disease or nutritional stress. From 1998 to 2011, blood samples were collected from 1,231 pups captured on 37 rookeries across their Alaskan range. Reference ranges are reported separately for the western and eastern distinct population segments (DPS) of Steller sea lion after cluster analysis and discriminant function analysis (DFA) supported underlying stock structure. Variables with greater loading scores for the DFA (creatinine, total protein, calcium, albumin, cholesterol, and alkaline phosphatase) also were greater for sea lions from the endangered western DPS, supporting previous studies that indicated pup condition in the west was not compromised during the first month postpartum. Differences between population segments were likely a result of ecological, physiological, or age related differences.

Maniscalco, J. M., & Parker, P. (2018). Maternal and Offspring Effects on the Timing of Parturition in Western Steller Sea Lions (*Eumetopias Jubatus*). *Canadian Journal of Zoology, 96*(4), 333-339. <u>https://doi.org/10.1139/cjz-2017-0058</u>

Identifying factors that affect the timing of parturition among annual breeders is important to aid our understanding of how variations may adversely affect population trends over both short and long temporal scales. We investigated the effect of several parameters on the timing of parturition among

individual Steller sea lions (*Eumetopias jubatus* (Schreber, 1776)) over 6 years between 2005 and 2016 using an information-theoretic approach. In addition to the random effect of year, birth and care of a pup in the previous year had the largest effect on parturition, causing a 2.4 day delay. Maternal age was negatively correlated with timing of parturition and male pups were born nearly a day earlier than female pups, on average. There was limited support for effects of sex and mass, with heavier pups born marginally earlier than lighter ones. This study illustrates some of the complexity of variables that can influence the timing of birth in this species and which should be considered in models that attempt to identify long-term trends in changing marine ecosystems.

Mashburn, K. L., & Atkinson, S. (2004). Evaluation of Adrenal Function in Serum and Feces of Steller Sea Lions (*Eumetopias Jubatus*): Influences of Molt, Gender, Sample Storage, and Age on Glucocorticoid Metabolism. *General and Comparative Endocrinology*, 136(3), 371-381. <u>https://doi.org/10.1016/j.ygcen.2004.01.016</u>

Fecal corticosterone concentrations, measured via radio immuno assay (RIA), were validated as a method to monitor adrenal function in Steller sea lion physiology. Quantification of adrenal response to an acute stressor and relevance of data produced by developed methodologies was determined through physiological challenge with exogenous administration of adrenocorticotropic hormone (ACTH) to captive adult, reproductively intact, Steller sea lions of both sexes (n = 3, 1 male, 2 female) during seasonal molt. Following ACTH administration, serial blood and fecal samples were collected and analyzed by RIA to determine adrenal response. Storage regimens and weather exposure were examined to establish external impact on fecal corticosterone concentrations. High-pressure liquid chromatography (HPLC) of both serum and feces of Steller sea lions was employed to explore potential gender-based differences extant in either sample media. ACTH challenges produced >3-fold increases in serum cortisol concentrations which were reflected in >18-fold increases in fecal corticosterone concentrations post-injection at 3.25 and 32 h, respectively, and fecal corticosterone concentrations returned to baseline 52 It post-injection. Neither outdoor exposure to weather nor variation in duration and temperature of freezer storage impacted fecal corticosterone concentrations. HPLC of individual fecal samples produced eluate immunoreactivity profiles that differed consistently with both sex and age class. Techniques developed herein effectively detected physiologically relevant corticosterone data in Steller sea lion feces, unaffected by conditions likely to be encountered with field collection samples. Additionally, results quantify an acute response to ACTH and provide methodology for examining chronically heightened adrenal activity in Steller sea lions.

Mashburn, K. L., & Atkinson, S. (2008). Variability in Leptin and Adrenal Response in Juvenile Steller Sea Lions (*Eumetopias Jubatus*) to Adrenocorticotropic Hormone (Acth) in Different Seasons. *General and Comparative Endocrinology*, 155(2), 352-358. <u>https://doi.org/10.1016/j.ygcen.2007.05.030</u>

Eight free-ranging juvenile Steller sea lions (SSL; 6 males, 2 females; 14-20 months) temporarily held under ambient conditions at the Alaska SeaLife Center were physiologically challenged through exogenous administration of adren ocortico tropic hormone (ACTH). Four individuals (3 males, 1 female) underwent ACTH challenge in each of two seasons, summer and winter. Following ACTH injection serial blood and fecal samples were collected for up to 3 and 96 h, respectively. A radioimmunoassay (RIA) was validated for leptin, and using a previously validated RIA for cortisol, collected sera were analyzed for both cortisol and leptin. ACTH injection resulted in a 2.9-fold increase (P = 0.164) in leptin which preceded a 3.2-fold increase (P = 0.0290) in cortisol by 105 min in summer. In winter, a 1.7-fold increase in leptin (P = 0.020) preceded a 2.1-fold increase (P = 0.001) in serum cortisol by 45 min. Mean fecal corticosteroid maxima were 10.4 and 16.7-fold above baseline 28 and 12 h post-injection and returned to baseline 52 and 32 h post-injection, in summer and winter, respectively. Data indicate acute activity in juvenile adrenal glands is detectable in feces approximately 12-24 h post-stimulus in either season, with a duration of approximately 40 h in summer and 20 h in winter. Changes in serum cortisol proved statistically significant both seasons and elevated concentrations were detected by 30 min post-stimulus (baseline 64.8 +/- 4.2; peak 209.5 +/- 18.3 ng/ml: summer: baseline 87.0 +/- 15.7; peak 237.6 +/- 10.0 ng/ml: winter), whereas the changes that occurred in serum leptin proved to be significant only in winter (baseline 6.4 +/- 0.6; peak 18.7 +/- 7.0 ng/ml: summer; baseline 4.2 +/- 0.5; peak 7.5 +/- 0.6 ng/ml: winter). Changes in fecal corticosteroids proved significant only in summer (baseline 117.8 +/-36.7; peak 1219.3 +/- 298.4 ng/g, P = 0.038: summer; baseline 71.8 +/- 13.7; peak 1198.6 +/- 369.9 ng/g, P = 0.053: winter) due to a high degree of individual variability in winter months. The data indicate that ACTH stimulates leptin production earlier than cortisol in both summer and winter, and that while the leptin response appears most variable in summer, fecal corticosteroids are most variable in winter.

Mass, A. M. (2004). A High-Resolution Area in the Retinal Ganglion Cell Layer of the Steller's Sea Lion (*Eumetopias Jubatus*): A Topographic Study. *Doklady Biological Sciences, 396*(1-6), 187-190. <u>https://doi.org/10.1023/B:DOBS.0000033272.90536.a6</u>

Studies of the retina in marine mammals adapted to various habitats have demonstrated its remarkable morphological and functional organization, quite different from that of terrestrial mammals. In this respect, data on pinnipeds are of special importance. Pinnipeds are semiaquatic animals with both aerial and aquatic vision. A well-developed somatosensory system, with its unique vibrissal apparatus [1], and vision play the major role in their life [11]. Pinnipeds have a large repertoire of mechanisms that adapt them for seeing under and above water [13].

Mass, A. M., & Supin, A. Y. (2005). Ganglion Cell Topography and Retinal Resolution of the Steller Sea Lion *Eumetopias Jubatus*). *Aquatic Mammals, 31*(4), 393-402. Retrieved from <u>https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=46</u> <u>5:ganglion-cell-topography-and-retinal-resolution-of-the-steller-sea-lion-eumetopiasjubatus&catid=19&Itemid=157</u>

The total number, soma size, topographic distribution, and density of ganglion cells were studied in retinal wholemounts of the Steller sea lion (*Eumetopias jubatus*). Ganglion cell soma size varied from 6 to 37 mu m, and the majority of cells were of a size from 10 to 25 mu m. A distinct group were large ganglion cells of more than 25 to 37 mu m, which were similar to the alpha -cells known in terrestrial mammals. The number of alpha -like cells constituted 8% of the total ganglion cell population. The topographic distribution of ganglion cells showed a definite area of high cell density similar to the area centralis of terrestrial carnivores. This area was located in the temporal retinal quadrant, 8 to 9 mm from the optic disk. In this area, the peak cell densities in six wholemounts ranged from 1,512 to 2,520 (mean 1,904) cells/mm super(2). With a posterior nodal distance of 19 mm (underwater), these densities corresponded to 166 to 277 (mean 209) cells/deg super(2). This predicts a mean retinal resolution of 4.15' of minimum visibility (7.2 cycle/deg) in water and 5.5' (5.5 cycle/deg) in air. Topographic distribution of alpha -like cells was qualitatively similar to that of the total ganglion cell population, but the density of alpha -like cells reached only 45 to 72 (mean 59) cells/mm super(2).

Mellish, J. A. E., Horning, M., & York, A. E. (2007). Seasonal and Spatial Blubber Depth Changes in Captive Harbor Seals (Phoca Vitulina) and Steller's Sea Lions (*Eumetopias Jubatus*). *Journal of Mammalogy*, 88(2), 408-414. <u>https://doi.org/10.1644/06-mamm-a-157r2.1</u>

Pinniped blubber supports multiple functions including thermoregulation, reproduction, and buoyancy. Although blubber depth is frequently used as an indicator of health, the effect of sample site and seasonality are rarely taken into account. We monitored blubber depth via imaging ultrasound at 10 sites monthly for 1 year in 2 adult Steller's sea lions (*Eumetopias jubatus*) and 3 adult harbor seals (Phoca vitulina). Blubber of harbor seals was thicker and more variable than blubber of sea lions, and was thickest in winter. Changes in harbor seal blubber at all sites tracked variation due to season and mass. Sea lion blubber changed with mass only at specific sites, with no seasonal effect. The differing effects of season, mass, and location on the body must be carefully considered in both species before any interpretation of condition.

Miller, C. N., Polasek, L. K., Oliveira, A. C. M., Frost, C. J., & Maniscalco, J. M. (2018). Milk Fatty Acid Composition of Perinatal and Foraging Steller Sea Lions (*Eumetopias Jubatus*): Examination from Pup Stomachs. *Canadian Journal of Zoology*, 96(2), 153-162. <u>https://doi.org/10.1139/cjz-2016-0015</u>

To investigate the milk fatty acid composition of female Steller sea lions (*Eumetopias jubatus* (Schreber, 1776)) between and within maternal states (i.e., perinatal or foraging), milk samples were collected in 2010 and 2011 via gastric intubation from Steller sea lion pups on a small rookery in the central Gulf of Alaska. Maternal states of lactating females were determined upon reuniting with their sampled pups via remotely operated video cameras on the rookery. Milk fatty acid composition between Steller sea lion maternal states was significantly different, and thus can be utilized to distinguish between perinatal and foraging Steller sea lions of the same geographic region in the absence of direct observation. However, milk fatty acid composition remained relatively constant within perinatal Steller sea lions, suggesting steady mobilization of fatty acids from blubber to milk, and within foraging Steller sea lions, implying females forage on similar prey species within several days after their perinatal period. Differences in milk fatty acid composition between maternal states, including differences in the relative percentages of polyunsaturated fatty acids, may have important implications for growth and development of offspring.

Miller, E. H., Pitcher, K. W., & Loughlin, T. R. (2000). Bacular Size, Growth, and Allometry in the Largest Extant Otariid, the Steller Sea Lion (*Eumetopias Jubatus*). *Journal of Mammalogy*, 81(1), 134-144. <u>https://doi.org/10.1644/1545-1542(2000)081<0134:Bsgaai>2.0.Co;2</u>

Bacula rue relatively small in terrestrially mating species of pinnipeds (otariids and elephant seals, Mirounga), perhaps reflecting adaptive size reduction to minimize bacular fracture. Fur seals and sea lions (Otariidae) are a good group with which to investigate this question, because most species copulate solely on land and body size varies interspecifically. We studied bacular size and relative growth in the largest extant otariid, the Steller sea lion (*Eumetopias jubatus*). Bacula roughly tripled in length and increased 30-fold in mass between 1 and 8 years of age. Allometric relationships changed over development; bacular length and mass changed from being initially positively allometric to body
length to negatively allometric and isometric, respectively; bacular mass and thickness were positively allometric to body length throughout life, and apical growth was isometric then was positively allometric to bacular length. in adults (>7 years of age), bacula averaged 18.1 cm length (6.2% of body length), 36.7 g mass, and 2.02 g/cm density (mass:length). The baculum of Eumetopias is about the same length relative to body length as in other adult male otariids but is about twice the density, presumably to increase strength. Information on small or aquatically mating species of otariid are needed to extend our findings and interpretations.

Mulsow, J., & Reichmuth, C. (2009). A Comparison of Behavioral and Electrophysiological Measures of Aerial Hearing Sensitivity in a Steller Sea Lion (*Eumetopias Jubatus*). *Journal of the Acoustical Society of America*, 125(4) https://doi.org/10.1121/1.4784216

A number of studies with odontocete cetaceans have demonstrated that hearing sensitivity measurements using electrophysiological auditory steady-state responses (ASSRs) can provide an efficient means of estimating a subject's behavioral audiogram. Expansion of ASSR methods to another marine mammal group, the otariid pinnipeds (sea lions and fur seals), holds the potential to increase the number of otariid individuals and species for which hearing sensitivity data are available. A within-subject comparison of ASSR and behavioral measures of aerial hearing sensitivity was conducted with an individual of the largest otariid species, the Steller sea lion. Psycho-physical methods were used to obtain an unmasked aerial audiogram at 13 frequencies spanning a range of 0.125 to 34 kHz. Corresponding ASSR thresholds measured at frequencies of 1, 2, 5, 10, 20, and 32 kHz had differences (relative to behavioral thresholds) ranging from 1 dB at 20 kHz to 30 dB at 1 kHz. Overall, the ASSR audiogram was a fairly accurate predictor of the behavioral audiogram at frequencies of 2 kHz and above. Our results suggest that ASSR methods can be appropriately applied to otariid pinnipeds in estimating aerial sensitivity at frequencies of approximately 2 kHz and above.

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. <u>https://doi.org/10.1121/1.3327662</u>

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.

Myers, M. J., & Atkinson, S. (2012). Temporal Variability in Organochlorine Contamination in Blood and Blubber of Captive Steller Sea Lions (*Eumetopias Jubatus*). *Marine Mammal Science, 28*(1), 105-123. <u>https://doi.org/10.1111/j.1748-7692.2011.00466.x</u>

Three adult captive Steller sea lions (SSL; two females, one male) housed in Alaska were longitudinally sampled for organochlorine contaminant (OC) analysis in both blubber (n= 19) and blood (n= 69) over a 2 yr period (March 2001 to March 2003). Blood OC concentrations were similar between individuals, and exhibited significant increases in summer months (July through September) relative to winter (January through March). Additionally, paired blood and blubber sample (n= 18) OC were significantly related for all animals. The relationship of blubber OC concentrations to lipid content was significant in all animals. Although limited to a small number of animals, our study results indicate that in SSLs, blood OC were both consistent among all animals and likely changed in association with physiologically driven metabolism of blubber.

Myers, M. J., Rea, L. D., & Atkinson, S. (2006). The Effects of Age, Season and Geographic Region on Thyroid Hormones in Steller Sea Lions (*Eumetopias Jubatus*). *Comparative Biochemistry and Physiology a-Molecular & Integrative Physiology*, 145(1), 90-98. https://doi.org/10.1016/j.cbpa.2006.05.004

The purpose of this study was to investigate thyroid hormone concentrations, thyroxine (T-4) and triiodothyronine (T-3) in order to determine basal levels in Steller sea lions of different ages and over seasons. Serum concentrations of total T-4 were highest in Steller sea lions followed by total T-3 concentrations. Concentrations of free T-4 and free T-3 were three to four orders of magnitude lower. Concentrations for all four thyroid hormone measurements tended to a lower level as animals matured beyond the neonatal stage. When thyroid hormones from captive sea lions were evaluated across seasons, all thyroid hormones were highest in the July to September period. When compared across the geographic range, animals in southeast Alaska tended to have lower, thyroid hormone levels, while the Steller sea lions west of Prince William Sound and animals from the Russian Far East had significantly higher concentrations. Significant inter-annual differences in concentrations were also observed across the geographic range. With an understanding of the basic changes in thyroid hormone concentrations, changes in plane of nutrition or life history states (i.e. fasting, pregnancy or lactation) can now be evaluated for their effect on the overall health of this endangered species.

Narita, M., Kodama, H., Takeda, T., Sugawara, A., Mikami, K., Kimura, M., . . . Kaneda, I. (2018). Chemical and Mechanical Characteristics of Steller Sea Lion Meat Caught in Hokkaido. *Journal of the Japanese Society for Food Science and Technology-Nippon Shokuhin Kagaku Kogaku Kaishi,* 65(9), 451-456. <u>https://doi.org/10.3136/nskkk.65.451</u>

To clarify the chemical and mechanical characteristics of Steller sea lion (SL) meat, the fatty acid composition, free amino acid content and shear force value of SL meat were analyzed. The major fatty acids were 16 0, 18 0, 18 1 and 22 : 6. The fatty acid composition was similar to that of whale and tuna. The major free amino acids were anserine, carnosine, glutamine, alanine and taurine, and their composition was similar to that of pork. Moreover, the shear force value was almost the same as that of pork loin. These results suggested that SL meat can be utilized as a functional food containing n-3 fatty acids, anserine and carnosine.

Okamoto, M., Tanaka, K., Tsunokawa, M., Kasamatsu, M., Yokota, H., Tanida, K., . . . Taniyama, H. (2006). Small Intestinal Volvulus in a Captive Steller Sea Lion (*Eumetopias Jubatus*). *Veterinary Record: Journal of the British Veterinary Association, 159*(1), 21-23. <u>https://doi.org/10.1136/vr.159.1.21</u>

The article focuses on the digestive diseases of Steller sea lion. It discusses the case of volvulus of the small intestine in a sea lion wherein it become anorexic and vomited several stones then after two days, the sea lion died without treatment. Moreover, they performed a postmortem examination wherein they determined that the venous infarction was mainly due to volvulus although the E tarda was isolated from the intestinal contents of the sea lion.

Olawale, K. O., Petrell, R. J., Michelson, D. G., & Trites, A. W. (2005). The Dielectric Properties of the Cranial Skin of Five Young Captive Steller Sea Lions (*Eumetopias Jubatus*), and a Similar Number of Young Domestic Pigs (Sus Scrofa) and Sheep (Ovis Aries) between 0.1 and 10 Ghz. *Physiological Measurement*, 26(5), 627-637. <u>https://doi.org/10.1088/0967-3334/26/5/005</u>

To aid in the development of a long-range subcutaneous radio frequency identification tag to monitor the fate of sea lion pups, the dielectric properties of the cranial skin of young female otariids, and possible test subjects of similar size and age, or pigs (Sus scrofa) and sheep (Ovis aries) were obtained over a frequency range of 0.1-10 GHz at the base of their heads where the tag will be implanted. The resulting curves were similar in shape to adult human skin data, but the values were generally lower. Between subjects, variations were noted in all the species. Circuitry for the RF-ID tag is being designed to account for antenna detuning as a result of the lossy media or skin and the variation in dielectric properties.

Park, T. G., Iida, K., & Mukai, T. (2006). *Characteristics of Vocalizations in Steller Sea Lions*. https://doi.org/10.4027/slw.2006.34

We investigated the acoustics of Steller sea lion (*Eumetopias jubatus*) calls in wild individuals hauled out on shore reefs off the west coast of Hokkaido, northern Japan, and in captive sea lions at an aquarium using video camera observations. Steller sea lion calls were classified as "communication," "threat," "wheedling," and "acknowledge" according to associated behaviors. Classified calls were analyzed by means of sonograms for formant frequency (F-1), sound duration (T), and pitch pattern. All sounds emitted by males were lower in formant frequency than those of females, while sounds made by wild animals were lower than those of captive animals. Sounds by males were also longer in duration than those by females, while those made by wild animals were shorter than those by captive ones. Pitch of "communication" calls was a long flat pattern type, "threat" was a short descending type, and "wheedling" was a short ascending type for wild animals and a short wave-like type for the captives. The characteristics of pitch patterns of wild and captive animals suggest that the calls of Steller sea lions are for communication.

Perez, M. A., McAlister, W. B., & Mooney, E. E. (1990). Estimated Feeding Rate Relationship for Marine Mammals Based on Captive Animal Data. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS F/NWC 184. Retrieved from https://repository.library.noaa.gov/view/noaa/5928 A feeding rate relationship for active energy expenditure by marine mammals was estimated from data obtained from aquariums and the literature for 115 active, captive pinnipeds and cetaceans (age \geq years). The calculated geometric mean regression line (r2 = 86.2%) obtained from fitting the food consumption data (expressed as energy consumption) of the captive animals to body mass data was presented log10E = 2.520 + 0.747(log10M), which may also be written as E = 331M0.75

Perlov, A. S. (1971). The Onset of Sexual Maturity in Sea Lions. *Transactions of the Institute of Marine Fisheries, 80:174-189.*

The onset of sexual maturity in sea liions is assessed on the basis of weight characteristics, macroscopic and histologic analyses of 56 pairs of testicles and 59 pairs of ovaries. Individual spermatazoa are found in smears taken from the epididymis of males at the age of 5 and older. In males at the age of 5-7 the weights of testicles and baculum increase. The highest rate of increase in the diameters of the spermic canals is observed in specimens younger than 5 year old and later the values range insignificantly. In spite of the fact that males start maturing at the age of 5 the 6 year-olds do not take part in the harem activities. The form of ovaries varies with age. In new born pups and one-year-olds the form of ovaries resembles mashrooms, in 4-year-old females and older they are bean-shaped. Besides, epithelial projections inside the ovary stroma are observed in one-summer-olds. No difference is found in the weights of the right or left ovaries of young animals. In mature females some difference may appear due to their physiologic condition. Likewise in other seals, the sizes and weights of ovaries in sea lions are reduced in the first few weeks of life. It is notes that ovary follicles are intensively developed even in immature specimens in the harem period, which is likely to be responsible for their ununiform development. In mature females the sizes of 2-3 follicles increase by the moment of ovulation. The analysis shows that both ovaries have up to two corpora lutea of the last pregnancy, a developing corpus luteum of pregnancy and a trace. The regression of the corpus luteum of the last preganancy takes place as rapidly as a new corpus luteum is developed. The physiologic studies indicate that females reach sexual maturity at the age of 3-4.

Petrauskas, L., Atkinson, S., Gulland, F., Mellish, J. A., & Horning, M. (2008). Monitoring Glucocorticoid Response to Rehabilitation and Research Procedures in California and Steller Sea Lions. *Journal* of Experimental Zoology Part a-Ecological Genetics and Physiology, 309A(2), 73-82. <u>https://doi.org/10.1002/jez.435</u>

We used serum and fecal corticosteroid analysis to study the physiological response to a range of invasive and non-invasive procedures in sea lions. Four experimental groups of California sea lions (Zalophus californianus; Group A: restraint only [n = 9], Group 13: gas anesthesia without surgery [n = 101, Group C: minimally invasive surgery [n = 10], and Group D: invasive surgery [n = 51) were monitored for adrenal response. Feces were collected opportunistically from 72 hr before 72 hr post procedure for corticosterone analysis. All experimental groups showed substantial individual variation and no significant change in corticosterone levels after the procedures. Additional fecal and serum corticoid samples were collected from six free-ranging Steller sea lions (*Eumetopias jubatus*) in temporary captivity undergoing abdominal implantation of long-term telemetry devices. Only one sea lion exhibited a significant fecal corticosterone increase in response to the surgery. Capture and restraint appear to elicit a greater glucocorticoid response than invasive or non-invasive procedures.

Petrauskas, L. R., & Atkinson, S. K. (2006). Variation of Fecal Corticosterone Concentrations in Captive Steller Sea Lions (*Eumetopias Jubatus*) in Relation to Season and Behavior. *Aquatic Mammals*, 32(2), 168-170,172-174. <u>https://doi.org/http://dx.doi.org/10.1578/AM.32.2.2006.168</u>

Little information is available regarding the adrenal activity of Steller sea lions (*Eumetopias jubatus*) in relation to season and behavior. The objective of this study was to test for seasonal changes in fecal corticosterone concentrations and potential relationships to behavioral scoring in captive Steller sea lions. For this study, fecal samples were obtained opportunistically over a 3-y period (September 2001 to September 2004) from three adult (1 male, 2 female), reproductively intact, long-term captive Steller sea lions housed at the Alaska SeaLife Center in Seward, Alaska. Daily behavior scores based on a scale of 1 (poor) to 5 (excellent) of appetite, energy, attention, sociability, and enrichment were also recorded. The male (SSL-01) had a significantly higher fecal corticosterone concentration in the breeding season, while one of the females (SSL-03) had a significantly higher fecal corticosterone concentration in between the molting and breeding seasons. Fecal corticosterone concentration was significantly higher for one of the females (SSL-03) in comparison to the other female (SSL-02; p ... 0.001). There was a significant negative relationship between behavior score and fecal corticosterone concentrations for the male and one female (SSL-03). The results of this study do indicate that Steller sea lions have a highly seasonal physiology that can be reflected in the fecal corticosterone concentrations of both sexes.

Pitcher, K. W., & Calkins, D. G. (1981). Reproductive Biology of Steller Sea Lions in the Gulf of Alaska. Journal of Mammalogy, 62, 599-605. <u>https://doi.org/10.2307/1380406</u>

Reproductive biology of Steller sea lions (*Eumetopias jubatus*) in Gulf of Alaska was studied between 1975 and 1979 by examination of reproductive tracts, estimation of ages from dental annuli, and observations at rookeries and hauling areas. Timing of key reproductive events was: 1) birth, mid-May to mid-July; 2) breeding, late-May to mid- or late-July; and 3) implantation, late-September and October. The female-pup bond usually was 1 year, however, 1-, 2-, and 3-year-old animals occasionally were seen to suckle females. Some males became sexually mature by 3 years and all were sexually mature by 8 years. Mature males had seasonal spermatogenic activity with abundant epididymal spermatozoa from late April through July. Initial ovulations and pregnancies occurred between 2 and 8 years of age. The average age at first ovulation was 4.6 ? 0.8 years (95% confidence limits) and first pregnancy 4.9 + 1.2 years. Ovulation rates ranged from 26% at 3 years to 100% for animals >6 years. Incidence of pregnancy ranged from 20% at 3 years to 87% for females 8 to 20 years. Prenatal mortality between implantation and birth was estimated at 4.7% per month. The annual birth rate of full-term pups was estimated to be about 63% for sexually mature females.

Pitcher, K. W., Calkins, D. G., & Pendleton, G. W. (2000). Steller Sea Lion Body Condition Indices. *Marine Mammal Science*, *16*(2), 427-436. <u>https://doi.org/10.1111/j.1748-7692.2000.tb00934.x</u>

We evaluated various measurements of mass, morphology, and blubber thickness as indices of fatness for Steller sea lions by correlation with the percentage of total body mass comprised by the sculp (%SCULP). We concluded LMD-index was the best index evaluated because it had a relatively high r(2) (0.58), had a linear relationship with %SCULP, and the intercept term was not different from 0. We suggest the development of a LMD-index for otariids would likely reduce the unexplained variation in the index. We developed a multiple regression model (r(2) = 0.745, P < 0.001) for predicting %SCULP

with LMD-index and functions of sex, age, and season as predictor variables. Steller sea lions <5 yr of age had higher %SCULP values than those greater than or equal to 5 yr. %SCULP declined with age for sea lions <5 yr. Both younger and older males were fatter during the winter/spring period than during summer/fall. Females of both age classes had similar %SCULP values throughout the year. Steller sea lions are relatively lean pinnipeds; estimates of blubber and total body lipids ranged from 5% to 17% of total body mass.

Rea, L. D. (1995). *Prolonged Fasting in Pinnipeds*. (Doctor of Philosophy), University of Alaska Fairbanks, Retrieved from

https://scholarworks.alaska.edu/bitstream/handle/11122/9447/Rea_L_1995.pdf?sequence=1

Marine mammals are capable of fasting for extremely long periods at different stages of their life cycle. The first objective of this thesis was to determine how plasma chemistry changed during fasting in large free-ranging phocids, northern elephant seal pups. Next, elephant seals of very low (LWM) and very high weaning mass (HWM) were examined to address how weaning mass impacts fasting chemistry. In the third section, blood chemistry was utilized to study the transition from suckling to weaning in Weddell seal pups, because behavioral verification of weaning is difficult in this species. Lastly, blood chemistry and body morphology of Steller sea lion pups were examined for indications of possible nutritional deficiency that could be associated with apparent declines in juvenile survival of sea lions in Alaska. In average mass (AWM) elephant seals, changes in blood urea nitrogen (BUN), non-esterified fatty acid (NEFA) and beta-hydroxybutyrate (P-HBA) concentrations provide strong evidence that the pups effectively minimize protein loss through increased reliance on lipid metabolism and ketone body production early in the fast. Elephant seals maintain this phase of protein sparing for up to 11 weeks. Size of elephant seal pups at weaning influenced how stored fuels were utilized during the fast. LWM pups showed higher NEFA and P-HBA levels than average or HWM pups but showed no indication of increasing protein mobilization before they left the beach. HWM pups showed evidence that they may be able to spare more protein.

Rea, L. D., Berman-Kowalewski, M., Rosen, D. A. S., & Trites, A. W. (2009). Seasonal Differences in Biochemical Adaptation to Fasting in Juvenile and Subadult Steller Sea Lions (*Eumetopias Jubatus*). *Physiological and Biochemical Zoology*, 82(3), 236-247. https://doi.org/10.1086/597528

Nine Steller sea lions (*Eumetopias jubatus*) aged 1.75-6 yr were experimentally fasted for 7-14 d during the breeding and non-breeding seasons to identify changes in plasma metabolites that are indicative of fasting and to determine whether the ability of sea lions to fast varies seasonally or with age. Although some animals approached the limit of their protein-sparing ability by the end of our fasting experiments, there was no sign of irreversible starvation biochemistry. Plasma blood urea nitrogen (BUN) concentrations decreased in all animals within the first week of fasting, reflecting a shift to a fasting-adapted state; however, significant increases in plasma BUN concentration at the end of the nonbreeding season fasts suggest that subadult Steller sea lions were not able to maintain a protein-sparing metabolism for a full 14 d during the nonbreeding season. In contrast, juveniles were able to enter protein sparing sooner during the breeding season. Subadult and juvenile sea lions had low circulating ketone body concentrations compared with young sea lion pups, suggesting an age-related difference in how body reserves are utilized during fasting or how the resulting metabolites are

circulated and catabolized. Our data suggest that metabolite concentrations from a single blood sample cannot be used to accurately predict the duration of fast; however, threshold metabolite concentrations may still be useful for assessing whether periods of fasting in the wild are unusually long compared with those normally experienced.

 Rea, L. D., Castellini, M. A., Fadely, B. S., & Loughlin, T. R. (1998). Health Status of Young Alaska Steller Sea Lion Pups (*Eumetopias Jubatus*) as Indicated by Blood Chemistry and Hematology. *Comparative Biochemistry and Physiology a-Molecular and Integrative Physiology*, 120(4), 617-623. <u>https://doi.org/10.1016/S1095-6433(98)10074-0</u>

Blood chemistry and hematology were examined in 238 Steller sea lion pups (*Eumetopias jubatus*) to assess the health status of pups < 1 month of age. Failure of juvenile recruitment (possibly due to nutritionally or physiologically compromised pups) into breeding populations has been proposed as a cause of recent declines of this endangered species in Alaska. To identify potential correlations with areas of high population decline, blood chemistry data were considered for three areas: eastern Aleutian Islands (low rates of population decline to stable populations), Gulf of Alaska (high rates of decline), and Southeast Alaska (stable to increasing population). Southeast Alaska pups showed elevated ketone body concentrations (beta-hydroxybutyrate, (beta-HBA)) and depressed glucose levels when compared with animals from the Aleutian Islands and lower blood urea nitrogen (BUN) and glucose levels than pups in the Gulf of Alaska. Over 40% of the pups from Southeast Alaska had elevated beta-HBA concentrations suggesting they underwent longer periods of fasting than seen in pups from other areas. Hematocrit (Hct), hemoglobin concentration (Hb) and water content of the blood exhibited typical mammalian relationships. In summary, blood chemistry and hematology data showed no indication that Steller sea lion pups < 1 month old from areas of population decline were nutritionally compromised.

Rea, L. D., Christ, A. M., Hayden, A. B., Stegall, V. K., Farley, S. D., Stricker, C. A., . . . Pitcher, K. W. (2015). Age-Specific Vibrissae Growth Rates: A Tool for Determining the Timing of Ecologically Important Events in Steller Sea Lions. *Marine Mammal Science*, *31*(3), 1213-1233. <u>https://doi.org/10.1111/mms.12221</u>

Steller sea lions (SSL; *Eumetopias jubatus*) grow their vibrissae continually, providing a multiyear record suitable for ecological and physiological studies based on stable isotopes. An accurate age-specific vibrissae growth rate is essential for registering a chronology along the length of the record, and for interpreting the timing of ecologically important events. We utilized four methods to estimate the growth rate of vibrissae in fetal, rookery pup, young-of-the-year (YOY), yearling, subadult, and adult SSL. The majority of vibrissae were collected from SSL live-captured in Alaska and Russia between 2000 and 2013 (n = 1,115), however, vibrissae were also collected from six adult SSL found dead on haul-outs and rookeries during field excursions to increase the sample size of this underrepresented age group. Growth rates of vibrissae were generally slower in adult (0.44 +/- 0.15 cm/mo) and subadult (0.61 +/- 0.10 cm/mo) SSL than in YOY (0.87 +/- 0.28 cm/mo) and fetal (0.73 +/- 0.05 cm/mo) animals, but there was high individual variability in these growth rates within each age group. Some variability in vibrissae growth rates was attributed to the somatic growth rate of YOY sea lions between capture events (P = 0.014, r(2) = 0.206, n = 29).

 Rea, L. D., Fadely, B. S., Farley, S. D., Avery, J. P., Dunlap-Harding, W. S., Stegall, V. K., . . . Pitcher, K. W. (2016). Comparing Total Body Lipid Content of Young-of-the-Year Steller Sea Lions among Regions of Contrasting Population Trends. *Marine Mammal Science*, 32(4), 1200-1218. https://doi.org/10.1111/mms.12327

Steller sea lion (*Eumetopias jubatus*) young-of-the-year (YOY) are nutritionally dependent upon their dam through the majority of their first year. Several indices of body condition were measured in YOY 1.5-9 mo of age captured in Southeast Alaska (n = 122), the Gulf of Alaska (n = 182), and the Aleutian Islands (n = 38) to test the hypothesis that nutritional stress impacted the ability of adult female Steller sea lions to adequately nourish their late gestation YOY in the central Aleutian Islands in the early 2000s. Body mass (kg) and percent total body lipid content (% TBL) increased with age in all three regions of Alaska that were sampled (P < 0.05). Young-of-the-year 7-9 mo of age were leaner in Southeast Alaska (27.6% +/- 1.0%) and Gulf of Alaska (29.5% +/- 0.8%) than in the Aleutian Islands (35.7% +/- 1.2%, P < 0.001). Condition indices calculated from morphometric measures did not strongly predict the %TBL measured by isotope dilution. The trend for Aleutian Island YOY to have larger body mass and larger body fat reserves are counter to what would be expected if dams were unable to adequately provision their late lactation YOY due to inadequate food availability in the central Aleutian Islands.

Rea, L. D., Rosen, D. A. S., & Trites, A. W. (1999). Seasonal Differences in Adaptation to Prolonged Fasting in Juvenile Steller Sea Lions(*Eumetopias Jubatus*). *FASEB Journal*, 13(5), A740-A740. <u>https://doi.org/10.1086/597528</u>

Five juvenile Steller sea lious (Eumetopias jubatus) between the ages of 3 and 4 years were experimentally fasted for 9 to 14 d to assess changes in mass and in key plasma metabolites indicative of biochemical adaptation to fasting. The 5 sea lions lost 20.4 to 35.1 kg each, at a rate of 1 to 2% of their initial body mass per day. Two animals fasted during the natural breeding season (June) exhibited a mean daily mass loss of 1.6 ± 0.1 kg d-J.. This was significantly lower than the mean 2.8 ± 0.1 kg d-1 lost by sea lions fasted outside of the normal breeding season in April, October and November (p < 0.001). Blood urea nitrogen (BUN) levels decreased significantly in all animals from 7.5 ± 0.4 mM to 4.9 ± 0.6 mM after 2 to 3 d of fasting (p < 0.001). The two sea lions studied in June maintained low BUN concentrations throughout the remainder of the study, while the remaining 3 animals showed significant increases after 7 d of fasting. Only the two juveniles fasted during the breeding season maintained a protein sparing metabolism, typical of other species adapted to long-term fasting. With the exception of the smallest female (after 12 d of fasting), ketone body levels ranged from 0.03 to 0.17 niM. Seasonal differences in how sea lions adapt to fasting suggest that these animals would be more severely impacted by limited food resources during the non-breeding season.

Rea, L. D., Rosen, D. A. S., & Trites, A. W. (2000). Metabolic Response to Fasting in 6-Week-Old Steller Sea Lion Pups (*Eumetopias Jubatus*). *Canadian Journal of Zoology-Revue Canadienne De Zoologie, 78*(5), 890-894. <u>https://doi.org/10.1139/cjz-78-5-890</u>

Four Steller sea lions (*Eumetopias jubatus*) aged 6 weeks were fasted for 2.5 d to determine how young pups mobilize energy reserves during short periods of fasting similar to those experienced in the wild. At 6 weeks of age, the pups lost 5.1 + - 0.3% of their body mass during 2 d of fasting, with an average daily mass loss of 0.7 + - 0.1 kg.d(-1). Plasma blood urea nitrogen (BUN) concentration increased significantly from 3.0 + - 0.1 mM, after an overnight fast, to 4.8 + - 0.5 mM, after 2.5 d of fasting. It is apparent that

BUN levels are quickly depressed, since after only an overnight fast, these pups showed BUN levels 2- to 4-fold lower than those measured after the same pups, when 9 months of age, had recently been fed fish. Plasma ketone body (beta-HBA) concentrations of the 6-week-old pups increased significantly from 0.32 +/- 0.08 to 0.42 +/- 0.08 mM between 0.5 and 1.5 d of fasting. There was no significant change in mean plasma concentration beyond 1.5 d, owing to variable individual responses to extended fasting. Plasma beta-HBA levels at 9 months of age ranged from 0.07 to 0.18 mM. Six-week-old Steller sea lion pups showed blood chemistry consistent with metabolic adaptation to fasting within 16 h but were unable to sustain a protein-sparing metabolism for a prolonged period. The pups appeared to revert to protein catabolism after only 2.5 d of fasting. This infers a decrease in lipid catabolism that might be due to the depletion of available lipid resources.

Rea, L. D., Rosen, D. A. S., & Trites, A. W. (2007). Utilization of Stored Energy Reserves During Fasting Varies by Age and Season in Steller Sea Lions. *Canadian Journal of Zoology-Revue Canadienne De Zoologie, 85*(2), 190-200. <u>https://doi.org/10.1139/z06-204</u>

Nine captive Steller sea lions (*Eumetopias jubatus* (Schreber, 1776), 1.75-6 years of age) were fasted for 7-14 d to test the effect of short-term fasting on changes in body mass and body condition. Trials were repeated during both the summer breeding season and the nonbreeding season in seven animals to elucidate whether there was a seasonal component to the ability of Steller sea lions to adapt to limited food resources. Mean percent mass loss per day was higher during the breeding season in juveniles (1.8% +/- 0.2%center dot d(-1)) than in subadults (1.2% +/- 0.1%center dot d(-1)), but there were no significant age-related differences during the nonbreeding season (juveniles, 1.5% +/- 0.3%center dot d(-1)); subadults, 1.7% +/- 0.3%center dot d(-1)). A decrease in the rate of mass loss occurred after the first 3 d of fasting only in subadults during the breeding season. Percent total body lipid ranged from 11% to 28% of total body mass at the initiation of fasting trials. Animals with lower initial percent total body lipid exhibited higher subsequent rates of mass loss and a lower percentage of tissue catabolism derived from lipid reserves. There was no evidence of metabolic adaptation to fasting in juveniles, which suggests that juvenile sea lions would be more negatively impacted by food limitation during the breeding season than would subadults.

Rehberg, M. J., Rea, L. D., & Eischens, C. A. (2018). Overwintering Steller Sea Lion (*Eumetopias Jubatus*) Pup Growth and Behavior Prior to Weaning. *Canadian Journal of Zoology*, *96*(2), 97-106. <u>https://doi.org/10.1139/cjz-2016-0296</u>

We measured individual growth, looked for evidence of weaning, and examined the interaction of these changes with diving behavior in young-of-year Steller sea lion (*Eumetopias jubatus* (Schreber, 1776)) pups in Alaska, USA, during their first winter. Steller sea lions employ an income breeding strategy, in which females provision their young over an individually variable period of months to years. Thus, we set out to identify whether these young sea lions showed evidence of weaning during the challenging winter months, describe the nature of their growth during this time, and examine their behaviors in light of these changes. Between 2005 and 2008, we captured 71 pups during early winter and recaptured 33 of these pups in early spring. Mark-resight and stable nitrogen isotope ratios in vibrissae indicated most pups remained nutritionally dependent on adult females throughout the winter. All pups increased both mass and lipid mass, with half of growth contributed by lipid mass. Changes in behavior were not correlated with growth excepting a weak but significant effect on rate of vertical travel. This study

demonstrated that capture-recapture of Steller sea lion pups is possible, provided seasonal timing, locations, and age classes are carefully considered for their likelihood of capture success.

Richmond, J. P. (2008). Evaluation of the Somatotropic Axis in Two Marine Mammal Species with Diverse Early Life History Strategies: Influence of Physiologic Age and Nutrition on Growth of Harbor Seals (Phoca Vitulina) and Steller Sea Lions (Eumetopias Jubatus). University of Connecticut, Retrieved from https://opencommons.uconn.edu/dissertations/AAI3329127/

The somatotropic axis, including growth hormone, insulin-like growth factor (IGF)-I and IGF binding proteins, is a bridge between growth physiology, sex, developmental age and nutritional status in domestic animals. However, the importance of the somatotropic axis in growth and development of marine mammals has not been previously explored. Furthermore, developmental changes in the somatotropic axis in species that preferentially deposit lipid during periods of rapid growth, such as pinnipeds, have not been studied. Harbor seals and Steller sea lions represent two pinniped species with diverse early life history strategies, differential growth rates leading to differences in mature size, and contrasting expression of sexual dimorphism. Understanding hormonal regulation of growth in species with distinct developmental patterns will enhance our knowledge of the link between physiology, nutrition and life history of diverse species. Parallel studies in captive (longitudinal data) and freeranging (cross-sectional data) harbor seals and Steller sea lions were conducted through collaborative research efforts with several aquariums, research, and rehabilitation facilities across North America. The research objectives for this dissertation research are to describe the ontogeny and evaluate the affect of reduced nutrient intake and re-alimentation on components of the somatotropic axis, to investigate the relationship of the somatotropic axis to growth rate and composition of gain, and to compare the expression of the components of the somatotropic axis of harbor seals and Steller sea lions with respect to their differential mass specific growth rate, composition of gain, mature size, and early life history strategies. Understanding growth, development, and nutrient allocation during times of reduced nutrient intake and re-alimentation may provide a unique perspective into the survival of wildlife. Environmental change caused by natural or anthropogenic affect may change the quality or quantity of prey available for wildlife. Nutritional stress can lead to decreased growth making animals vulnerable to disease and predation which may have substantial impacts on survival and hence population trends. Monitoring nutritional status of populations of marine mammals is essential to maintaining healthy sustainable populations and minimizing anthropogenic effects on population trends. The somatotropic axis appears to by a useful tool to evaluate nutritional status of pinniped populations.

Richmond, J. P., Burns, J. M., Rea, L. D., & Mashburn, K. L. (2005). Postnatal Ontogeny of Erythropoietin and Hematology in Free-Ranging Steller Sea Lions (*Eumetopias Jubatus*). *General and Comparative Endocrinology*, 141(3), 240-247. <u>https://doi.org/10.1016/j.ycgen.2005.01.004</u>

The hormone erythropoietin (EPO) is responsible for the increased production of red blood cells (RBC) in response to tissue hypoxia. While the role of EPO in hematological development has been established in humans and terrestrial mammals, this relationship has never been examined in marine mammals that rely heavily on stored oxygen to maintain aerobic metabolism while diving. Since blood is the major oxygen storage site in marine mammals, it was hypothesized that EPO may have a significant influence on the development of hematology parameters associated with the expansion of blood oxygen stores during development. To explore this hypothesis, serum EPO concentrations were determined by radioimmunoassay in 235 free-ranging Steller sea lions (*Eumetopias jubatus*), throughout their Alaskan

range. Hematocrit (Hct), hemoglobin (Hb), and red blood cell (RBC) counts were also measured, and mean corpuscular hemoglobin content (MCHC), mean corpuscular volume (MCV), and mean corpuscular hemoglobin (MCV) values determined. Erythropoietin and most hematological parameters varied with age. Hematocrit, Hb, RBC, and MCHC decreased after birth, reached their lowest values at two to three months of age, and then increased to values similar to those of adults by five months of age. Since changes in Hct and Hb account for the majority of the changes in blood oxygen stores and EPO was negatively correlated with both, it appears that EPO may play an important role in blood development of Steller sea lions, similar to previous studies on terrestrial mammals.

Richmond, J. P., Du Dot, T. J., Rosen, D. A. S., & Zinn, S. A. (2010). Seasonal Influence on the Response of the Somatotropic Axis to Nutrient Restriction and Re-Alimentation in Captive Steller Sea Lions (*Eumetopias Jubatus*). Journal of Experimental Zoology Part A-Ecological Genetics and Physiology, 313A(3), 144-156. https://doi.org/10.1002/jez.584

Fluctuations in availability of prey resources can impede acquisition of sufficient energy for maintenance and growth. By investigating the hormonal mechanisms of the somatotropic axis that link nutrition, fat metabolism, and lean tissue accretion, we can assess the physiological impact of decreased nutrient intake on growth. Further, species that undergo seasonal periods of reduced intake as a part of their normal life history may have a differential seasonal response to nutrient restriction. This experiment evaluated the influence of season and age on the response of the somatotropic axis, including growth hormone (GH), insulin-like growth factor (IGF)-I, and IGF-binding proteins (BP), to reduced nutrient intake and re-alimentation in Steller sea lions. Eight captive females (five juveniles, three sub-adults) were subject to 28-day periods of food restriction, controlled re-feeding, and ad libitum recovery in summer (long-day photoperiod) and winter (short-day photoperiod). Hormone concentrations were insensitive to type of fish fed (low fat pollock vs. high fat herring), but sensitive to energy intake. Body mass, fat, and IGF-I declined, whereas GH and IGFBP-2 increased during feed restriction. Reduced IGF-I and IGFBP with increased GH during controlled re-feeding suggest that animals did not reach positive energy balance until fed ad libitum. Increased IGF-I, IGFBP-2, IGFBP-3, and reduced GH observed in summer reflected seasonal differences in energy partitioning. There was a strong season and age effect in the response to restriction and re-alimentation, indicating that older, larger animals are better able to cope with stress associated with energy deficit, regardless of season.

Richmond, J. P., Keogh, M., Atkinson, S., & Zinn, S. A. (2010, Jul). Seasonal Changes in Leptin and Ghrelin Concentrations Associated with Intake and Body Condition of Captive Steller Sea Lions. Paper presented at the Integrative and Comparative Biology. Retrieved from <u>http://www.sicb.org/meetings/2010/schedule/abstractdetails.php3?id=555</u>

Leptin and ghrelin are peripheral endocrine signals that regulate body fat and appetite in mammals, and are involved in photoperiod-mediated, seasonal regulation of food intake. While intake is known to vary seasonally in Steller sea lions (SSL; *Eumetopias jubatus*), seasonality of hormones that regulate intake is not known. The objectives of this study were to 1) validate assays that accurately and precisely quantify serum concentrations of leptin and ghrelin, 2) determine the seasonal pattern of these hormones, and 3) quantify their relationship to body composition and intake in SSL. Blood samples were collected monthly for 18 mo from captive adult SSL (n=4). Intake was recorded daily. Hormones were quantified using kits for Human ghrelin RIA and Canine leptin ELISA. Sensitivity, recovery of mass, assay precision, parallelism and dilution linearity were determined for each assay. Both ghrelin and leptin immunoassays

exhibited validation parameters indicating both assays provide accurate and precise quantification of serum hormone concentrations. Intake and ghrelin were greatest (P=0.02) in the winter (2332±139 pg/ml) and declined in the summer (1048±191 pg/ml). In contrast, leptin followed the opposite pattern with the greatest concentrations (P=0.01) observed in summer (8.5±0.7 ng/ml; winter 4.9±0.9 ng/ml) when animals' intake was reduced. These results suggest that ghrelin and leptin are strongly influenced by season in SSL. The insensitivity of ghrelin and leptin to intake in the winter may facilitate SSL foraging by stimulating appetite. The contrasting pattern in summer may inhibit appetite during the summer breeding season when SSL typically fast for extended periods of time.

 Rosen, D., Williams, L., & Trites, A. (2000). Effect of Ration Size and Meal Frequency on Digestive and Assimilation Efficiency in Yearling Stellar Sea Lions, *Eumetopias Jubatus*. *Aquatic Mammals*, 26(1), 76-82. Retrieved from <u>https://aquaticmammalsjournal.org/share/AquaticMammalsIssueArchives/2000/AquaticMammals_26-01/26-01_Rosen.pdf</u>

Assimilation and digestive efficiencies were measured in four juvenile Steller sea lions (*Eumetopias jubatus*) fed three ration sizes of herring (3%, 6%, or 9% of body mass) at three frequencies (2, 3, or 4 times daily). Assimilation efficiency (dry matter digestive efficiency) was 90.02.0% (mean1 SD). Digestive efficiency (efficiency of energy digestion) was 95.51.0%. There was a strong linear relationship between digestive and assimilation efficiency, but no significant differences in either assimilation or digestive efficiency with changes in feeding frequency or changes in daily food intake within the ranges offered.

Rosen, D. A., & Trites, A. W. (1997). Heat Increment of Feeding in Steller Sea Lions, *Eumetopias Jubatus*. *Comp Biochem Physiol A Physiol*, *118*(3), 877-881. <u>https://doi.org/10.1016/s0300-</u> <u>9629(97)00039-x</u>

The heat increment of feeding (HIF) was measured in six captive, juvenile Steller sea lions (*Eumetopias jubatus*), fed meals of either 2 or 4 kg of herring. HIF was calculated as the post-prandial increase in metabolism above baseline levels, and was measured using open-circuit (gas) respirometry. It averaged 12.4 +/- 0.9% (SE) of ingested energy intake for the 4-kg meal trials, and 9.9 +/- 0.9% for the 2-kg meal size. The effect lasted 8-10 hr for the larger meal size. Metabolism peaked 3.7 hr after feeding, and was 2.13 times higher than baseline levels. For the 2-kg meal size, the effect lasted 6-8 hr, with metabolism peaking 2.8 hr after ingestion at 1.76 times baseline levels. Our estimates of HIF for Steller sea lions are at the lower end of estimates for terrestrial mammals, and are consistent with estimates for other marine mammals.

Rosen, D. A., & Trites, A. W. (1999). Metabolic Effects of Low-Energy Diet on Steller Sea Lions, *Eumetopias Jubatus. Physiol Biochem Zool, 72*(6), 723-731. <u>https://doi.org/10.1086/316705</u>

Diets of six Steller sea lions (*Eumetopias jubatus*) were switched between a high (herring) and a low (squid) energy density food for 14 d to determine the effects on ingested prey mass, body mass, resting metabolic rate, and the heat increment of feeding. Body mass was measured daily, and resting metabolism was measured weekly by gas respirometry. Ingested food mass did not differ significantly between the squid diet and the control or the recovery herring diet periods. As a result of differences in energy density, gross energy intake was significantly lower during the squid diet phase than during

either the control or recovery periods. As a result, sea lions lost an average of 1.1 kg/d, totaling 12.2% of their initial body mass by the end of the experimental period. The heat increment of feeding for a 4-kg squid meal was significantly lower than for a similarly sized meal of herring. Decreases in both absolute (24.0 to 18.0 MJ/d, -24%) and mass-corrected (903 to 697 kJ/d/kg0.67, -20%) metabolism were observed by the end of the squid feedings. This study suggests that sea lions can depress their resting metabolism in response to decreases in energy intake or body mass, regardless of satiation level.

Rosen, D. A. S. (2009). Steller Sea Lions *Eumetopias Jubatus* and Nutritional Stress: Evidence from Captive Studies. *Mammal Review, 39*(4), 284-306. <u>https://doi.org/10.1111/j.1365-2907.2009.00150.x</u>

ABSTRACT 1 Numbers of Steller sea lions *Eumetopias jubatus* in the North Pacific have declined. According to the nutritional stress hypothesis, this decline is due to reduced food availability. Data from studies conducted on pinnipeds in the laboratory are used here to test if the nutritional stress hypothesis can explain the decline of Steller sea lions. 2 Overall, there is strong evidence for biologically meaningful differences in the nutritional quality of major prey species. Steller sea lions can partly compensate for low-quality prey by increasing their food consumption. 3 There appear to be no detrimental effects of low-lipid prey on sea lion growth or body composition when sea lions can consume sufficient quantities of prey. However, the ability to increase consumption is physiologically limited, particularly in young animals. Overall, it is more difficult to maintain energy intake on a diet of low-quality prey than on a normal diet. 4 Under conditions of inadequate food intake (either due to decreased prey availability or quality, or increased energy requirements) the overall impacts of nutritional stress are complex, and are dependent upon season, prey quality, age and the duration and intensity of the nutritional stress event. 5 Studies on pinnipeds in the laboratory have been instrumental in identifying the conditions under which changes in sea lion prey can result in nutritional stress and the nature of the physiological impacts of nutritional stress events.

Rosen, D. A. S., Gerlinsky, C. D., & Trites, A. W. (2015). Evidence of Partial Deferment of Digestion During Diving in Steller Sea Lions (*Eumetopias Jubatus*). *Journal of Experimental Marine Biology and Ecology*, 469, 93-97. <u>https://doi.org/10.1016/j.jembe.2015.04.017</u>

Past foraging success of diving air-breathing vertebrates can adversely affect future foraging capabilities and costs through changes in circulation or increased metabolic costs associated with digestion that are incompatible with efficient diving. This study tested the physiological interaction between digestion and diving by comparing the cost of diving in fasted and pre-fed trained Steller sea lions foraging under controlled conditions in the open ocean. Pre-dive and post-dive surface metabolism and diving metabolic rate were all higher in the pre-fed animals than the fasted animals, indicating an effect of digestion on metabolism. However, the sea lions displayed a significant reduction in the apparent additive effect of digestion during diving. The increase in rate of oxygen consumption associated with digestion was reduced by 54% during diving compared to the increase observed in pre-dive metabolism. This truncation of the additional cost of digestion rapidly disappeared following cessation of diving. The results suggest that Steller sea lions diving to depth demonstrate a partial deferment of digestion while actively foraging and that the classically held view that digestion and diving are incompatible processes may be much more variable and adaptable to specific diving conditions and behaviors than previously thought.

 Rosen, D. A. S., Hindle, A. G., Gerlinsky, C. D., Goundie, E., Hastie, G. D., Volpov, B. L., & Trites, A. W. (2017). Physiological Constraints and Energetic Costs of Diving Behaviour in Marine Mammals: A Review of Studies Using Trained Steller Sea Lions Diving in the Open Ocean. *Journal of Comparative Physiology B-Biochemical Systemic and Environmental Physiology, 187*(1), 29-50. https://doi.org/10.1007/s00360-016-1035-8

Marine mammals are characterized as having physiological specializations that maximize the use of oxygen stores to prolong time spent under water. However, it has been difficult to undertake the requisite controlled studies to determine the physiological limitations and trade-offs that marine mammals face while diving in the wild under varying environmental and nutritional conditions. For the past decade, Steller sea lions (*Eumetopias jubatus*) trained to swim and dive in the open ocean away from the physical confines of pools participated in studies that investigated the interactions between diving behaviour, energetic costs, physiological constraints, and prey availability. Many of these studies measured the cost of diving to understand how it varies with behaviour and environmental and physiological conditions. Collectively, these studies show that the type of diving (dive bouts or single dives), the level of underwater activity, the depth and duration of dives, and the nutritional status and physical condition of the animal affect the cost of diving and foraging. They show that dive depth, dive and surface duration, and the type of dive result in physiological adjustments (heart rate, gas exchange) that may be independent of energy expenditure. They also demonstrate that changes in prey abundance and nutritional status cause sea lions to alter the balance between time spent at the surface acquiring oxygen (and offloading CO2 and other metabolic by-products) and time spent at depth acquiring prey. These new insights into the physiological basis of diving behaviour further our understanding of the potential scope for behavioural responses of marine mammals to environmental changes, the energetic significance of these adjustments, and the consequences of approaching physiological limits.

Rosen, D. A. S., & Kumagai, S. (2008). Hormone Changes Indicate That Winter Is a Critical Period for Food Shortages in Steller Sea Lions. *Journal of Comparative Physiology B-Biochemical Systemic and Environmental Physiology*, 178(5), 573-583. <u>https://doi.org/10.1007/s00360-007-0247-3</u>

Given that many marine mammals display seasonal energetic priorities, it is important to investigate whether the impact of unexpected food restriction differs during the year. Steller sea lions (*Eumetopias jubatus*) fed restricted diets for up to 9 days during spring, summer, fall, and winter lost an average of 10% of their initial body mass. We tracked changes in the levels of three hormones (cortisol, total thyroxine-TT4, total triiodothyronine-TT3) and one blood metabolite (blood urea nitrogen-BUN) following a food restriction in relation to season, body mass, body composition, and metabolism. Degree of changes in cortisol, TT3, and BUN after food restriction was significantly affected by season. The greatest changes in cortisol (+231%), BUN (+11.4%), TT4 (-23.3%), and TT3 (-35.6%) occurred in the winter (November/December) when rates of body mass loss were also greatest. Changes in cortisol levels were positively related to total body mass loss, while changes in TT3 levels were negatively related. While greater increases in BUN were related to greater rates of mass loss, the use of BUN levels as an indicator of metabolic state is complicated by the type and level of food intake. The observed changes in hormone levels support morphological data suggesting Steller sea lions may be more strongly impacted by short-term, reduced energy intake during winter than at other times of the year.

 Rosen, D. A. S., & Trites, A. W. (1999). The Bioenergetic Interactions of Thermoregulation, Activity, and Digestion in Steller Sea Lions, *Eumetopias Jubatus*. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, 124, S101. <u>https://doi.org/10.1016/S1095-6433(99)90399-</u> <u>9</u>

[NO ABSTRACT AVAILABLE]

Rosen, D. A. S., & Trites, A. W. (2000). Digestive Efficiency and Dry-Matter Digestibility in Steller Sea Lions Fed Herring, Pollock, Squid, and Salmon. *Canadian Journal of Zoology-Revue Canadienne De Zoologie*, 78(2), 234-239. <u>https://doi.org/10.1139/cjz-78-2-234</u>

Dry-matter digestibility and energy digestive efficiency were measured in six juvenile Steller sea lions (*Eumetopias jubatus*) fed three diets each consisting of a single species: herring, pollock, and squid. Two of the animals were also fed pink salmon. Dry-matter digestibility (DMD) and digestive efficiency (DE) were measured using the energy and manganese concentration in fecal and food samples. DE values were high for all prey species (herring: 95.4 +/- 0.7% (mean +/- SD), pollock: 93.9 +/- 1.4%, salmon: 93.4 +/- 0.5%, squid: 90.4 +/- 1.3%). Steller sea lions appear to digest prey of high energy density more efficiently than prey of low energy density. DMD values were also high for all prey species (herring: 90.1 +/- 1.8%, pollock: 86.5 +/- 3.4%, salmon: 87.3% +/- 2.6, squid: 90.5 +/- 1.2%). The low DMD value for pollock compared with herring and squid was due to the high proportion of bony material in pollock. There was a strong linear relationship between DE and DMD for each prey type, but the terms cannot be used interchangeably. DE measures are more meaningful than DMD in conveying the energetic benefits derived by sea lions from different types of prey. Species-specific measures of the digestible energy obtained from an array of prey items are a necessary component in understanding the bioenergetic consequences of consuming different prey species.

Rosen, D. A. S., & Trites, A. W. (2002). Changes in Metabolism in Response to Fasting and Food Restriction in the Steller Sea Lion (*Eumetopias Jubatus*). *Comparative Biochemistry & Physiology Part B*, 132(2), 389. <u>https://doi.org/10.1016/S1096-4959(02)00048-9</u>

Many animals lower their resting metabolism (metabolic depression) when fasting or consuming inadequate food. We sought to document this response by subjecting five Steller sea lions to periods of: (1) complete fasting; or (2) restricting them to 50% of their normal herring diet. The sea lions lost an average of 1.5% of their initial body mass per day (2.30 kg/d) during the 9–14-day fast, and their resting metabolic rates decreased 31%, which is typical of a 'fasting response'. However, metabolic depression did not occur during the 28-day food restriction trials, despite the loss of 0.30% of body mass per day (0.42 kg/d). This difference in response suggests that undernutrition caused by reduced food intake may stimulate a 'hunger response', which in turn might lead to increased foraging effort. The progressive changes in metabolism we observed during the fasts were related to, but were not directly caused by, changes in body mass from control levels. Combining these results with data collected from experiments when Steller sea lions were losing mass on low energy squid and pollock diets reveals a strong relationship between relative changes in body mass and relative changes in resting metabolism across experimental conditions. While metabolic depression caused by fasting or consuming large amounts of low energy food reduced the direct costs from resting metabolism, it was insufficient to completely overcome the incurred energy deficit.

Rosen, D. A. S., & Trites, A. W. (2002). Cost of Transport in Steller Sea Lions, *Eumetopias Jubatus. Marine Mammal Science*, 18(2), 513-524. <u>https://doi.org/10.1111/j.1748-7692.2002.tb01052.x</u>

The cost of swimming is a key component in the energy budgets of marine mammals. Unfortunately, data to derive predictive allometric equations are limited, and estimates exist for only one other species of otariid. Our study measured the oxygen consumption of three juvenile Steller sea lions (*Eumetopias jubatus*) swimming in a flume rank at velocities up to 2.2 m sec(-1). Minimum measured cost of transport ranged from 3.5-5.3 J kg(-1) m(-1), and was reached at swimming speeds of 1.7-2.1 m s(-1). These cost-of-transport values are higher than those reported for other marine mammals. However, once differences in stationary metabolic rate were accounted for, the locomotor costs (LC) for the Steller sea lions were commensurate with those of other marine mammals. Locomotor costs (LC in J m(-1)) appeared to be directly proportional to body mass (M in kg) such that LC = 1.651M(1.01). These estimates for the cost of locomotion can be incorporated into bioenergetic models and used to determine the energetic consequences of observed swimming behavior in wild marine mammals.

Rosen, D. A. S., & Trites, A. W. (2003). No Evidence for Bioenergetic Interaction between Digestion and Thermoregulation in Steller Sea Lions *Eumetopias Jubatus*. *Physiological and Biochemical Zoology*, *76*(6), 899-906. <u>https://doi.org/10.1086/378140</u>

The increase in metabolism during digestion - the heat increment of feeding - is often regarded as an energetic waste product. However, it has been suggested that this energy could offset thermoregulatory costs in cold environments. We investigated this possibility by measuring the rate of oxygen consumption of four juvenile Steller sea lions (*Eumetopias jubatus*) before and after they ingested a meal in water temperatures of 2degrees - 8degreesC. Rates of oxygen consumption of fasted and fed animals increased in parallel with decreasing water temperature, such that the apparent heat increment of feeding did not change with water temperature. These results suggest that Steller sea lions did not use the heat released during digestion to offset thermoregulatory costs.

Sato, S., Kitamura, H., Mori, M., Fukazawa, M., Takeda, M., & Kadota, K. (1998). Adenocarcinoma of the Lung in a Steller Sea Lion (*Eumetopias Jubatus*). *Journal of Veterinary Medical Science*, 60(12), 1349-1351. <u>https://doi.org/10.1292/jvms.60.1349</u>

The histological and ultrastructural characteristics of an adenocarcinoma of the lung are described in an about 16-year-old female Steller sea lion with a 1.5 month history of cough and anorexia. The animal had multiple neoplastic nodules in the lungs and diaphragmatic pleura. The bronchial and mediastinal lymph nodes were replaced by neoplastic tissue, and there were several metastatic lesions in the liver and spleen. The lung tumor was characterized by accumulations of encapsulated lesions with central necrosis, and the neoplastic cells showing a papillary growth pattern produced small amounts of mucin. Ultrastructurally, some cells contained basal bodies, and cilia were rarely seen. This neoplasm was considered to be of ciliated bronchial or bronchiolar epithelium origin.

Sattler, R., Bishop, A., Woodie, K., & Polasek, L. (2018). Characterizing Estrus by Trans-Abdominal Ultrasounds, Fecal Estrone-3-Glucuronide, and Vaginal Cytology in the Steller Sea Lion

(Eumetopias Jubatus). Theriogenology, 120, 25-32. https://doi.org/10.1016/j.theriogenology.2018.07.020

The ability to monitor the estrus cycle in wild and captive marine species is important for identifying reproductive failures, ensuring a successful breeding program, and monitoring animal welfare. Minimally invasive sampling methods to monitor estrus in captive populations have been developed, but results suggest these tools can be species-specific in their precision and accuracy. Therefore, the minimally invasive sampling methods of trans-abdominal ultrasounds, a fecal steroid analysis (estrone-3glucuronide, E1G), and vaginal cytology, were evaluated for their efficacy to characterize and monitor estrus in a captive breeding population of Steller sea lions (*Eumetopias jubatus*). Three adult females were sampled over five breeding seasons, resulting in six estrus profiles characterized by transabdominal ultrasounds, five by fecal E1G, and four by vaginal cytology. Animals were trained to allow transabdominal ultrasounds, fecal samples, and vaginal swabs to be collected approximately daily. Of the 76 trans-abdominal ultrasound sessions attempted, 8 successfully visualized both ovaries. From these scans, the chronology of ovarian changes during proestrus and estrus was estimated. The time from the detection of developing follicles to the identification of a dominate follicle occurred in 2-5 days and a corpus hemorrhagicum formed approximately 4 days later. However, because visualization of the ovaries was prevented by the gastrointestinal system in 88% of scans, this tool was overall unreliable for monitoring changes associated with estrus. To detect fine scale physiological changes associated with estrus, we analyzed changes in fecal E1G (n = 62) and vaginal cytology (n = 157) 15 days before and after each female's single copulation event (Day = 0). Changes in fecal E1G had the highest accuracy at detecting Day = 0. Fecal E1G increased leading up to estrus, peaked at Day = 0, and then declined. Although we did observe the characteristic increase in superficial cells associated with impending estrus, the type of cell which peaked closest to Day = 0 was intermediate. The uncertainty around the peak in intermediate cells, indicating estrus, was greater than the uncertainty associated with detecting estrus from fecal E1G. Collectively, these results suggest that changes in fecal E1G and vaginal cytology are viable tools to detect estrus in Steller sea lions, but require daily sampling to detect gradual changes, limiting their applicability to studies of wild populations.

Sattler, R., & Polasek, L. (2017). Serum Estradiol and Progesterone Profiles During Estrus, Pseudopregnancy, and Active Gestation in Steller Sea Lions. *Zoo Biology, 36*(5), 323-331. <u>https://doi.org/10.1002/zoo.21381</u>

While the proximate driver behind the decline of the Western stock of Steller sea lions (*Eumetopias jubatus*, >80% since 1970s) is likely multifactorial, the population reduction may have been powered by a decrease in fecundity. A harvest of Steller sea lions in the 1970s and 80s revealed a 30% reduction in the proportion of pregnant females from early (October-November) to late gestation (April-May). Identification and quantification of these reproductive failures are difficult when we lack species-specific data on endocrinology associated with discrete stages of the reproductive cycle (i.e., estrus, implantation, and gestation). We tracked changes in serum estradiol and progesterone in three adult female Steller sea lions from 2011 to 2015. In all years and most females, a discrete increase in estradiol was observed during the breeding season (June-August), indicative of estrus. Estradiol concentrations from October to May in a pregnant female compared to her corresponding values when non-pregnant did not consistently differ through gestation. An elevation in progesterone was observed in all females and all years beginning approximately in June and lasting through November. This likely results from progesterone production by the corpus luteum in both pregnant and pseudopregnant females. Serum progesterone shows promise as a diagnostic tool to identify pregnancy during months 3-5 (December-

February) of the 8-month active gestation following embryonic implantation. This study provides ranges of key hormones during estrus, embryonic diapause/pseudopregnancy, and gestation in pregnant and non-pregnant females for studying reproduction in Steller sea lions.

Skinner, J. P., Tuomi, P. A., & Mellish, J. A. E. (2015). The Influence of Time in Captivity, Food Intake and Acute Trauma on Blood Analytes of Juvenile Steller Sea Lions, *Eumetopias Jubatus*. *Conservation Physiology*, 3(1). <u>https://doi.org/10.1093/conphys/cov008</u>

The Steller sea lion, *Eumetopias jubatus*, has experienced regionally divergent population trends over recent decades. One potential mechanism for this disparity is that local factors cause reduced health and, therefore, reduced survival of individuals. The use of blood parameters to assess sea lion health may help to identify whether malnutrition, disease and stress are important drivers of current trends, but such assessments require species-specific knowledge of how parameters respond to various health challenges. We used principal components analysis to identify which key blood parameters (principal analytes) best described changes in health for temporarily captive juvenile Steller sea lions in known conditions. Generalized additive mixed models were used to estimate the changes in principal analytes with food intake, time in captivity and acute trauma associated with hot-iron branding and transmitter implant surgery. Of the 17 blood parameters examined, physiological changes for juvenile sea lions were best described using the following six principal analytes: red blood cell counts, white blood cell counts, globulin, platelets, glucose and total bilirubin. The white blood cell counts and total bilirubin declined over time in captivity, whereas globulin increased. Elevated red blood cell counts, white blood cell counts and total bilirubin and reduced globulin values were associated with lower food intake. After branding, white blood cell counts were elevated for the first 30 days, while globulin and platelets were elevated for the first 15 days only. After implant surgery, red blood cell counts and globulin remained elevated for 30 days, while white blood cell counts remained elevated during the first 15 days only. Glucose was unassociated with the factors we studied. These results were used to provide expected ranges for principal analytes at different levels of food intake and in response to the physical challenges of branding and implant surgery. These results provide a more detailed reference for future evaluations of health-related assessments.

Solntseva, G. N. (1998). Development of the Auditory Organ and Vestibular Apparatus in a Representative Eared Seals (*Eumetopias Jubatus*). *Doklady Akademii Nauk, 358*(1), 140-144. Retrieved from

http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch &qid=20&SID=8AKBSJ5RixL6hagr5Wp&page=1&doc=1

[NO ABSTRACT AVAILABLE]

 Stegall, V. K., Farley, S. D., Rea, L. D., Pitcher, K. W., Rye, R. O., Kester, C. L., . . . Bern, C. R. (2008). Discrimination of Carbon and Nitrogen Isotopes from Milk to Serum and Vibrissae in Alaska Steller Sea Lions (*Eumetopias Jubatus*). *Canadian Journal of Zoology-Revue Canadienne De Zoologie, 86*(1), 17-23. <u>https://doi.org/10.1139/z07-115</u>

Knowledge of diet-tissue stable isotope discrimination is required to properly interpret stable isotope values and to identify possible diet shifts, such as might be expected from nursing through weaning. This

study compared delta C-13 and delta N-15 of paired serum and vibrissal roots with those of ingested milk (n = 52) from free-ranging Steller sea lion (*Eumetopias jubatus* (Schreber, 1776)) pups (1-11 months) and juveniles (14-27 months) to estimate diet-tissue discrimination. Mean N-15 enrichment from ingested milk to serum was 2.1 parts per thousand +/- 0.6 parts per thousand and delta N-15 at the root of the vibrissae (representing current growth) were not significantly different from serum values. Milk was enriched for mean C-13 by 5.0 parts per thousand +/- 1.0 parts per thousand and 7.3 parts per thousand +/- 1.2 parts per thousand relative to serum and vibrissal roots, respectively, which was due to the presence of C-13-depleted lipids in milk. This was confirmed by lipid extraction from a subset of milk and serum samples, resulting in a 5.8 parts per thousand +/- 1.0 parts per thousand change only in milk. This study established that vibrissal roots and serum are reflective of a milk diet with approximately 2.0 parts per thousand C-13 enrichment. These discrimination factors are important to establish for stable isotope studies assessing diet shifts.

Stelle, L. L., Blake, R. W., & Trites, A. W. (2000). Hydrodynamic Drag in Steller Sea Lions (*Eumetopias Jubatus*). Journal of Experimental Biology, 203(Pt 12), 1915-1923. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/10821748

Drag forces acting on Steller sea lions (*Eumetopias jubatus*) were investigated from 'deceleration during glide' measurements. A total of 66 glides from six juvenile sea lions yielded a mean drag coefficient (referenced to total wetted surface area) of 0.0056 at a mean Reynolds number of 5.5x10(6). The drag values indicate that the boundary layer is largely turbulent for Steller sea lions swimming at these Reynolds numbers, which are past the point of expected transition from laminar to turbulent flow. The position of maximum thickness (at 34 % of the body length measured from the tip of the nose) was more anterior than for a 'laminar' profile, supporting the idea that there is little laminar flow. The Steller sea lions in our study were characterized by a mean fineness ratio of 5.55. Their streamlined shape helps to delay flow separation, reducing total drag. In addition, turbulent boundary layers are more stable than laminar ones. Thus, separation should occur further back on the animal. Steller sea lions are the largest of the otariids and swam faster than the smaller California sea lions (Zalophus californianus). The mean glide velocity of the individual Steller sea lions ranged from 2.9 to 3.4 m s(-)(1) or 1.2-1.5 body lengths s(-)(1). These length-specific speeds are close to the optimum swim velocity of 1.4 body lengths s(-)(1) based on the minimum cost of transport for California sea lions.

Svard, C., Fahlman, A., Rosen, D. A. S., Joy, R., & Trites, A. W. (2009). Fasting Affects the Surface and Diving Metabolic Rates of Steller Sea Lions *Eumetopias Jubatus*. *Aquatic Biology*, 8(1), 71-82. <u>https://doi.org/10.3354/ab00211</u>

Changes in metabolic rates were measured in 3 captive female Steller sea lions *Eumetopias jubatus* that experienced fasts during summer and winter. We measured metabolic rates (via O-2 consumption) before (MRs, surface) and after (DMR, dive + surface interval) the sea lions dove to 10-50 m depths. Measurements were obtained prior to and immediately after 9 to 10 d fasts, and during a 14 d recovery period. The sea lions lost significantly more body mass (M-b) during the winter fast (10.6%), compared with the summer (9.5%). Mass-corrected dive metabolic rate (cDMR = DMR x M-b(-0.714)) was not affected by dive depth or duration, but increased significantly following the winter fasts (13.5 +/- 8.1%), but did not change during summer (-1.1 +/- 3.2%). However, mass-corrected surface metabolic rate (cMRs) decreased significantly after both the summer (-16.4 +/- 4.7%) and winter (-8.0 +/- 9.0%) fasts.

Consequently, the ratio between cDMR and cMRs was significantly higher in winter, suggestive of an increased thermal challenge and convective heat loss while diving. Increased cMRs following the fast indicated that digestion began during foraging and was not deferred, implying that access to ingested energy was of higher priority than optimizing diving ability. cDMR was elevated throughout the recovery period, independent of season, resulting in a 12% increase in foraging cost in winter and a 3% increase in summer. Our data suggest that Steller sea lions are more sensitive to changes in body condition due to food shortages in the winter compared with the summer.

Svard, C. E., Fahlman, A., Joy, R., Rosen, D., & Trites, A. (2008). Effect of Fasting on Resting and Diving Metabolic Rate in Steller Sea Lions (*Eumetopias Jubatus*). *FASEB Journal, 22*. Retrieved from <u>http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch_&qid=23&SID=8AKBSJ5RixL6hagr5Wp&page=1&doc=1</u>

The metabolic trade off between thermoregulation and fasting was assessed for foraging Steller sea lions. Pre-dive resting (RMR) and diving (dive + surface) metabolic rates (DMR, $1 O2 \cdot min-1$) were measured for dives ranging between 20 to 50 m in 3 female Steller sea lions (mean initial body masses, Mb: 144.3, 167.4 and 219.9 kg) before and after a 9-day fast. The sea lions lost an average of 9.8 % of their body mass (Mb) or 1.1 % per day. Dive duration and dive depth did not significantly affect DMR (p > 0.1). Average RMR and DMR before fasting ranged between 0.71 and 1.98 O2 • min-1 and was positively correlated with Mb (r2 = 0.97, p < 0.05). Both RMR (36.3 ± 5.22 %) and DMR (14.2 ± 12.3 %) decreased after fasting. The smaller decrease in DMR compared to RMR indicates that the cost of thermoregulation increased during diving compared to resting. RMR tended to increase in fasted sea lions within 1 hour of feeding, but was not observed in fed sea lions (p = 0.07). This suggests that digestion of food started while diving and had a greater energetic priority than dive performance in fasted animals.

Thomton, J. D., & Mellish, J. A. E. (2007). Haptoglobin Concentrations in Free-Range and Temporarily Captive Juvenile Steller Sea Lions. *Journal of Wildlife Diseases, 43*(2), 258-261. <u>https://doi.org/10.7589/0090-3558-43.2.258</u>

Haptoglobin (Hp) is an acute-phase protein synthesized in the liver that circulates at elevated concentrations in response to tissue damage caused by inflammation, infection, and trauma. As part of a larger study, sera Hp concentrations were measured in temporarily captive (n=21) and free-range (n = 38) western stock juvenile Steller sea lions (*Eumetopias jubatus*) sampled from 2003 to 2006. Baseline Hp concentration at time of capture was 133.3 +/- 17.4 mg/dl. Temporarily captive animals exhibited a 3.2-fold increase in Hp concentrations during the first 4 wk of captivity, followed by a return to entry levels by week 5. Haptoglobin levels were not influenced by age, season, or parasite load. There was a significant positive correlation between Hp concentrations and white blood cell count (P<0.001) and globulin levels (P<0.001) and a negative correlation to red blood cell count and hematocrit (P<0.001 for both). There was no correlation between Hp levels and platelet count (P=0.095) or hemoglobin (P=0.457). Routine blubber biopsies collected under gas anesthesia did not produce a measurable Hp response. One animal with a large abscess bad an Hp spike of 1,006.0 mg/dl that returned to entry levels after treatment. In conclusion, serum Hp levels correlate to the stable clinical health status observed during captivity, with moderate Hp response during capture and initial acclimation to captivity and acute response to inflammation and infection.

Trites, A. W., & Donnelly, C. P. (2003). The Decline of Steller Sea Lions *Eumetopias Jubatus* in Alaska: A Review of the Nutritional Stress Hypothesis. *Mammal Review*, *33*(1), 3-28. https://doi.org/10.1046/j.1365-2907.2003.00009.x

1. The decline of Steller sea lions *Eumetopias jubatus* in the Gulf of Alaska and Aleutian Islands between the late 1970s and 1990s may have been related to reduced availability of suitable prey. Many studies have shown that pinnipeds and other mammals suffering from nutritional stress typically exhibit reduced body size, reduced productivity, high mortality of pups and juveniles, altered blood chemistry and specific behavioural modifications. 2. Morphometric measurements of Steller sea lions through the 1970s and 1980s in Alaska indicate reduced body size. Reduced numbers of pups born and an apparent increase in juvenile mortality rates also appear to be nutritionally based. Blood chemistry analyses have further shown that Steller sea lions in the Gulf of Alaska and Aleutian Islands area exhibited signs of an acute phase reaction, or immune reaction, in response to unidentified physical and/or environmental stress. Behavioural studies during the 1990s have not noted any changes that are indicative of an overall shortage in the quantity of prey available to lactating female sea lions. 3. The data collected in Alaska are consistent with the hypothesis that Steller sea lions in the declining regions were nutritionally compromised because of the relative quality of prey available to them (chronic nutritional stress), rather than because of the overall quantity of fish per se (acute nutritional stress). This is further supported by captive studies that indicate the overall quality of prey that has been available to Steller sea lions in the declining population could compromise the health of Steller sea lions and hinder their recovery.

Trites, A. W., & Jonker, R. A. (2000). Morphometric Measurements and Body Condition of Healthy and Starveling Steller Sea Lion Pups (*Eumetopias Jubatus*). *Aquatic Mammals*, 26(2), 151-157. Retrieved from https://aquaticmammalsiournal.org/share/AquaticMammalsIssueArchives/2000/AquaticMamr

https://aquaticmammalsjournal.org/share/AquaticMammalsIssueArchives/2000/AquaticMammals_26-02/26-02_Trites.pdf

The thickness and weight of skin, blubber, and body core were measured from 12 dead Steller sea lion pups (Eumetopias jubatus). These necropsied pups represented a wide range of body sizes and conditions (small to large, and fat to no-fat), and were chosen to compare the relative body conditions of healthy and starved pups. Seven of the pups lacked blubber and were significantly lighter for a given length compared to the five that had fat at their time of death. Volume exceeded mass by a factor of 1.3% with density averaging 0.987 g cm3. Skin and blubber were not uniformly thick over the body surface. Skin was thinnest on the head and around the flippers (3 mm), and became thicker towards the rump (5 mm). Skin thickness did not differ between dorsal and ventral sides, unlike blubber, which was thickest on the ventral side, increasing from the snout (1.5 mm) to mid-trunk (7 mm) and decreasing posteriorly (5 mm at the tail). Along the back, blubber increased from 1 mm at the snout to about 4.5 mm at mid-trunk. The five pups that died of trauma had about 13% skin and 10% blubber (expressed as a proportion of total body mass). Starvelings lost an estimated 43% of their body mass before dying (10% blubber, and 33% body core). Morphometric measurements applied to three proposed indices of body condition suggest that girth is not a good predictor of body condition for Steller sea lion pups. Only the ratio of observed to predicted body mass derived from standardized mass-length relationships could distinguish starvelings from pups with body fat.

 Vollenweider, J., Womble, J., & Heintz, R. (2006). Estimation of Seasonal Energy Content of Steller Sea Lion (Eumetopias Jubatus) Diet. In Sea Lions of the World. A.W. Trites, S.K. Atkinson, D.P.
DeMaster, L.W. Fritz, T.S. Gelatt, L.D. Rea, and K.M. Wynne (Eds.) Sea Grant Alaska. https://doi.org/10.4027/slw.2006.12

We estimated the energy consumption of Steller sea lions (Eumetopias jubatus) in southeastern Alaska by integrating seasonal scat collection data with seasonal energy content of prey species of Steller sea lions. During 2001 and 2002, sea lion scat samples were collected quarterly at Benjamin Island in conjunction with quarterly collections of sea lion prey species from mid-water trawls near Benjamin Island. The biomass of prey species was reconstructed using biomass-variable (BV) and biomass-fixed (BF) techniques, and combined with prey energy content to estimate the amount of energy from each prey species during each season. Energy content of scats was variable across seasons and was lowest in February of both years and highest in December. A total of 41 prey species were identified from scat samples; however, the BV and BF models identified only five prey as constituting the majority of energy in sea lion scats. The five primary prey include salmon (Oncorhynchus sp.), skate (Rajidae), Pacific cod (Gadus macrocephalus), Pacific herring (Clupea pallasii), and walleye pollock (Theragra chalcogramma). These prey accounted for 91% of the total energy in the BV model and 84% in the BF model. Both models depicted similar seasonal trends in prey-derived energy, likely related to ephemeral prey aggregations associated with spawning or overwintering. In the BV model the primary prey species contributed relatively equal proportions of energy, with the exception of mature pollock. In contrast, herring was the predominant energy source in the BF model. The relative importance of prey types resulting from BV and BF models were more similar to each other than to raw biomass estimates or frequency of occurrence. Likely the true prey-derived energy is intermediate to the two models due to opposing inherent biases of each model.

Volpov, B. L., Goundie, E. T., Rosen, D. A. S., Arnould, J. P. Y., & Trites, A. W. (2016). Transiting to Depth Disrupts Overall Dynamic Body Acceleration and Oxygen Consumption Rate in Freely Diving Steller Sea Lions. *Marine Ecology Progress Series, 562*, 221-236. <u>https://doi.org/10.3354/meps11943</u>

Previous research has presented contradictory evidence on the ability of overall dynamic body acceleration (ODBA) to predict mass-corrected oxygen consumption (s(V) over dotO(2)) in air-breathing diving vertebrates. We investigated a potential source of these discrepancies by partitioning the ODBAs(V)over dotO(2) relationship over 3 phases of the dive cycle (transiting to and from depth, bottom time, and post-dive surface interval). Trained Steller sea lions *Eumetopias jubatus* executed 4 types of dives to 40 m (single dives, long-duration dive bouts of 4-6 dives, short-duration dive bouts of 10 or 12 dives, and transit dives with minimal bottom duration). Partitioning single dives by dive phase showed differing patterns in the ODBA-s(V)over dotO(2) relationship among dive phases, but no significant linear relationships were observed. The proportion of the dive cycle spent tran siting to and from the surface was a significant predictive factor in the ODBA-s(V)over dotO(2) relationship, while bottom duration or post-dive surface interval had no effect. ODBA only predicted s(V)over dotO(2) for dives when the proportion of time spent transiting was small. The apparent inability of ODBA to reliably predict s(V)over dotO(2) reflects differences in the inherent relationships between ODBA and s(V)over dotO(2) during different phases of the dive. These results support the growing body of evidence that ODBA on its own is not a reliable field predictor of energy expenditure at the level of the single dive or dive bout in airbreathing diving vertebrates likely because ODBA (a physical measure) cannot account for physiological changes in s(V) over dotO(2) that occur during the different phases of a dive cycle.

Volpov, B. L., Rosen, D. A. S., Trites, A. W., & Arnould, J. P. Y. (2015). Validating the Relationship between 3-Dimensional Body Acceleration and Oxygen Consumption in Trained Steller Sea Lions. *Journal* of Comparative Physiology B-Biochemical Systemic and Environmental Physiology, 185(6), 695-708. <u>https://doi.org/10.1007/s00360-015-0911-y</u>

We tested the ability of overall dynamic body acceleration (ODBA) to predict the rate of oxygen consumption () in freely diving Steller sea lions (Eumetopias jubatus) while resting at the surface and diving. The trained sea lions executed three dive types-single dives, bouts of multiple long dives with 4-6 dives per bout, or bouts of multiple short dives with 10-12 dives per bout-to depths of 40 m, resulting in a range of activity and oxygen consumption levels. Average metabolic rate (AMR) over the dive cycle or dive bout calculated was calculated from . We found that ODBA could statistically predict AMR when data from all dive types were combined, but that dive type was a significant model factor. However, there were no significant linear relationships between AMR and ODBA when data for each dive type were analyzed separately. The potential relationships between AMR and ODBA were not improved by including dive duration, food consumed, proportion of dive cycle spent submerged, or number of dives per bout. It is not clear whether the lack of predictive power within dive type was due to low statistical power, or whether it reflected a true absence of a relationship between ODBA and AMR. The average percent error for predicting AMR from ODBA was 7-11 %, and standard error of the estimated AMR was 5-32 %. Overall, the extensive range of dive behaviors and physiological conditions we tested indicated that ODBA was not suitable for estimating AMR in the field due to considerable error and the inconclusive effects of dive type.

Walker, K. A., Horning, M., Mellish, J. A. E., & Weary, D. M. (2009). Behavioural Responses of Juvenile Steller Sea Lions to Abdominal Surgery: Developing an Assessment of Post-Operative Pain. *Applied Animal Behaviour Science*, 120(3-4), 201-207. <u>https://doi.org/10.1016/j.applanim.2009.06.003</u>

Marking and tracking of marine mammals is required to gain abetter understanding of life history traits: however, some marking procedures used are likely painful. Recent technological advances include intraabdominally implanted archival telemetry devices for the life-long monitoring of individual animals. No research to date has assessed any aspect of post-operative pain in marine mammals. This study specifically evaluated behavioural responses in nine juvenile Steller sea lions to the abdominal surgery required for insertion of telemetry devices. Behaviours predicted to reflect post-operative pain, including posture and body movements, were assessed during 3-day pre-, 3-day post-, and days 10-12 post-surgery. The proportion of time sea lions spent on land standing increased from 0.00 to 0.07 and then decreased to 0.04, for pre-, post-, and late post-surgery respectively. Similarly, the proportion of land time spent with the back arched increased from 0.01 to 0.57, and then decreased to 0.33. The time sea lions spent on land with pressure on their ventral side while sitting or lying down declined from 1.0 pre-surgery to 0.17 post-surgery, and increased to 0.20 late post-surgery. The time sea lions spent in locomotion on land and in the water decreased from 0.05 in pre-surgery to 0.01 post-surgery, and returned to 0.06 by late post-surgery. These results suggest that behaviours such as back arch, standing, time spent with pressure on the ventral side, and locomotion may be useful in the assessment of pain following abdominal surgery in sea lions. The presence of these behaviours and their persistence for LIP to 12 days after surgery suggest that more work is required to further develop safe and effective analgesic methods for this procedure.

Walker, K. A., Horning, M., Mellish, J. A. E., & Weary, D. M. (2011). The Effects of Two Analgesic Regimes on Behavior after Abdominal Surgery in Steller Sea Lions. *Veterinary Journal*, 190(1), 160-164. <u>https://doi.org/10.1016/j.tvjl.2010.08.011</u>

This study examined the effects of two non-steroidal anti-inflammatory drug (NSAID) treatment protocols on the behavioral responses of juvenile Steller sea lions after abdominal surgery. Sea lions were randomly assigned to one of two treatments designed to control post-operative pain. The flunixin group (n = 6) received flunixin meglumine (1 mg/kg) administered as a single intramuscular (IM) injection before extubation from surgery. The carprofen group (n = 5) received carprofen (4.4 mg/kg) as an IM injection before extubation, then orally at 24, 48 and 72 h after surgery. Seven behaviors related to post-operative pain were monitored by observers, blinded to treatment, for a total of 10 days (3 days pre-, day of surgery, and 6 days post-surgery). All seven behaviors changed after surgery regardless of NSAID treatment, two of which returned to baseline within 6 days of surgery. Only one behavior was mildly affected by analgesic treatment: sea lions in the carprofen group tended to spend less time lying down in Days 1-3 following surgery (i.e., the days which they received oral carprofen). These results suggested that neither treatment, at the dose administered, was effective in controlling pain in the days following this surgery.

Walker, K. A., Mellish, J. A. E., & Weary, D. M. (2010). Behavioural Responses of Juvenile Steller Sea Lions to Hot-Iron Branding. *Applied Animal Behaviour Science*, 122(1), 58-62. https://doi.org/10.1016/j.applanim.2009.11.013

Here we present the first data showing the post-branding behavioural responses in a marine mammal. Eleven captive juvenile Steller sea lions (*Eumetopias jubatus*) were observed for 3 days before and 3 days after hot-iron branding. Four of six monitored behaviours changed significantly after branding. The proportion of time sea lions spent in locomotion decreased from 0.07 before branding to 0.03 during the first 24 h following branding. Wound-directed behaviour (scratching, biting and head rubbing the branded area) increased from 0.0 before branding to 0.01-0.02 during the first 48 h after branding and returned to baseline thereafter. Time in the pool declined from 0.17 before branding to 0.05 during the first 24 h after branding and approached baseline by the second 24-h period. The time spent with pressure on the branded side showed little change from the 0.08 before branding to 0.10 during the first 24 h after branding; however, this behaviour decreased to 0.02 and 0.01 on following two days. These results show that Steller sea lion behaviour changes for up to 72 h after hot-iron branding. Changes in these behaviours may be useful in assessing alternative effective analgesic protocols for this procedure.

Walker, K. A., Mellish, J. E., & Weary, D. M. (2011). Effects of Hot-Iron Branding on Heart Rate, Breathing Rate and Behaviour of Anaesthetised Steller Sea Lions. *Veterinary Record*, 169(14), 363-U352. <u>https://doi.org/10.1136/vr.d4911</u>

This study assessed the heart rate, breathing rate and behavioural responses of 12 juvenile Steller sea lions during hot-iron branding under isoflurane anaesthesia. Physiological and behavioural measures were recorded in four periods: baseline (five minutes), sham branding (one minute), branding (approximately 2.7 minutes) and postbranding (five minutes). No difference in heart rate was noted from baseline to sham branding, but heart rate increased from mean (sem) 78.3 (2.4) bpm in the

baseline period to 85.6 (2.5) bpm in the branding period. Heart rate remained elevated in the postbranding period, averaging 84.7 (2.5) bpm. Breathing rate averaged 2.5 (1.0) breaths/minute in the baseline and sham branding periods increased to 8.9 (1.0) breaths/minute during branding, but returned to baseline by the postbranding period. Behaviourally, half of the sea lions exhibited trembling and head and shoulder movements during branding.

Willis, K., Horning, M., Rosen, D. A. S., & Trites, A. W. (2005). Spatial Variation of Heat Flux in Steller Sea Lions: Evidence for Consistent Avenues of Heat Exchange Along the Body Trunk. *Journal of Experimental Marine Biology and Ecology*, *315*(2), 163-175. <u>https://doi.org/10.1016/j.jembe.2004.09.018</u>

Maintaining insulative fat stores is vital for homeothermic marine mammals foraging in cold polar waters. To accomplish this, animals must balance acquisition and expenditure of energy. If this balance is shifted, body condition can decrease, challenging thermal homeostasis and further affecting energy balance. Prior studies of temperature regulation in sea lions have neither quantified basic all-inclusive heat flux values for animals swimming in cold water, nor determined whether they exhibit consistent spatial patterns of heat flux. Heat flux and skin temperature data were thus collected from four captive Steller sea lions using heat flux sensors (HFSs) with embedded thermistors. Optimal sensor placement was established using infrared thermography to locate the major areas of heat flux along the surface of the animals. Experiments were conducted on swimming animals in a large habitat tank with and without a drag harness, and on stationary animals in a temperature- and current-controlled swim flume. All heat flux measurements were corrected by a previously determined correction factor of 3.42 to account for insulative effects of the HFSs and attachment mechanism. Heat flux from shoulders and hips was consistently greater than from mid-trunk and axillary areas in both swimming and stationary animals, suggesting that certain areas of the body are preferentially used to offload excess heat. Mean heat flux for animals swimming with a drag harness was significantly greater than for unencumbered animals, indicating a likely increase in heat production beyond minimum heat loss. Thus, thermal stress does not appear to constitute significant costs for Steller sea lions swimming under conditions of increased drag at speeds of approximately 1 m/s in water temperatures of approximately 8.0 degrees C.

Winship, A. J. (2000). Growth and Bioenergetic Models for Stellar Sea Lions (Eumetopias Jubatus) in Alaska. University of British Columbia, Retrieved from <u>https://open.library.ubc.ca/cIRcle/collections/ubctheses/831/items/1.0074863</u>

The primary goal of my study was to develop a bioenergetic model to predict the food requirements of Steller sea lions (*Eumetopias jubatus*). An important component of the bioenergetic model was a physical growth model. Growth models were constructed using morphometric measurements of males (> 1 year old), females (> 1 year old), and pregnant females with a foetus that had been shot on rookeries, haulouts, and in the coastal waters of southeastern Alaska, the Gulf of Alaska and along the Bering Sea ice edge between 1976 and 1989. A Richards model best described age related growth in body length and mass. Males grew (in length) over a longer period than females and exhibited a growth spurt in mass which coincided with sexual maturity. Sexual dimorphism in both body length and mass was significant by 3 years of age. The average predicted standard lengths of males and females older than 12 years were 3.04 m and 2.32 m respectively, while the average predicted weights were 681 kg and 273 kg respectively. Residuals of the size at age models indicated seasonal changes in growth rates.

Young animals (<6 years old) and adult males grew little during the breeding season (May - July), and adult males did not resume growth until sometime after November.

Winship, A. J., Trites, A. W., & Calkins, D. G. (2001). Growth in Body Size of the Steller Sea Lion (*Eumetopias Jubatus*). *Journal of Mammalogy, 82*(2), 500-519. <u>https://doi.org/10.1644/1545-1542(2001)082<0500:Gibsot>2.0.Co;2</u>

Growth models (mass and length) were constructed for male (greater than or equal to1 year old), female (greater than or equal to1 year old), and pregnant female Steller sea lions (*Eumetopias jubatus*) shot on rookeries or haulouts, or in coastal waters of southeastern Alaska, the Gulf of Alaska, or the Bering Sea ice edge between 1976 and 1989. The Richards model best described growth in body length and mass. Females with fetuses were 3 cm longer and 28 kg heavier on average than females of the same age without fetuses. Males grew in length over a longer period than did females and exhibited a growth spurt in mass that coincided with sexual maturity between 5 and 7 years of age. Average predicted standard lengths of males and females greater than or equal to 12 years of age were 3.04 and 2.32 m, respectively, and average predicted masses were 681 and 273 kg, respectively. Maximum recorded mass was 910 kg for an adult male. Males achieved 90% of their asymptotic length and mass by 8 and 9 years of age, respectively, compared with 4 and 13 years, respectively, for females. Residuals of the size-at-age models indicated seasonal changes in growth rates. Young animals (<6, years old) and adult males grew little during the breeding season (May-July), and adult males did not resume growth until sometime after November.

York, A. E., Thomason, J. R., Sinclair, E. H., & Hobson, K. A. (2008). Stable Carbon and Nitrogen Isotope Values in Teeth of Steller Sea Lions: Age of Weaning and the Impact of the 1975-1976 Regime Shift in the North Pacific Ocean. *Canadian Journal of Zoology*, 86(1), 33-44. <u>https://doi.org/10.1139/z07-108</u>

We measured delta N-15 and delta C-13 values and tooth width from the first 4 years' dentinal growth layer groups (GLGs) in the teeth of 113 female Steller sea lions (*Eumetopias jubatus* (Schreber, 1776)) born between 1960 and 1983, a period that included a large population decrease and a climate regime shift. A linear discriminant analysis on the 613 C and delta N-15 values estimated 60% of Steller sea lions were weaned in their 1st year, 30% in their 2nd year, and 8% in their 3rd year. GLG-1 was wider in "weaned" animals than those still "nursing" in their 2nd year, suggesting that faster growing pups weaned earlier. Except during the regime shift, the average age at weaning increased and the size of GLG-1 in weaned animals decreased. We suggest that during the regime shift a greater proportion of pups which survived (to have their teeth sampled for this study) grew faster and were weaned by the end of their 1st year. We hypothesize that the long-term weaning age increase and growth rate decrease are consistent with a change in relative mortality of weaned pups and those that continued to nurse, possibly caused by a reduction in available resources, characterized as a switch from a "live-fast" to a "live-slow" life history.

Young, B. L., Rosen, D. A. S., Haulena, M., Hindle, A. G., & Trites, A. W. (2011). Environment and Feeding Change the Ability of Heart Rate to Predict Metabolism in Resting Steller Sea Lions (*Eumetopias Jubatus*). Journal of Comparative Physiology B-Biochemical Systemic and Environmental Physiology, 181(1), 105-116. https://doi.org/10.1007/s00360-010-0504-8 The ability to use heart rate (fh) to predict oxygen consumption rates (V[·]O2) in Steller sea lions and other pinnipeds has been investigated in fasting animals. However, it is unknown whether established fh:V[·]O2 relationships hold under more complex physiological situations, such as when animals are feeding or digesting. We assessed whether fh could accurately predict V[·]O2 in trained Steller sea lions while fasting and after being fed. Using linear mixed-effects models, we derived unique equations to describe the fh:V[·]O2 relationship for fasted sea lions resting on land and in water. Feeding did not significantly change the fh:V[·]O2 relationship on land. However, Steller sea lions in water displayed a different fh:V[·]O2 relationship after consuming a 4-kg meal compared with the fasting condition. Incorporating comparable published fh:V[·]O2 from telemetered fh, but that only environment affects the practical ability to predict metabolism from fh. Updating current bioenergetic models with data gathered using these predictive fh:V[·]O2 equations will yield more accurate estimates of metabolic rates of free-ranging Steller sea lions under a variety of physiological, behavioral, and environmental states.

Zenteno-Savin, T. (1997). Physiology of the Endocrine, Cardiorespiratory and Nervous Systems in Pinnipeds: Integrative Approach and Biomedical Considerations. University of Alaska Fairbanks, Retrieved from

https://scholarworks.alaska.edu/bitstream/handle/11122/9508/Zenteno_Savin_T_1997.pdf?se guence=1

This thesis explored several aspects of the hormonal and cardiovascular physiology in pinnipeds (seals and sea lions). Plasma concentrations of the vasoactive hormones angiotensin II (Ang II), arginine vasopressin (AVP, the antidiuretic hormone) and atrial natriuretic peptide (ANP) were studied in six species of seals and sea lions. Resting levels of AVP, ANP and Ang II in these pinnipeds were similar to those reported for other vertebrate species, including humans. Age-related differences were found in the concentrations of these hormones in seals and sea lions. Geographic differences in hormone concentrations were found in Steller sea lions and harbor seals. To address the endocrine and cardiovascular responses to breath-holding (apnea) in marine mammals, heart rates and plasma levels of Ang n, AVP and ANP were studied in Weddell seal (Leptonychotes weddellii) and northern elephant seal (Mirounga angustirostris) pups during periods of spontaneous breathing (eupnea) and apnea. Ang II, AVP, and ANP, as well as the autonomic nervous system, were found to contribute differently to the control of heart rate in seal pups, depending whether the respiratory system was in eupnea or apnea. Because of changes in seals of different ages, it appeared that the integration of cardiorespiratory and hormonal function is not fully mature at birth, but develops post-natally, probably simultaneously to the development of diving behavior. These studies also suggested that the factors affecting cardiorespiratory function, including hormones, may differ by species. Plasma concentrations of AVP, ANP and Ang II were measured during food limitation and fasting in captive Steller sea lions (Eumetopias jubatus) and compared to levels in free-ranging conspecifics. The results suggest that Steller sea lions have a remarkable capacity to maintain hydrosmotic and endocrine balance during short-term food limitation and fasting. Hormonal studies did not provide conclusive evidence that Steller sea lions in Alaskan waters are currently affected by long-term food limitation.

Zenteno-Savin, T., & Castellini, M. A. (1998). Plasma Angiotensin II, Arginine Vasopressin and Atrial Natriuretic Peptide in Free Ranging and Captive Seals and Sea Lions. *Comparative Biochemistry and Physiology - Part C: Toxicology & Pharmacology, 119*(1), 1-6. <u>https://doi.org/10.1016/s0742-</u> 8413(97)00136-9

We used radioimmunoassay methods to quantify arginine vasopressin (AVP), atrial natriuretic peptide (ANP), and angiotensin II (Ang II) in plasma samples from harbor seals (Phoca vitulina richardsii), Weddell seals (Leptonychotes weddellii), northern elephant seals (Mirounga angustirostris), ringed seals (Phoca hispida), California sea lions (Zalophus californianus), and Steller sea lions (*Eumetopias jubatus*). Plasma concentrations of AVP, ANP, and Ang II in these pinniped species were within the ranges reported for other vertebrates under resting conditions. However, there were species, geographic and developmental variations in these hormones: Levels of AVP in plasma samples from adult Steller sea lions and harbor seals were higher than in pups of the same species; higher levels of plasma ANP were found in wild captured Alaskan Steller sea lions and in hunted ringed seals; differences in plasma levels of all three hormones were found throughout the geographic distribution of harbor seals and Steller sea lions in Alaska. This is the first report on circulating concentrations of vasoactive hormones in pinnipeds, and demonstrates that further studies are needed to ascertain the natural variability in these levels with the impact of molting, fasting, diving and environmental factors in seals and sea lions.

Section XI: Predation

Baird, R. W., & Stacey, P. J. (1989). Observations on the Reactions of Sea Lions, Zalophus Californianus and *Eumetopias Jubatus*, to Killer Whales, Orcinus Orca, Evidence of ""Prey" Having a ""Search Image" for Predators. *Canadian Field-Naturalist*, 103(3), 426. Retrieved from http://www.cascadiaresearch.org/files/Projects/KillerWhales/sealionkwCFN.pdf

Observations on the reactions of California Sea Lions (Zalophus californianus) and Steller Sea Lions (*Eumetopias jubatus*) to the presence of foraging transient Killer Whales (Orcinus orca) were made on three occasions. Alert and avoidance responses by sea lions were made in the presence of Killer Whales of typical appearance. In the presence of a single, foraging Killer Whale of atypical appearance, no alert or avoidance response was observed. It is possible that the sea lions did not recognize the atypical whale as a Killer Whale, suggesting that sea lions may have a perceptual "search image" for the detection of predators, based on visual cues.

Barrett-Lennard, L. G., Heise, K., Saulitis, E., Ellis, G., & Matkin, C. (1995). The Impact of Killer Whale Predation on Steller Sea Lion Populations in British Columbia and Alaska. *Report to North Pacific* Universities Marine Mammal Research Consortium, University of British Columbia, Vancouver, BC, Canada. Retrieved from <u>http://www.marinemammal.org/wp-</u> <u>content/pdfs/Barrett_etal1995-killer.pdf</u>

Steller sea lion populations in Alaska have declined precipitously over the last 25 years. Much research has been conducted on the role of anthropogenic factors in this decline. The retrieval of 14 sea lion flipper tags from a dead killer whale in 1992 underscored the need for a similar appraisal of predation. We used simulation models to examine (1) the extent to which killer whales contributed to the sea lion

decline, and (2) the present effect of killer whale predation on depleted sea lion populations. We estimated the model parameters using three sources: a survey of researchers and mariners, the stomach contents of stranded killer whales, and killer whale identification photographs from several collections. The 126 survey respondents described 52 attacks including 32 reported kills. Eight out of 15 killer whale stomachs with identifiable contents contained marine mammals, and two contained Steller sea lion remains. The survey and stomach content data were consistent with earlier findings that only members of the transient killer whale population commonly prey on marine mammals. Based on identification photographs, we estimated that at least 250 transient killer whales feed in Alaskan waters. We ran Leslie matrix simulations under various assumptions concerning the functional responses of killer whales to changes in sea lion density. Our models suggest that killer whale predation did not cause the sea lion decline, but may now be a contributing factor. At present, approximately 18% of sea lions that die annually in Western Alaska may be taken by killer whales.

Dahlheim, M. E., & White, P. A. (2010). Ecological Aspects of Transient Killer Whales Orcinus Orca as Predators in Southeastern Alaska. *Wildlife Biology*, *16*(3), 308-322. <u>https://doi.org/10.2981/09-075</u>

In this study we present empirical data on predator numbers, movements and area usage, and predation obtained from tracking transient killer whales Orcinus orca throughout the inland waters ofsoutheastern Alaska, USA. During 19912007, we documented 155 transient killer whales via photoidentification methodology within the large study area (27,808 km2). Transient killer whales were distributed throughout southeastern Alaska and were present during all seasons, although not all individuals were seen every year. Resighting data suggested that within southeastern Alaska, maternal groupsmay partition area usage of their environment. By following whales for 1,467 km, we calculated amean travel speed of 7.2 km/hour with mean daily movements of 134 km688 km/24 hours and ranging within 59-240 km/24 hours. Photographic matches demonstrated that most of the transient killer whales (86%) identified in southeastern Alaska also utilized British Columbiaand Washington State waters. In contrast, photographic matches between whales in southeastern Alaska and whales seenoffofCalifornia, USA, were rare, suggesting that different transient killer whale stocks occupy these two regions. Transient killer whales preyed upon Dall's porpoise Phocoenoides dalli, Pacific whitesided dolphins Lagenoryhncus obliquidens, harbor porpoise Phocoena phocoena, minke whales Balaenoptera acutorostrata, Steller sea lions Eumetopias jubatus, harbor seals Phoca vitulina and seabirds. Potential prey species that were available, but not targeted, included humpback whales Megaptera novaeangliae, elephant seals Mirounga angustirostris and sea otters Enhydra lutris. Prey-handling techniques varied depending on the prey being targeted with no evidence of prey specialization. During 114 encounters totaling 332.5 hours of direct observations of transient killer whales, we documented 36 predation events for a calculated kill rate of 0.62 prey items/24-hour period/whale. The data we present in this article provide a foundation of transient killer whale ecology aimed at improving our ability to understand the impact of transient killer whale predation on southeastern Alaska prey populations.

Durban, J., Ellifrit, D., Dahlheim, M., Waite, J., Matkin, C., Barrett-Lennard, L., . . . Wade, P. (2010). Photographic Mark-Recapture Analysis of Clustered Mammal-Eating Killer Whales around the Aleutian Islands and Gulf of Alaska. *Marine Biology*, *157*(7), 1591-1604. <u>https://doi.org/10.1007/s00227-010-1432-6</u> We used photographic mark-recapture methods to estimate the number of mammal-eating "transient" killer whales using the coastal waters from the central Gulf of Alaska to the central Aleutian Islands, around breeding rookeries of endangered Steller sea lions. We identified 154 individual killer whales from 6,489 photographs collected between July 2001 and August 2003. A Bayesian mixture model estimated seven distinct clusters (95% probability interval = 7–10) of individuals that were differentially covered by 14 boat-based surveys exhibiting varying degrees of association in space and time. Markov Chain Monte Carlo methods were used to sample identification probabilities across the distribution of clusters to estimate a total of 345 identified and undetected whales (95% probability interval = 255–487). Estimates of covariance between surveys, in terms of their coverage of these clusters, indicated spatial population structure and seasonal movements from these near-shore waters, suggesting spatial and temporal variation in the predation pressure on coastal marine mammals.

Ford, J. K., Ellis, G. M., Barrett-Lennard, L. G., Morton, A. B., Palm, R. S., & Balcomb III, K. C. (1998). Dietary Specialization in Two Sympatric Populations of Killer Whales (*Orcinus Orca*) in Coastal British Columbia and Adjacent Waters. *Canadian Journal of Zoology*, 76(8), 1456-1471. <u>https://doi.org/10.1139/cjz-76-8-1456</u>

Two forms of killer whale (Orcinus orca), resident and transient, occur sympatrically in coastal waters of British Columbia, Washington State, and southeastern Alaska. The two forms do not mix, and differ in seasonal distribution, social structure, and behaviour. These distinctions have been attributed to apparent differences in diet, although no comprehensive comparative analysis of the diets of the two forms had been undertaken. Here we present such an analysis, based on field observations of predation and on the stomach contents of stranded killer whales collected over a 20-year period. In total, 22 species of fish and 1 species of squid were documented in the diet of resident-type killer whales; 12 of these are previously unrecorded as prey of O. orca. Despite the diversity of fish species taken, resident whales have a clear preference for salmon prey. In field observations of feeding, 96% of fish taken were salmonids. Six species of salmonids were identified from prey fragments, with chinook salmon (Oncorhynchus tshawytscha) being the most common. The stomach contents of stranded residents also indicated a preference for chinook salmon. On rare occasions, resident whales were seen to harass marine mammals, but no kills were confirmed and no mammalian remains were found in the stomachs of stranded residents. Transient killer whales were observed to prey only on pinnipeds, cetaceans, and seabirds. Six mammal species were taken, with over half of observed attacks involving harbour seals (Phoca vitulina). Seabirds do not appear to represent a significant prey resource. This study thus reveals the existence of strikingly divergent prey preferences of resident and transient killer whales, which are reflected in distinctive foraging strategies and related sociobiological traits of these sympatric populations.

Ford, J. K., Ellis, G. M., Matkin, C. O., Wetklo, M. H., Barrett-Lennard, L. G., & Withler, R. E. (2011). Shark Predation and Tooth Wear in a Population of Northeastern Pacific Killer Whales. *Aquatic Biology*, 11(3), 213-224. <u>https://doi.org/10.3354/ab00307</u>

The cosmopolitan killer whale Orcinus orca feeds on a wide variety of prey types over its global range, but in at least some regions, genetically distinct and ecologically specialised lineages of killer whales coexist sympatrically. In coastal waters of the northeastern Pacific, 2 such lineages have been well described: the so-called 'residents' prey on teleost fish, especially salmonids and the other ('transients') on marine mammals. A third lineage in this region ('offshores') appears from chemical tracers to be

ecologically distinct from residents and transients, but its diet is very poorly known. Here we describe 2 encounters with offshore killer whales during which multiple predation events involving sharks were observed. Using DNA analysis of tissue samples collected from these predation events, we identified the prey species as Pacific sleeper shark Somniosus pacificus and determined that a minimum of 16 individuals were consumed over the 2 encounters. This represents the first confirmed prey species of offshore killer whales based on field observations of foraging and the first record of any Somniosus species in the prey of Orcinus. We also show quantitatively that apical tooth wear is far greater in offshores than in resident and transient killer whales, and propose that such wear is at least in part due to abrasion from dermal denticles embedded in shark skin. Further studies are needed to determine whether offshore killer whales are as specialised ecologically as resident and transient killer whales, and whether sharks play a dominant role in their diet.

Frost, K. J., Russell, R. B., & Lowry, L. F. (1992). Killer Whales, Orcinus Orca, in the Southeastern Bering Sea: Recent Sightings Andpredation on Other Marine Mammals. *Marine Mammal Science*, 8(2), 110-119. <u>https://doi.org/10.1111/j.1748-7692.1992.tb00370.x</u>

An unusual number of killer whales appeared in inshore waters of the southeastern Bering Sea in summer 1989 and 1990. Multiple sightings occurred in Bristol and Kuskokwim bays where killer whales had been seen only rarely in previous years. Three animals became stranded on mud flats in Kuskokwim Bay but were able to free themselves on a high tide. Killer whales were observed interacting with salmon, harbor seals, Steller sea lions, walruses, and beluga whales. Detailed observations were made of killer whales attacking belugas in the Naknek River. Local conditions and behavioral adaptations may reduce the susceptibility of belugas to killer whale predation. Continued killer whale activity in this area would be unlikely to affect fish resources, but might have some influence on beluga whales.

Ghai, R., & Insley, S. J. (2011). Probable Effects of Resident and Transient Killer Whales (Orcinus Orca) on the Activity Levels of Steller Sea Lions (*Eumetopias Jubatus*) at Carmanah Point, British Columbia. *Marine Mammal Science*, 27(3). <u>https://doi.org/10.1111/j.1748-7692.2010.00424.x</u>

The article presents a study on the effect of transient and resident killer whales to Steller sea lions' activity levels at Carmanah Point, Vancouver Island, British Columbia. It describes resident killer whales as nonthreatening while transient ones are classified as predators. Teh study found that Steller sea lions are able to identify the two classes of killer whales and can respond solely to those that threaten them.

Guénette, S., Heymans, S. J., Christensen, V., & Trites, A. W. (2007). *Ecosystem Models of the Aleutian Islands and Southeast Alaska Show That Steller Sea Lions Are Impacted by Killer Whale Predation When Sea Lion Numbers Are Low.* Paper presented at the Proceedings of the Fourth Glacier Bay Science Symposium, US Geological Survey, Juneau, Alaska. Retrieved from <u>https://pubs.er.usgs.gov/publication/sir20075047</u>

We constructed ecosystem models using the Ecopath with Ecosim software to evaluate whether predation by killer whales might explain the decline of Steller sea lions since the late 1970s in the central and western Aleutian Islands. We also sought to understand why sea lions increased in the presence of killer whales in Southeast Alaska. Modelling results reproduced the time series of abundances for exploited species and sea lions in both ecosystems. Simulation results suggest that killer whale

predation contributed to the decline of sea lions in the central and western Aleutians, but that predation was not the primary cause of the population decline. However, predation could have become a significant source of mortality during the 1990s when sea lion numbers were much lower. In Southeast Alaska, predation was also determined to be a significant source of mortality in the 1960s when sea lions were low, but ceased to control population growth through the 1980s and 1990s. Overall, the ecosystem models suggest that large populations of Steller sea lions can withstand predation, but that small populations are vulnerable to killer whales.

 Heise, K., Barrett-Lennard, L. G., Saulitis, E., Matkin, C., & Bain, D. (2003). Examining the Evidence for Killer Whale Predation on Steller Sea Lions in British Columbia and Alaska. *Aquatic Mammals*, 29(3), 325-334. Retrieved from

https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=23 7:examining-the-evidence-for-killer-whale-predation-on-steller-sea-lions-in-british-columbiaand-alaska&catid=10&Itemid=157

The discovery of flipper tags from 14 Steller sea lions (*Eumetopias jubatus*) in the stomach of a dead killer whale (Orcinus orca) in 1992 focused attention on the possible role of killer whale predation in the decline of Steller sea lions in western Alaska. In this study, mariners in British Columbia and Alaska were surveyed to determine the frequency and outcome of observed attacks on sea lions, the age classes of sea lions taken, and the areas where predatory attacks occurred. The 126 survey respondents described 492 killer whale/sea lion interactions, of which at least 32 were fatal attacks on the sea lion. The greatest rate of observed predation occurred in the Aleutian Islands. The stomach contents of dead and stranded whales also were examined. Stomachs that were not empty contained only sh or marine mammal remains, but not both. This supports earlier evidence of dietary segregation between sh-eating resident and marine mammal-eating transient killer whales in Alaska between 1990 and 2001. Stomach contents from two offshore killer whales provided the first direct evidence that this third form of killer whale feeds on fish.

Horning, M., & Mellish, J. A. (2012). Predation on an Upper Trophic Marine Predator, the Steller Sea Lion: Evaluating High Juvenile Mortality in a Density Dependent Conceptual Framework. *PLoS ONE*, 7(1). <u>https://doi.org/10.1371/journal.pone.0030173</u>

The endangered western stock of the Steller sea lion (*Eumetopias jubatus*)--the largest of the eared seals--has declined by 80% from population levels encountered four decades ago. Current overall trends from the Gulf of Alaska to the Aleutian Islands appear neutral with strong regional heterogeneities. A published inferential model has been used to hypothesize a continuous decline in natality and depressed juvenile survival during the height of the decline in the mid-late 1980's, followed by the recent recovery of juvenile survival to pre-decline rates. However, these hypotheses have not been tested by direct means, and causes underlying past and present population trajectories remain unresolved and controversial. We determined post-weaning juvenile survival and causes of mortality using data received post-mortem via satellite from telemetry transmitters implanted into 36 juvenile Steller sea lions from 2005 through 2011. Data show high post-weaning mortality by predation in the eastern Gulf of Alaska region. To evaluate the impact of such high levels of predation, we developed a conceptual framework to integrate density dependent with density independent effects on vital rates and population trajectories. Our data and model do not support the hypothesized recent recovery of

juvenile survival rates and reduced natality. Instead, our data demonstrate continued low juvenile survival in the Prince William Sound and Kenai Fjords region of the Gulf of Alaska. Our results on contemporary predation rates combined with the density dependent conceptual framework suggest predation on juvenile sea lions as the largest impediment to recovery of the species in the eastern Gulf of Alaska region. The framework also highlights the necessity for demographic models based on agestructured census data to incorporate the differential impact of predation on multiple vital rates.

Maniscalco, J. M., Matkin, C. O., Maldini, D., Calkins, D. G., & Atkinson, S. (2007). Assessing Killer Whale Predation on Steller Sea Lions from Field Observations in Kenai Fjords, Alaska. *Marine Mammal Science*, 23(2), 306-321. <u>https://doi.org/10.1111/j.1748-7692.2007.00103.x</u>

The behavioral and predatory patterns of Gulf of Alaska (GOA) transient killer whales (Orcinus orca) were studied between 2000 and 2005 using remote video and vessel-based observations near the Chiswell Island Steller sea lion (*Eumetopias jubatus*) rookery and in the broader Kenai Fjords (KF) region of the northern GOA. GOA transient killer whales were observed on 118 d over the 6-yr period; the median group size was two (range: 1-9). Nine predation events were observed from vessels and an additional sixteen were inferred from remote video studies; all involved Steller sea lions. Estimates from field observations suggest that fifty-nine sea lions were consumed over the summer seasons of 2002-2005; whereas estimates based on published caloric requirements of transient killer whales would suggest a loss of 103 sea lions over the same time period. GOA transients spent a large proportion (43%) of their time resting which may be a strategy for conserving energy. Predation on sea lion pups at the Chiswell Island rookery was greatest during years when a single killer whale was foraging alone and when a 1.5-yr-old calf was evidently being trained to handle prey. Predation on pups was low during years when killer whales were foraging in groups and were observed and presumed to be taking mostly juvenile sea lions. Our study suggests that GOA transients are having a minor effect on the recovery of Steller sea lions in the GOA.

Mashburn, K. L., & Atkinson, S. (2007). Seasonal and Predator Influences on Adrenal Function in Adult Steller Sea Lions: Gender Matters. *General and Comparative Endocrinology*, *150*(2), 246-252. <u>https://doi.org/10.1016/j.ygcen.2006.08.009</u>

Chronically heightened adrenal activity indexed by fecal corticosteroids has been shown to be a valid descriptor of stress in many species. As part of an ongoing investigation of adrenal activity in Steller sea lions (SSL), adrenocorticotropic hormone (ACTH) challenges were performed during the summer at the Alaska SeaLife Center (ASLC). These results were compared to earlier data from winter months. Additionally, adrenal response of free-ranging females SSL to a presumed in situ stressor, pup predation by killer whales (Orcinus orca), was evaluated as a field trial of developed methodologies. Summer ACTH results indicated that gender-dependent differences in baseline fecal corticosterone concentrations exist, with summer baseline fecal corticosterone concentrations higher in males than in females, based on season when compared with previously reported values in winter ACTH trials for this species. ACTH trials in the male in the summer resulted in 2468 ng/g basal to 10,937 ng/g maximal fecal corticosterone concentrations (27.9-852.0 ng/g dry weight), with a return to just above baseline concentrations by hour 25. Additionally, female 2 exhibited a 64.4-fold increase at 25 h post-stimulation (31.7-2042.0 ng/g dry weight), with a return to orca predation on pups (54.6 +/- 18.5 ng/g mean pre-attack,

542.5 +/- 252.7 ng/g mean post-attack) during the field trial. Data from both the summer ACTH and subsequent field trial underscore the necessity of gender determination of collected seat source and knowledge of conditions at collection sites for proper interpretation of fecal corticosterone data, particularly in studies that focus on population-wide stress. With elimination of gender bias and delineation of acute response to natural stimuli, corticosterone data can now be evaluated within context and provide meaningful information about stress and potentially reproductive physiology in free-ranging Steller sea lions.

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.

Matkin, C. O., Durban, J. W., Saulitis, E. L., Andrews, R. D., Straley, J. M., Matkin, D. R., & Ellis, G. M. (2012). Contrasting Abundance and Residency Patterns of Two Sympatric Populations of Transient Killer Whales (*Orcinus Orca*) in the Northern Gulf of Alaska. *Fishery Bulletin, 110*(2), 143-155. Retrieved from https://spo.NMFS.noaa.gov/sites/default/files/pdf-content/2012/1102/matkin.pdf

Two sympatric populations of "transient" (mammal-eating) killer whales were photo-identified over 27 years (1984-2010) in Prince William Sound and Kenai Fjords, coastal waters of the northern Gulf of Alaska (GOA). A total of 88 individuals were identified during 203 encounters with "AT1" transients (22 individuals) and 91 encounters with "GOA" transients (66 individuals). The median number of individuals identified annually was similar for both populations (AT1=7; GOA=8), but mark-recapture estimates showed the AT1 whales to have much higher fidelity to the study area, whereas the GOA whales had a higher exchange of individuals. Apparent survival estimates were generally high for both populations, but there was a significant reduction in the survival of AT1 transients after the Exxon Valdez oil spill in 1989, with an abrupt decline in estimated abundance from a high of 22 in 1989 to a low of seven whales at the end of 2010. There was no detectable decline in GOA population abundance or survival over the same period, but abundance ranged from just 6 to 18 whales annually. Resighting data from adjacent coastal waters and movement tracks from satellite tags further indicated that the GOA whales are part of a larger population with a more extensive range, whereas AT1 whales are resident to the study area.

Matkin, C. O., & Saulitis, E. (1994). *Killer Whale (Orcinus Orca): Biology and Management in Alaska:* North Gulf Oceanic Society. Marine Mammal Commission.

A report summarizing key areas of study related to killer whales, including distribution and abundance, life history and biology, conservation issues, and research and management recommendations.

Permyakov, P. A., & Burkanov, V. N. (2009). Interactions between Killer Whales (*Orcinus Orca*) and Steller Sea Lions (*Eumetopias Jubatus*) in the Vicinity of Brat Chirpoev Island, Kuril Islands. *Russian Journal of Marine Biology*, *35*(3), 255-258. <u>https://doi.org/10.1134/s1063074009030109</u>

The behaviors of breeding Steller sea lions in response to encounters with killer whales near the shore were observed on Brat Chirpoev Island, Kuril Islands between May and July 2002–2007. Approaches by killer whales and sea lion behavior was observed visually and recorded. Killer whales approached the rookery 104 times during the entire period of observations (289 days). In most cases (n = 95), beached sea lions did not show any apparent reactions to the presence of killer whales, and there were no observed interactions. Sea lions showed agitation during nine of the approaches; five of these events were considered to be predation attempts. The killer whales attacked the sea lions three times, however all the attacks were unsuccessful. We recorded two different types of responses towards the killer whales: (1) beaching on the shore (three times) and (2) mass exodus from the rookery with subsequent formation of a tight, actively swimming and vocalizing group (six times). The latter is the first recorded observations of this behavior for Steller sea lions. The observation suggests a low degree of interactions between these two species near the studied rookery. Despite the numerous observations of killer whales near the rookery, there were no observations of direct predation on sea lions. It is likely the killer whale predation has little or no direct impact on the Steller sea lion population on Brat Chirpoev Islands during the breeding period.

 Robson, B. W., Goebel, M. E., Baker, J. D., Ream, R. R., Loughlin, T. R., Francis, R. C., . . . Costa, D. P. (2004). Separation of Foraging Habitat among Breeding Sites of a Colonial Marine Predator, the Northern Fur Seal (Callorhinus Ursinus). *Canadian Journal of Zoology, 82*(1), 20-29. https://doi.org/10.1139/z03-208

This study examines whether lactating northern fur seals (Callorhinus ursinus) from different breeding sites on the Pribilof Islands in the eastern Bering Sea forage in separate areas. Satellite transmitters were attached to 97 northern fur seal females from nine breeding areas for 119 complete foraging trips during the 1995 and 1996 breeding seasons. Females from St. Paul and St. George islands tended to travel in different directions relative to their breeding site in both years of the study. St. Paul Island females dispersed in all directions except to the southeast, where St. George Island females foraged. Habitat separation was also observed among breeding areas on northeastern and southwestern St. Paul Island and to a lesser degree on northern and southern St. George Island. Although foraging direction led to geographical separation among sites, the maximum distance traveled and the duration of foraging trips did not differ significantly among islands in either year. The results of this study document that lactating fur seals from the same site share a common foraging area and that females from different breeding sites tend to forage in separate areas and hydrographic domains.

Sigler, M. F., Hulbert, L. B., Lunsford, C. R., Thompson, N. H., Burek, K., O'Corry-Crowe, G., & Hirons, A. C. (2006). Diet of Pacific Sleeper Shark, a Potential Steller Sea Lion Predator, in the North-East Pacific Ocean. *Journal of Fish Biology*, 69(2), 392-405. <u>https://doi.org/10.1111/j.1095-8649.2006.01096.x</u>

Pacific sleeper sharks Somniosus pacificus were captured near Steller sea lion *Eumetopias jubatus* rookeries during the period when Steller sea lion pups are most vulnerable to Pacific sleeper shark predation (first water entrance and weaning). Analysis of stomach contents revealed that teleosts were the dominant prey in August and cephalopods were the dominant prey in May (n = 198). Marine mammals were found in 15% of stomachs regardless of season, but no Steller sea lion tissues were detected. Molecular genetic analysis identified grey whale Eschrichtius robustus and harbour seal Phoca vitulina remains in some Pacific sleeper shark stomachs. Most mammals were cetacean and at least 70% of the cetaceans were probably scavenged. Although Pacific sleeper shark and Steller sea lion ranges overlapped, so predation could potentially occur, the diet study suggested that predation on Steller sea lions is unlikely, at least when pups first enter the water or during weaning. Harbour seals were infrequent prey and may have been consumed alive. Pacific sleeper sharks consume fast-swimming prey like Pacific salmon Oncorhynchus sp., most likely live animals rather than scavenged animals. Pacific sleeper sharks appeared to be opportunistic consumers of the available prey and carrion, feeding both on the bottom and in the water column, and their diet shifted to teleosts and cetacean carrion as the fish grew larger.

Williams, T. M., Estes, J. A., Doak, D. F., & Springer, A. M. (2004). Killer Appetites: Assessing the Role of Predators in Ecological Communities. *Ecology*, 85(12), 3373-3384. <u>https://doi.org/10.1890/03-0696</u>

Large body size, carnivory, and endothermic costs lead to exceptionally high caloric demands in many mammalian predators. The potential impact on prey resources may be marked but is difficult to demonstrate because of the mobility, sparseness, and cryptic nature of these animals. In this study, we developed a method based on comparative bioenergetics and demographic modeling to evaluate predator effects and then used this approach to assess the potential impact of killer whales on sea otter and Steller sea lion populations in the Aleutian Islands. Daily caloric requirements of killer whales determined from allometric regressions for field metabolic rate show that an adult killer whale requires 51–59 kcal·kg-1·d-1 (2.5–2.9 W/kg). Caloric values of prey items determined by bomb calorimetry ranged from 41 630 kcal for an adult female sea otter to sequentially higher values for male otters, sea lion pups, and adult Steller sea lions. Integrating these results with demographic changes in marine mammal populations show that fewer than 40 killer whales could have caused the recent Steller sea lion decline in the Aleutian archipelago; a pod of five individuals could account for the decline in sea otters and the continued suppression of sea lions. The collapse of the historical prey base of killer whales due to human whaling may have contributed to a sequential dietary switch from high to low caloric value prey, thereby initiating these declines. This study demonstrates that a combined physiologicaldemographic approach increases our ability to critically evaluate the potential impact of a predator on community structure and enables us to define underlying mechanisms that drive or constrain top-down forcing in dynamic ecosystems.
Section XII: Program and Method Assessment

Andrews, R. D. (1998). Remotely Releasable Instruments for Monitoring the Foraging Behaviour of Pinnipeds. *Marine Ecology Progress Series,* 175, 289-294. <u>https://doi.org/10.3354/meps175289</u>

The use of stomach temperature data loggers to record prey ingestion has proven to be very valuable when combined with time-depth recorders and satellite tracking devices in studies of seabird foraging ecology. This paper presents a similar system that will allow biologists to determine the precise timing and location of foraging by pinnipeds. The system includes a stomach temperature transmitter and an animal-mounted instrument package. The instrument package contains a satellite transmitter, for remote tracking of movements, and a data logger, for recording dive depth, swim speed, water temperature, and stomach temperature (made possible by an incorporated telemetry receiver). The instrument package can be remotely released upon command to allow data recovery without animal recapture. The system was tested on 6 Steller sea lions *Eumetopias jubatus* in Southeast Alaska and found to be a powerful tool for quantifying foraging behaviour, although some suggestions for improve ment are presented.

Baba, N., Nitto, H., & Nitta, A. (2000). Satellite Tracking of Young Steller Sea Lion Off the Coast of Northern Hokkaido. *Fisheries Science*, *66*(1), 180-181. <u>https://doi.org/10.1046/j.1444-2906.2000.00030.x</u>

Deals with a study which detailed the procedure of tracking a Steller sea lion off the coast of northern Hokkaido, Japan using satellite. Features of the satellite technology used in the study; Description of the sea lion under study; Information on how the tracking data was recorded.

Balsiger, J. W., & Merrill, G. (2015). *Revisions to the Steller Sea Lion Protection Measures for the Bering Sea and Aleutian Islands Management Area Groundfish Fisheries Environmental Assessment/Regulatory Impact Review*. National Marine Fisheries Service. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/19137</u>

This environmental assessment/regulatory impact review provides decision-makers and the public with an evaluation of the environmental, social, and economic effects of alternatives to the Steller sea lion protection measures for the Bering Sea and Aleutian Islands Management Area groundfish fisheries, in particular the Atka mackerel and Pacific cod fisheries. The western distinct population segment (WDPS) of Steller sea lion is listed as endangered under the Endangered Species Act, and the species population in the Aleutian Islands is declining. Atka mackerel and Pacific cod are principal prey species for Steller sea lions in the Aleutian Islands. This proposed action would revise management of the Atka mackerel and Pacific cod fisheries are not likely to result in jeopardy of extinction or adverse modification or destruction of critical habitat for the WDPS of Steller sea lions. This document addresses the requirements of the National Environmental Policy Act and Executive Order 12866.

Barbeaux, S. J., Fritz, L., & Logerwell, E. (2018). Exploring Local Fishery Management through Cooperative Acoustic Surveys in the Aleutian Islands. *Marine Policy, 90*, 68-77. <u>https://doi.org/10.1016/j.marpol.2018.01.005</u> An alternate management system is introduced which uses seasonal and spatially explicit multi-species quotas generated from small-scale cooperative fishery acoustic surveys to manage the Aleutian Islands walleye pollock (Gadus chalcogrammus) fishery while limiting impacts on the endangered Western stock of Steller sea lions (Eumetopias jubatus). This is a novel collaboration among scientists, industry, and Alaska Natives considering a cooperative management approach. The proposed system integrates the catch monitoring and accounting systems already in place in the federal groundfish fisheries off Alaska with cooperative acoustic survey biomass estimates to facilitate more refined spatial and temporal fishery management decisions. Conditions were examined under which such a system could operate successfully and results from field work conducted to assess technical requirements were discussed. During field trials biomass estimates from each survey were produced within 24-h of survey completion. This suggests spatial abundance estimates can be available in a timely manner for managing local fisheries. The proposed management system was found feasible and relatively easy to initiate because of highly motivated and cooperative industry partners, a well-established mechanism for setting allowable catch limits, and a robust catch accounting system already in place. In addition, high quality commercial echosounders required for this system are currently used by industry and, with proper controls on calibration and survey design, produce biomass estimates of sufficient quality. The application of this approach beyond this case study is also discussed for managing fisheries worldwide where fine temporal and spatial scale management could benefit the conservation of other protected species.

Berman, M. (2004). Scientists to the Rescue? The Response of the Science Enterprise to the Steller Sea Lion-Alaska Fisheries Crisis. Paper presented at the Arctic Science Conference of the American Association for the Advancement of Science. Retrieved from https://search.proguest.com/docview/17300164?accountid=28258

Endangered Species Act litigation recently forced the National Marine Fisheries Service (NMFS) to restrict the lucrative groundfish fisheries off Alaska to prevent potential harm to the western population of Steller sea lions. Although fisheries exploitation had not been directly linked to the population decline, NMFS could not refute charges that the fishery had contributed to it, nor could the agency demonstrate that its previously adopted, less restrictive measures were sufficient to prevent further declines. Congress responded to the perceived crisis with a massive crash science program aimed at improving understanding of the role of fisheries and other factors in the western population decline and reducing uncertainty of the effects of fishery management on the species. I analyze the research program funded by this initiative, in order to understand how the scientific community responded to the opportunities presented by this political economy crisis. I compare the portfolio of projects sponsored by the various agencies receiving federal Steller sea lion research funds during the past four years to the short-term and long-term needs of NMFS fishery managers and the fishing industry, in light of expert reviews conducted by the National Academy of Sciences and National Academy of Public Administration. I attempt to ascertain to what extent the scientific community has responded by designing research that responds to the public need, and to what extent it appears that the scientists have opportunistically used the funding available to pursue interests of relatively little direct use to managers. I explicitly examine differences in the responsiveness among different agencies' programs, considering whether there appears to be a tradeoff between responsiveness and the degree that program managers rather than scientists direct the research agenda.

Berman, M. D. (2008). Endangered Species, Threatened Fisheries: Science to the Rescue! Evaluating the Congressionally Designated Steller Sea Lion Research Program. *Marine Policy*, 32(4), 580-591. <u>https://doi.org/10.1016/j.marpol.2007.10.007</u>

Between 2001 and 2004, the US Congress designated over \$120 million for research on the western population of Steller sea lions. This paper evaluates the science program, summarizing its context and motivation, the amount and distribution of funds, and how the recipients allocated funding to research activities. It considers factors affecting the science program's contribution to solving the problem that spurred Congress to act. While the program failed to achieve its immediate goals for a variety of reasons, it did provide long-term benefits for science and ecosystem management in the North Pacific.

Bowen, W. D. (2000). Reconstruction of Pinniped Diets: Accounting for Complete Digestion of Otoliths and Cephalopod Beaks. *Canadian Journal of Fisheries and Aquatic Sciences*, *57*(5), 898-905. https://doi.org/10.1139/f00-032

The recovery of sagittal fish otoliths and cephalopod beaks from fecal samples is an important source of information about the diets of marine mammals. Nevertheless, diet reconstructions are biased to some extent because of the partial and complete digestion of these prey structures. Although some authors have used correction factors to account for partial digestion of otoliths, none to date have corrected for the number of otoliths and cephalopod beaks that are completely digested, termed number correction factors (NCFs). Data from nine studies of captive pinnipeds show that corrections for the complete digestion of otoliths and cephalopod beaks range from 1.0 to 25.0 in the 28 prey species. Correction factors ranged from 1.0 to 10.0 in cases where seals could exercise by swimming during the experiment. In several species, NCFs vary inversely with prey length. The effect of applying NCFs will depend on the relative proportion of prey species in the diet and the NCFs of these species. Nevertheless, estimates of the species composition of marine mammal diets will benefit from the use of NCFs. Finally, standardization of experimental protocols and attention to the estimation of variability are needed to provide more reliable NCFs.

Bowen, W. D., Boness, D. J., & Lowry, L. F. (2007). *Review of the 2007 Draft Steller Sea Lion Recovery Plan.* North Pacific Research Board. National Marine Fisheries Service North Pacific Fishery Management Council Retrieved from http://52.20.14.83/sites/default/files/nprb_review0707.pdf

The Steller sea lion (*Eumetopias jubatus*) was listed under the Endangered Species Act (ESA) as a threatened species throughout its range in 1990. The National Marine Fisheries Service (NMFS) appointed a recovery team, and in 1992 they approved a Recovery Plan based on a draft prepared by the team. In 1997 the species was split into two Distinct Population Segments (DPS), and the eastern DPS was left classified as threatened under the ESA while the western DPS was uplisted to endangered. In 2001, NMFS assembled a new recovery team to assist them with revising the initial Plan. The team provided its draft of the revised plan to NMFS in March 2006. After releasing the first draft for public review and evaluating the comments received, NMFS decided to prepare a revision.

Boyd, I. L. (2010). Assessing the Effectiveness of Conservation Measures: Resolving the "Wicked" Problem of the Steller Sea Lion. *Biological Conservation*, 143(7), 1664-1674. <u>https://doi.org/10.1016/j.biocon.2010.04.006</u>

"Wicked" problems are those that are complex and that change when solutions are applied. Many conflicts in conservation fall into this category. The study approached the problem of how to constrain the apparent wickedness of a problem in the conservation management of a species by using simple empirical indicators to carry out iterative assessment of the risk to a population and to document how this risk evolves in relation to the addition of new data and the implementation of management actions. Effects of high levels of uncertainty within data and also concerning population structure were examined through stochastic simulation and by exploration of scenarios. Historical trends in the example used, the Steller sea lion, showed rapid declines in abundance in some regions during the 19805. The current total population is 130,000-150,000 Steller sea lions through Alaska and British Columbia and this number has been stable since about 1990 in spite of regional differences in population dynamics. Regional differences in the sequence of changes in the number of pups and non-pups, suggested that an internal re-distribution of juveniles could have happened between 1980 and 1990. Current productivity also appears close to the long-term mean. Stochastic population projection using various scenarios showed that, based upon this history, the risk of extinction for the population has declined and is below reasonable thresholds for considering the population to be endangered. The trends in risk suggest that management actions taken since 1990 have probably been effective. Consequently, the conservation management objectives for the Steller sea lion are probably being met. The approach provides a mechanism, based upon experience and scenario analysis, for exploring future policy options and may help to constrain the debate amongst stakeholders about the cost-benefit trade-offs associated with different options.

Breiwick, J. M. (2013). North Pacific Marine Mammal Bycatch Estimation Methodology and Results, 2007-2011. NOAA, National Marine Fisheries Service, Alaska Fisheries Science Center Technical Memorandum NMFS-AFSC-260. Retrieved from https://repository.library.noaa.gov/view/noaa/4578

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 2007-2011 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.

Bryant, B. C. (2009). Adapting to Uncertainty: Law, Science, and Management in the Steller Sea Lion Controversy. *Stanford Environmental Law Journal, 28*(2), 171-211. Retrieved from <u>https://heinonline.org/HOL/LandingPage?handle=hein.journals/staev28&div=9&id=&page=&t= 1560966593</u>

The article focuses on the proposed adaptive management experiments which are designed to address the decline and lack of recovery of the Alaskan Steller sea lion population. These species, accordingly, can be seen across the Northern Pacific to southern California, including the Gulf of Alaska and Aleutian Islands. They have been put under the endangered status when it was revealed that their population is declining since 1975. To address the problem, the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries) proposes BiOp 3 as its chosen management approach. The said approach believes that a combination of changes in the ocean environment and human exploitation of predator species is an effective solution to address the problem.

Conn, P. B., Johnson, D. S., Fritz, L. W., & Fadely, B. S. (2014). Examining the Utility of Fishery and Survey Data to Detect Prey Removal Effects on Steller Sea Lions *(Eumetopias Jubatus)*. *Canadian Journal* of Fisheries and Aquatic Sciences, 71(8), 1229-1242. <u>https://doi.org/10.1139/cjfas-2013-0602</u>

One focus of mitigation for Steller sea lion (*Eumetopias jubatus*) declines in Alaska has been to restrict commercial fishery activity around sea lion rookeries and haul-outs. However, a variety ofstatistical hypothesis tests have failed to relate sea lion population metrics to fish and fishing variables, prompting speculation that regulations may be unwarranted. In this study, we use simulation to show that standard hypothesis tests often have overstated power to detect a relationship between Steller sea lion vital rates and fish or fishing variables. The power and utility ofhypothesis tests largely depend on choosing appropriate dependent and independent variables. In particular, pup counts were the most effective for diagnosing fecundity effects, and successive ratios of adult counts were the most effective for diagnosing survival effects. Fish relative abundance was the most effective independent variable, with other choices (e.g., fishery catch) often resulting in misleading inferences. We argue that Bayes factors are best suited for characterizing the relationship between fish abundance and Steller sea lion vital rates and that existing evidence does not preclude a strong relationship between sea lion fecundity and the availability of commercially harvested fish stocks.

Cornick, L. A. (2002). Optimal Foraging Theory as a Model to Examine the Relationship between Relative Prey Accessibility and Foraging Energetics in Steller Sea Lions (Eumetopias Jubatus) in the Gulf of Alaska and Bering Sea. Texas A&M University. Retrieved from https://search.proquest.com/docview/18607391/F12C6BA33FB44250PQ/1?accountid=28258

The western stock of the Steller sea lion (*Eumetopias jubatus*) (SSL) along the Aleutian Islands and in the Gulf of Alaska (GOA) has continuously declined over the past three decades, and is now listed as

endangered. While the causes of this decline are not well understood, nutritional stress, resulting in excessive juvenile mortality, is the leading hypothesis. Optimal foraging theory predicts that predators should change their dive behavior (foraging strategy) as prey availability changes. Relative prey accessibility (RPA, the ability of an individual SSL to access prey during a dive cycle) is likely a crucial causal link between hypothesized reduced prey biomass resulting from commercial fishing activity and depressed foraging efficiency of SSL, but cannot be controlled in the wild, and is impossible to accurately quantify at the individual level. This study, for the first time, experimentally validates prey avail abilityforaging behavior relationships previously hypothesized by optimality and foraging theory, but never before experimentally tested for a diving mammal. I employed a combined approach of predictive model development and controlled experiments. Testable predictions were determined by developing a bioenergetics-based model of individual dive behavior for aerobic dives of otariids. To determine the relationship between RPA and dive behavior, I examined how dive duration, foraging time, surface interval, percent time foraging, submerged: surface time, dive efficiency, and foraging efficiency varied with changes in simulated RPA in optimal foraging experiments performed with three seven-year-old SSL (two females, one male) held captive at the Alaska Sea Life Center in Seward, AK RPA had a significant positive effect on dive duration, foraging time, percent time foraging, and relative foraging efficiency. The dive model accurately predicted the observed effect of changing RPA on dive behavior and foraging efficiency. A population-based model was also developed in order to predict the effects of varying regimes of commercial fisheries activity on SSL population trends, based upon an estimate of annual SSL energetic requirements. The model accurately portrayed SSL abundance trends predicted by published projections, but failed to implicate competition with the commercial groundfish fishery in Alaska as a cause of the decline of SSL.

Dalton, R. (2005). Animal-Rights Group Sues over 'Disturbing' Work on Sea Lions. *Nature, 436*(7049), 315-315. <u>https://doi.org/10.1038/436315a</u>

Animal rights group, the Humane Society of the United States, sued the National Marine Fisheries Service in June 2005 claiming it failed to properly monitorresearch being carried out on Steller sea lions (*Eumetopias jubatus*) in Alaska. They claim animal-protection laws were violated by allowing intrusive, duplicate, uncoordinated and unnecessary research on Steller sea lions. Administrators of the Steller research program say studies are conducted appropriately and some claim National Marine Fisheries Service are hostile to researchers.

Dalton, R. (2005). Is This Any Way to Save a Species? *Nature, 436*(7047), 14-16. <u>https://doi.org/10.1038/436014a</u>

Thanks to the influence of a powerful US senator, more than \$120 million has been pumped into research on Alaska's endangered Steller sea lions in just four years. Rex Dalton asks what we've learned.

Deagle, B. E., & Tollit, D. J. (2007). Quantitative Analysis of Prey DNA in Pinniped Faeces: Potential to Estimate Diet Composition? *Conservation Genetics*, 8(3), 743-747. https://doi.org/10.1007/s10592-006-9197-7

We investigate using relative amounts of prey DNA recovered from pinniped faeces to obtain diet composition data. Faeces were obtained from captive sea lions being fed a diet containing three fish

species (50%, 36% and 14% by mass). Real-time PCR was used to quantify mtDNA in undigested tissue and in the faecal samples. The percent composition of fish mtDNA extracted from tissue corresponded reasonably well to the mass of fish in the mixture. In faecal samples the absolute amount of fish mtDNA recovered varied 100-fold, but the percent composition of the samples was relatively consistent (57.5 +/- 9.3%, 19.3 +/- 6.6% and 23.2 +/- 12.2%). These results indicate there are prey-specific biases in DNA survival during digestion. However, the biases may be less than those commonly observed in conventional diet studies.

Dizon, A. E., Lockyer, C., Perrin, W. F., DeMaster, D. P., & Sisson, J. (1992). Rethinking the Stock Concept: A Phylogeographic Approach. *Conservation Biology*, 6(1), 24-36. <u>https://doi.org/10.1046/j.1523-1739.1992.610024.x</u>

The "stock" is the fundamental population unit of legally mandated conservation efforts, yet its formal definition in the scientific literature and in two U.S. conservation acts is varied and so general that attempts to apply it in practice are arbitrary. Because choice of stocks deserving management protection is sometimes politically contentious, improvement of the working definition is important. A key element should be the degree to which a population can be considered an evolutionarily significant unit. We propose that a hierarchial classification scheme be applied to stock designations. Category I populations, having the highest probability of being evolutionarily significant units, are characterized by a discontinuous genetic divergence pattern where locally adapted and closely related genome assemblages are separated from others geographically and by significant genetic distances. Category II populations are similarly characterized by significant genetic diversity, but with weak geographic partitioning. Category III populations are the converse of II, having little genetic differentiation between assemblages that are clearly separate and likely to be reproductively isolated. Category IV assemblages have the lowest probability of being evolutionarily significant units and are characterized by extensive gene flow and no subdivision by extrinsic barriers. In addition to phylogeographic designation, the following information is used in the classification, as indicated by single-letter abbreviations: distribution (a), population response (b), phenotypic (c), and genotypic (d) information. Included are evidence both for and against designating population as a separate stock. In the designation "Type II a/bc," for example, information to the right of the solidus would be evidence for "lumping," to the left would be for "splitting." Missing letter abbreviations would signify lack of reliable data. Note that phylogeographic designation depends on the results of selection operating to produce a locally adapted genome (indicated by differences in demographic, phenotypic, and genotypic measures) and on gene flow (indicated by differences in distribution or by movement data). Hierarchial stock categorization allows resource managers to direct limited resources to the populations most deserving of protection, that is, the populations that are most likely to be evolutionarily significant units. Using this comprehensive classification of stock allows preliminary, conservative splitting of assemblages where data are lacking without the danger that these divisions will become entrenched as biological dogma.

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 <u>https://repository.library.noaa.gov/view/noaa/4951</u>

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.

Fay, G., & Punt, A. E. (2006). Modeling Spatial Dynamics of Steller Sea Lions (Eumetopias Jubatus) Using Maximum Likelihood and Bayesian Methods: Evaluating Causes for Population Decline. <u>https://doi.org/10.4027/slw.2006.27</u>

The timing and extent of the negative population trend in the abundance of the western stock of Steller sea lions has not been geographically uniform. A stochastic metapopulation dynamics model is developed for Steller sea lions. This model allows for geographical differences in factors affecting population processes, and can be parameterized to represent a wide range of hypotheses for the decline in Steller sea lion abundance. Bayesian and maximum likelihood methods are used to fit this model to pup and non-pup count data, age structure samples, and survival estimates. Inferences from model selection criteria highlight the spatial variability in the types of impact deemed to provide most parsimonious representation of the data. Bayesian posteriors for the estimated model parameters show that many combinations of parameter values are able to provide similar fits to the data, even given a specific hypothesis for the decline. This highlights the uncertainty in the precise nature of the impact of these hypotheses. Indeed, while pup production is generally estimated consistently among models, estimates of the size of other components of the Steller sea lion population (such as total population size) depend greatly on the assumptions regarding the cause of the decline. The results demonstrate that future simulation modeling approaches will require more formal, spatial, and mechanistic descriptions of the manner in which specific hypotheses for the decline affect the population.

Fay, G., & Punt, A. E. (2013). Methods for Estimating Spatial Trends in Steller Sea Lion Pup Production Using the Kalman Filter. *Ecological Applications*, 23(6), 1455-1474. <u>https://doi.org/10.1890/12-1645.1</u>

Many species exhibit spatially varying trends in population size and status, often driven by differences among factors affecting individual subpopulations. Estimation and differentiation of such trends may be important for management, and a driving force for monitoring programs. The ability to estimate spatial differences in population trend may depend on assumptions regarding connectivity among subpopulations (stock structure or spatial overlap in stressors), information that is often poorly known. Linear state-space models using the Kalman filter were developed, tested, and applied for trend estimation of pup production for the western Alaska stock of Steller sea lions (*Eumetopias jubatus*), given only count data. Models were able to estimate trends and abundance even when data were missing. Models that assumed spatial correlation in trend among rookeries were more robust to stock structure assumptions when the stock structure was potentially mis-specified. High levels of spatial correlation among rookeries estimated from Steller sea lion pup count data are consistent with largescale covariance of population trend within the Steller sea lion metapopulation. Fritz, L. W., Ferrero, R. C., & Berg, R. J. (1995). The Threatened Status of Steller Sea Lions, *Eumetopias Jubatus*, under the Endangered Species Act: Effects on Alaska Groundfish Fisheries Management. *Marine Fisheries Review*, 57(2), 14-27. Retrieved from https://spo.NMFS.noaa.gov/sites/default/files/pdf-content/MFR/mfr572/mfr5722.pdf

In April 1990, the Steller sea lion, *Eumetopias jubatus*, was listed as threatened under the U.S. Endangered Species Act by emergency action. Competitive interactions with the billion-dollar Alaska commercial groundfish fisheries have been suggested as one of the possible contributing factors to the Steller sea lion population decline. Since the listing, fisheries managers have attempted to address the potential impacts of the groundfish fisheries on Steller sea lion recovery. In this paper, we review pertinent Federal legislation, biological information on the Steller sea lion decline, changes in the Alaska trawl fishery for walleye pollock, Theragra chalcogramma, since the late 1970's, and possible interactions between fisheries and sea lions. Using three cases, we illustrate how the listing of Steller sea lions has affected Alaska groundfish fisheries through: I) actions taken at the time of listing designed to limit the potential for direct human-related sea lion mortality, 2) actions addressing spatial and temporal separation of fisheries from sea lions, and 3) introduction of risk-adverse stock assessment methodologies and Steller sea lion conservation considerations directly in the annual quota-setting process. This discussion shows some of the ways that North Pacific groundfish resource managers have begun to explicitly consider the conservation of marine mammal and other nontarget species.

Gerber, L. R., & VanBlaricom, G. R. (2001). Implications of Three Viability Models for the Conservation Status of the Western Population of Stellar Sea Lions (*Eumetopias Jubatus*). *Biological Conservation*, 102(3), 261. https://doi.org/10.1016/S0006-3207(01)00104-5

Studies the implications of three viability models for the conservation status of the western population of the Stellar sea lions in Alaska. Classification of the long-lived vertebrates; Lack of objectivity in making Endangered Species Act conservation decisions; Sensitivity of extinction distributions to various levels of stochasticity.

Giraud, K., Turcin, B., Loomis, J., & Cooper, J. (2002). Economic Benefit of the Protection Program for the Steller Sea Lion. *Marine Policy*, *26*(6), 451-458. <u>https://doi.org/10.1016/s0308-597x(02)00025-8</u>

This paper examines willingness to pay (WTP) for an endangered species across geographically nested samples using the Contingent Valuation Method (CVM). The three samples range from (1) the boroughs that contain critical habitat for the Steller sea lion to (2) the state that contains these boroughs to and (3) the entire United States. Depending on the assumptions of the model, WTP varies tremendously from sample to sample. WTP for the United States is the highest and it is the lowest for the boroughs. The null hypotheses that mean WTP estimates are greater then zero were rejected for the boroughs and the state but were not rejected for the United States based on the 95% confidence intervals.

Giraud, K., & Valcic, B. (2004). Willingness-to-Pay Estimates and Geographic Embedded Samples: Case Study of Alaskan Steller Sea Lion. *Journal of International Wildlife Law & Policy*, 7(1/2), 57-72. https://doi.org/10.1080/13880290490480167 This paper examines willingness to pay for an endangered species protection program across geographically embedded samples. The samples range from the boroughs that contain critical habitat for the Steller sea lion to the state that contains these boroughs to the entire United States. The analysis is done using the contingent valuation method and comparing mean willingness to pay estimates using the Method of Convolution. When comparing willingness-to-pay estimates among paired samples, results indicate significantly different values across geographic samples, which may lead to dramatically different policy implications. Respondent motivating factors also vary from sample to sample, which may be of interest to the management agencies, especially federal agencies and those with a national scope.

Goldstein, T., Stephens, C. A., Jang, S. S., Conrad, P. A., Field, C., Dunn, J. L., & Mellish, J. A. (2007).
 Longitudinal Health and Disease Monitoring in Juvenile Steller Sea Lions (*Eumetopias Jubatus*) in
 Temporary Captivity in Alaska Compared with a Free-Ranging Cohort. *Aquatic Mammals*, 33(3), 337-348. http://dx.doi.org/10.1578/AM.33.3.2007.337

From March 2003 to June 2006, 77 juvenile Steller sea lions (Eumetopias jubatus) from the endangered western stock were captured in Resurrection Bay and Prince William Sound, Alaska. Thirty-one were brought into temporary captivity (transient juveniles) for short-term research studies, and 46 were captured, sampled, and released for a control comparison. The groups of wild-caught sea lions were rotated through a guarantine facility. The objectives of this study were to measure exposure to marine and terrestrial mammalian pathogens in temporarily captive Steller sea lions over time, screen for commensal and pathogenic bacteria, and monitor changes in antimicrobial resistance in bacterial isolates. Antibodies to Toxoplasma gondii and Brucella marinus were detected in both free-ranging and transient juveniles. Although an increase in titers to Leptospira spp. and phocine herpesvirus-1 was detected in a small number of sea lions while housed in temporary captivity, none developed evidence of clinical disease. Additionally, exposure was also found to these potential pathogens in the freeranging control Steller sea lions. There were no significant differences among the variety of bacterial types obtained from any culture site or animal groups, and antibiotic resistance did not occur in any transient juveniles while in captivity nor in isolates from the free-ranging controls. Results therefore indicated that free-ranging Steller sea lions were not placed at risk for disease following the release of the transient juveniles back into the marine environment.

 Gregr, E. J., & Trites, A. W. (2008). A Novel Presence-Only Validation Technique for Improved Steller Sea Lion *Eumetopias Jubatus* Critical Habitat Descriptions. *Marine Ecology Progress Series, 365*, 247-261. Retrieved from <u>https://www.int-res.com/abstracts/meps/v365/p247-261/</u>

We used published information about foraging behaviour, terrestrial resting sites, bathymetry and seasonal ocean climate to develop hypotheses relating life-history traits and physical variables to the atsea habitat of a wide-ranging marine predator, the Steller sea lion *Eumetopias jubatus*. We used these hypotheses to develop a series of habitat models predicting the probability of sea lions occurring within a $3 \times 3 \text{ km}^2$ grid in the Gulf of Alaska and the Bering Sea. We compared these deductive model predictions with opportunistic at-sea observations of sea lions (presence-only data) using (1) a likelihood approach in a small area where effort was assumed to be uniformly distributed and (2) an adjusted skewness Sk_{adj} that evaluated the distribution of the predicted values associated with true presence observations. We found that the Sk_{adj} statistic was comparable to the likelihood test when using pseudo-absence data, but it was more powerful for assessing the relative performance of the different

predictive spatial models across the entire study area. The habitat maps we produced for adult female sea lions using the deductive modelling approach captured a higher proportion of presence observations than the current habitat model (critical habitat) used by fisheries managers since 1993 to manage Steller sea lions. Such improved predictions of habitat are necessary to effectively design, implement and evaluate fishery mitigation measures. The deductive approach we propose is suitable for modelling the habitat use of other age and sex classes, and for integrating these age/sex-class-specific models into a revised definition of critical habitat for Steller sea lions. The skewness test provides a means of comparing the relative performance of such models, using presence-only data. The approach can be readily applied to other central-place foragers.

Hastings, K. K., Johnson, D. S., & Gelatt, T. S. (2018). Flipper Tag Loss in Steller Sea Lions. *Marine Mammal Science*, *34*(1), 229-237. <u>https://doi.org/10.1111/mms.12448</u>

The article uses statistical methods used by Johnson et al. for estimating flipper tag loss in California sea lions. Topics discussed include analyzing behavior and movement patterns of the same; use of data for analyzing the same; and use of single parameterization for observing tag loss in California sea lions.

Heath, R. B., Calkins, D., McAllister, D., Taylor, W., & Spraker, T. (1996). Telazol and Isoflurane Field Anesthesia in Free-Ranging Steller's Sea Lions (*Eumetopias Jubatus*). *Journal of Zoo and Wildlife Medicine*, 27(1), 35-43. Retrieved from <u>https://www.jstor.org/stable/20095541</u>

Free-ranging Steller's sea lions (*Eumetopias jubatus*) in various parts of Alaska were stalked and darted with telazol. The sea lions were then intubated and maintained with isoflurane anesthesia for 69-162 min (mean, 113 min; SD = 26 min) using large-animal anesthesia equipment and monitoring techniques. Forty-six adult female sea lions were successfully captured, studied physiologically, tested for disease states, and released unharmed. The animals returned to normal activity within 2 hr. Failure of darts resulted in 22 escaped captures. Five mortalities occurred: two sea lions drowned in pools of water on the haulouts; two died of telazol anesthesia complications; and one died early in inhalation anesthesia. Choice of animal, stalking, and darting methods were important factors in avoiding problems with capturing these animals. Isoflurane can be delivered safely for over 2 hr of spontaneous ventilation and anesthesia in this species.

Hennen, D. (2006). Associations between the Alaska Steller Sea Lion Decline and Commercial Fisheries. *Ecological Applications, 16*(2), 704-717. <u>https://doi.org/10.1890/1051-</u> 0761(2006)016[0704:ABTASS]2.0.CO;2

The Steller sea lion (SSL) population in Alaska was listed as threatened under the Endangered Species Act in 1990. At that time, several procedural restrictions were placed on the commercial fisheries of the region in an effort to reduce the potential for human-induced mortality on sea lions. Several years have elapsed since these restrictions were put into place, and questions about their efficacy remain. In an effort to determine whether or not fisheries management measures have helped the SSL population to recover, estimates of the fishing activity of the Bering Sea/Gulf of Alaska commercial fisheries in the vicinity of individual SSL rookeries and SSL population trends at those rookeries were made using data from the National Marine Fisheries Service (NMFS) Fisheries Observer Program and Steller Sea Lion Adult Count Database. Fisheries data from 1976-2000 were analyzed in relation to SSL population counts from 1956-2001 at 32 rookeries from the endangered western stock. Linear regression on the principal components of the fisheries data show that a positive correlation exists between several metrics of historical fishing activity and the SSL population decline. The relationship is less consistent after 1991, supporting a hypothesis that management measures around some of the rookeries have been effective in moderating the localized effects of fishing activity on SSL.

Himes Boor, G. K. (2010). Applying Novel Approaches to Old Datasets: Utilizing Opportunistic Observations and Bayesian Estimation to Describe Spatial Use Patterns for Steller Sea Lions. Montana State University, Retrieved from https://scholarworks.montana.edu/xmlui/handle/1/1473

Despite two decades of satellite telemetry studies conducted on Steller sea lions, scientists still lack basic spatially-explicit knowledge about Steller sea lion habitat use. The Platforms of Opportunity data collected by the National Marine Fisheries Service contain Steller sea lion sighting records throughout the species' entire range and have the potential to fill the critical gap in knowledge about what areas Steller sea lions are using. The Platforms of Opportunity data have not previously been used to identify marine mammal habitat because they contain sightings without associated effort records (e.g. time spent surveying or area sampled). In this study a novel approach was used to overcome this issue through development of an effort index that allowed for calculation of effort-corrected Steller sea lion encounter rates. A Bayesian negative binomial model was used to quantify both the encounter rate and the uncertainty surrounding that rate within 15 km2 grid cells across the species' entire range. Yearround encounter rate estimates were derived in addition to breeding and non-breeding season encounter rates. Although the results of this analysis confirmed many of the areas known to be important Steller sea lion habitat, several previously unrecognized high-use areas were identified. Current critical habitat designated areas only encompass about 37% of high use areas estimated using this methodology.

Hoberecht, L. K., Vos, D. J., & VanBlaricom, G. R. (2006). A Remote Biopsy System Used to Sample Steller Sea Lion (*Eumetopias Jubatus*) Blubber. *Marine Mammal Science*, 22(3), 683-689. <u>https://doi.org/10.1111/j.1748-7692.2006.00046.x</u>

The article describes a remote biopsy system designed to sample pinniped blubber and details regarding its successful use with Stellar sea lions (*Eumetopias jubatus*). Two Barnett crossbows, the Wildcat III recurve and the Rhino Sport Magnum compound, were used to propel biopsy darts. The design of dart heads was based on those of Karesh et al. and Gemmell and Majluf with the syringe barrel removed and sized to screw into a standard crossbow bolt. All parts of the biopsy head were sterilized, using an autoclave or disinfected with boiling water, prior to each use. Sampling was conducted April to July 2002-2004 across the Alaskan range of Steller sea lions.

Holmes, E., & York, A. (2003). Using Age Structure to Detect Impacts on Threatened Populations: A Case Study with Steller Sea Lions. *Conservation Biology*, *17*(6), 1794-1806. <u>https://doi.org/10.1111/j.1523-1739.2003.00191.x</u>

A delayed response to change is often a characteristic of long-lived species and presents a major challenge to monitoring their status. However, rapid shifts in age structure can occur even while

population size remains relatively static. We used time-varying matrix models to study age-structure information as a tool for improving detection of survivorship and fecundity change and status. We applied the methods to Steller sea lions (*Eumetopias jubatus*), a long-lived endangered marine mammal found throughout the North Pacific Rim. Population and newborn counts were supplemented with information on the fraction of the population that was juvenile, obtained by measuring animals in aerial photographs taken during range-wide censuses. By fitting the model to 1976-1998 data, we obtained maximum-likelihood estimates and 95% confidence intervals for juvenile survivorship, adult survivorship, and adult fecundity in the mid-1980s, late 1980s, and 1990s. We used a series of nested models to test whether the data were best fit by a model with one, two, or three temporal changes in demographic rates, and we fit the models to different lengths of data to test the number of years of data needed to detect a demographic change. The declines in the early 1980s were associated with severely low juvenile survivorship, whereas declines in the 1990s were associated with disproportionately low fecundity. We repeated these analyses, fitting only to the count data without the juvenile-fraction information, to determine whether the age-structure information changed the conclusions and/or changed the certainty and speed with which demographic-rate changes could be detected. The juvenile-fraction data substantially improved the degree to which estimates from the model were consistent with field data and significantly improved the speed and certainty with which changes in demographic rates were detected.

Hunt, K. E., Trites, A. W., & Wasser, S. K. (2004). Validation of a Fecal Glucocorticoid Assay for Steller Sea Lions (*Eumetopias Jubatus*). *Physiology & Behavior*, *80*(5), 595-601. https://doi.org/10.1016/j.physbeh.2003.10.017

The Steller sea lion (*Eumetopias jubatus*) is listed as endangered in parts of its range and is suspected of suffering from ecological stressors that may be reflected by fecal glucocorticoid hormones. We validated a fecal glucocorticoid assay for this species with an adrenocorticotropic hormone (ACTH) challenge. Feces were collected from captive Steller sea lions (two males and two females) for 2 days before injection with ACTH, and for 4 or more days postinjection. Feces were freeze-dried, extracted with a methanol vortex method, and assayed for glucocorticoids. The assay demonstrated good parallelism and accuracy. All animals showed the expected peak of fecal glucocorticoid excretion after ACTH injection. However, the two males had higher baselines, higher peaks, and more delayed peaks than the females. Peak glucocorticoid excretion occurred at 5 and 28 h postinjection for the two females, and at 71 and 98 h for the two males. Correction for recoveries by the addition of tritiated hormones produced ACTH profiles that were virtually identical in pattern to uncorrected data, but with higher within-sample coefficients of variation. Based on these results, we conclude that this fecal glucocorticoid assay accurately reflects endogenous adrenal activity of Steller sea lions, and that recovery corrections are not necessary for this species when using the methanol vortex extraction method. More research is needed to address possible sex differences and other possible influences on fecal glucocorticoid concentrations.

Ishinazaka, T., Suzuki, M., Yamamoto, Y., Isono, T., Harada, N., Mason, J. I., . . . Ohtaishi, N. (2001).
 Immunohistochemical Localization of Steroidogenic Enzymes in the Corpus Luteum and the
 Placenta of the Ribbon Seal (Phoca Fasciata) and Steller Sea Lion (*Eumetopias Jubatus*). *Journal of Veterinary Medical Science*, *63*(9), 955-959. https://doi.org/10.1292/jvms.63.955

To study the luteal and placental function of pinnipeds, we analyzed the localization of steroidogenic enzymes (P450scc, 3 beta HSD and P450arom) in the corpus luteum. and the placenta of ribbon seals

(Phoca fasciata) and Steller sea lions (*Eumetopias jubatus*) immunohistochemically. P450scc and 3 HSD were present in all luteal cells of both species. Almost all of the luteal cells were immunostained for P450arom, while P450scc and 3 beta HSD were negatively immunostained in placentae and P450arom was present in the syncytiotrophoblast of placentae. These findings suggest that 1) corpora lutea of both species synthesize pregnenolone, progesterone and estrogen during the entire pregnancy period, and 2) like other terrestrial carnivores in the suborder Caniformia, placentae of both species do not have the capability for synthesizing progesterone in the latter half of active pregnancy period.

Johnson, D. S., & Fritz, L. (2014). Agtrend: A Bayesian Approach for Estimating Trends of Aggregated Abundance. *Methods in Ecology andEvolution*, *5*, 1110–1115. <u>https://doi.org/10.1111/2041-210X.12231</u>

1. We describe a method and open source R package agTrend for analysing regional trends of abundance from sites with uneven sample schedules over space and time. 2. The method uses a hierarchical model to augment missing abundance measurements, while accounting for survey methodology changes and variability due to survey replication. A zero-inflated log-normal distribution is used to model abundance (normalized for methodology changes) and a log-normal distribution to model the observed abundance conditional on the true normalized abundance. 3. The proposed method and software are demonstrated with an analysis of regional abundance index trends of Steller sea lions (*Eumetopias jubatus*)inAlaska. 4. The package will be ofmost use to ecologists and resource managers interested in estimating regional trends of abundance surveys aggregated over several sites when sites have not been surveyed at concurrent times and hence regional abundance measurements cannot be directly calculated.

Jonker, R. A. H., & Trites, A. W. (2000). The Reliability of Skinfold-Calipers for Measuring Blubber Thickness of Steller Sea Lion Pups (*Eumetopias Jubatus*). *Marine Mammal Science*, 16(4), 757-766. <u>https://doi.org/10.1111/j.1748-7692.2000.tb00970.x</u>

Twelve dead Steller sea lion pups (*Eumetopias jubatus*) aged 3-14 d were recovered from rookeries in Southeast Alaska. They had a wide range of body sizes and conditions (small to large and fat to no fat). The ability of calipers to estimate the thickness of their blubber layer was assessed with a set of skinfold calipers. Average error of measurement for skin and blubber thickness was an acceptable 5.4%, but the skin and blubber of the pups were highly compressible. Skinfold thickness increased with body mass but did not necessarily reflect the development of blubber, given that pups with no blubber also showed an increase in skinfold thickness with increases in body mass. Skinfold thickness of sea lion pups appears to predict body site better than it predicts blubber thickness, making it difficult if not impossible to develop a simple index of body condition or a calculation of percent body far for Steller sea lion pups from skinfold caliper measurements.

Keech, A. L., Rosen, D. A. S., Booth, R. K., Trites, A. W., & Wasser, S. K. (2010). Fecal Triiodothyronine and Thyroxine Concentrations Change in Response to Thyroid Stimulation in Steller Sea Lions (*Eumetopias Jubatus*). General and Comparative Endocrinology, 166(1), 180-185. https://doi.org/10.1016/j.ygcen.2009.11.014 Variation in concentrations of thyroid hormones shed in feces may help to identify physiological states of animals, but the efficacy of the technique needs to be validated for each species. We determined whether a known physiological alteration to thyroid hormone production was reflected in hormone concentrations in the feces of Steller sea lions (Eumetopias jubatus). We quantified variation of triiodothyronine (T3) and thyroxine (T4) concentrations in feces following two intramuscular injections of thyrotropin (thyroid-stimulating hormone, TSH) at 24 h intervals in four captive female sea lions. We found fecal T3 concentrations increased 18-57% over concentrations measured in the baseline sample collected closest to the time of the first TSH injection (p = 0.03) and 1-75% over the mean baseline concentration (p = 0.12) for each animal of all samples collected prior to injections. Peak T3 concentrations were greater than the upper bound of the baseline 95% confidence interval for three animals. The peak T3 response occurred 48 h post-injection in three animals and 71 h in the fourth. Post-injection T4 concentrations did not differ between the baseline sample collected closest to the time of the first TSH injection (p = 0.29) or the mean baseline concentration (p = 0.23) for each animal. These results indicate that induced physiological alterations to circulating thyroid hormone concentrations can be adequately detected through analyses of fecal T3 concentrations and that the technique may provide a means of non-invasively detecting metabolic changes in Steller sea lions.

Kennedy, S. N., Castellini, J. M., Hayden, A. B., Fadely, B. S., Burkanov, V. N., Dajles, A., . . . Rea, L. D. (2019). Regional and Age-Related Variations in Haptoglobin Concentrations in Steller Sea Lions (*Eumetopias Jubatus*) from Alaska, USA. *Journal of Wildlife Diseases, 55*(1), 91-104. https://doi.org/10.7589/2017-10-257

Varying concentrations of the highly conserved acute phase response protein, haptoglobin, can indicate changes to the health and disease status of mammals, including the Steller sea lion (SSL; *Eumetopias jubatus*). To better understand factors relating to acute phase response in SSLs, circulating haptoglobin concentrations (Hp) were quantified in plasma collected from 1,272 individuals sampled near rookeries and haulouts off the coast of Alaska, US. We compared Hp in SSLs between sexes and among different age classes (young pups, young-of-the-year, yearlings, subadults, and adults) sampled within distinct regions in Alaska (Aleutian Islands, Gulf of Alaska, Southeast Alaska). Regional and age-related differences were observed, particularly in younger SSLs. No sex-related differences were detected. We identified weakly significant relationships between Hp and hematology measurements including white blood cell counts and hematocrit in young pups from the Aleutian Islands and Southeast Alaska. No relationship between Hp and body condition was found. Lastly, a nonlinear relationship of plasma Hp and whole blood total mercury concentrations (THg) was observed in SSLs from the endangered western distinct population segment in Alaska. These results demonstrated that regional variation in Hp, especially in younger SSLs, may reflect regional differences in health and circulating THg.

Kennedy, S. N., Wilhite, B., Castellini, J. M., Rea, L. D., Kuhn, T., & O'Hara, T. (2018). Validation of a Protein a-Based Elisa for Quantifying Immunoglobulin G in a Non-Traditional Wildlife Species, the Steller Sea Lion (Eumatopias Jubatus). *Journal of Immunology, 200*(1) Retrieved from <u>https://www.jimmunol.org/content/200/1_Supplement/120.44</u>

Immunoglobulins are key proteins that function to preserve immune homeostasis and are quantified to infer changes to the acquired humoral immune response in mammals. Measuring immunoglobulins in non-traditional wildlife for immune surveillance often requires ingenuity, and rigorous standardization of methodologies to provide consistent and reliable results especially for species lacking species-specific

reagents. We modified and optimized existing ELISA methodology that utilizes the binding properties of Staphylococcus derived Protein A (Prt A) with immunoglobulin G (IgG). We validated the assay for accurately quantifying IgG in Steller sea lion (SSL) serum using critical measures of validation including parallelism, spike and percent recoveries, and internal controls. Of the modifications made, heat inactivation of SSL serum proved pivotal to enhance accuracy and precision of IgG detection by improving linearity and percent recovery in parallelism dilutions and serum spikes. Purified canine IgG standard was not affected by the heat inactivation protocol. These results support that confounding serum proteins likely interfere with the binding of Prt A with IgG, and demonstrate the need for heat inactivation of serum to ensure optimal IgG quantification using the PrtA-ELISA. Further, incorporation of spike and recovery are essential validation measures to ensure proper standardization of this assay. Consequently, the improved and validated PrtA-ELISA guarantees a species-independent IgG detection with validation criteria to enhance accuracy, and precision for addressing future immunological questions concerning SSLs and other non-traditional wildlife in a clinical, ecological, and conservation context

Kennedy, S. N., Wilhite, B., Castellini, J. M., Rea, L. D., Kuhn, T. B., Ferrante, A., & O'Hara, T. M. (2018). Enhanced Quantification of Serum Immunoglobulin G from a Non-Model Wildlife Species, the Steller Sea Lion (*Eumetopias Jubatus*), Using a Protein a Elisa. *Journal of Immunological Methods*, 462, 42-47. https://doi.org/10.1016/j.jim.2018.08.004

Immunoglobulins (Ig) are proteins that preserve immune homeostasis and are quantified to infer changes to the acquired humoral immune response in mammals. Measuring Ig in non-model wildlife for immune surveillance often requires ingenuity, and rigorous standardization of methodologies to provide reliable results especially when lacking species-specific reagents. We modified and optimized existing ELISA methodology utilizing the binding properties of Staphylococcus-derived Protein A (PrtA) to immunoglobulin G (IgG). We enhanced the assay for quantifying IgG in Steller sea lion (SSL) serum using critical quality control measures including dilution linearity, spike and percent recoveries, and internal controls. Of the modifications made, heat treatment of SSL serum enhanced accuracy and precision of IgG measurements by improving linearity and percent recovery in parallel dilutions and serum spikes. Purified canine IgG standard was not affected by heat inactivation. These results support that confounding serum proteins interfere with binding of PrtA with IgG demonstrating the need for heat treatment of serum to optimize IgG quantification using the PrtA-ELISA. Further, essential validation measures ensure proper assay performance. Consequently, the improved PrtA-ELISA provides species-independent IgG detection with validation criteria to enhance accuracy and precision for addressing future immunological questions in non-model wildlife in clinical, ecological, and conservation contexts.

King, J. C., Gelatt, T. S., Pitcher, K. W., & Pendleton, G. W. (2007). A Field-Based Method for Estimating Age in Free-Ranging Steller Sea Lions (*Eumetopias Jubatus*) Less Than Twenty-Four Months of Age. *Marine Mammal Science*, 23(2), 262-271. <u>https://doi.org/10.1111/j.1748-</u> 7692.2007.00108.x

Studies of health, survival, and development of juvenile Alaskan Steller sea lions (*Eumetopias jubatus*, SSL) require accurate estimates of age for wild-captured animals. However, the value and accuracy of several potential predictors of age have not been assessed with data from known-age free-ranging animals. During 2001-2005, forty-six individual SSL originally branded or tagged at <= 6 mo of age were recaptured by the Alaska Department of Fish and Game (ADF&G). Using a series of general linear

models, we evaluated the ability of morphometrics measurements: permanent canine tooth length (CTL), diastema (DIAS), whisker length (WHIS), and dorsal standard length (DSL) to predict the age of forty-six known-age juveniles (n = $46 \le 23$ mo of age). Permanent CTL was the strongest individual predictor (r(2) = 0.80); followed by DSL, DIAS, and WHIS (r(2) = 0.70, 0.56, and 0.45, respectively). The inclusion of a single sample from a 44-mo-old sea lion suggested quadratic relationships between age and all predictors for older animals. Only models including CTL predicted age to within 6 mo of known age. The equation Age = (-3.0112 + [0.6726 * CTL) + [0.4965 * DIAS]) allows for accurate age estimates of SSL <= 23 mo for both sexes.

Lander, M. E., & Gulland, F. M. D. (2003). Rehabilitation and Post-Release Monitoring of Steller Sea Lion Pups Raised in Captivity. *Wildlife Society Bulletin, 31*(4), 1047-1053. Retrieved from https://www.jstor.org/stable/3784450

Three stranded Steller sea lion (*Eumetopias jubatus*) pups were retrieved from Ano Nuevo Island, California, and admitted for rehabilitation to The Marine Mammal Center, Sausalito, California on 22 June 1995 (n=2 males, SSL12 and SSL13) and 17 June 1999 (n=1 female, SSL15). After about 10 months in captivity, we attached a satellite-linked time-depth recorder to the dorsal fur of each sea lion to examine their movements, diving behaviors, and survival after release. We received transmissions for 1, 4, and 3 months for SSL12, SSL13, and SSL15, respectively. Overall, diving behaviors of the 3 sea lions, including mean dive depth ((x) over bar =22.60 m, SD=6.42) and duration ((x) over bar =1.13 min, SD=0.40), were similar to those reported in the literature for free-ranging Steller sea lions. This study provided us with an opportunity to observe the performance of naive, weaned, captive-reared individuals introduced back into the environment. To ascertain whether rehabilitation would be an additional option for the conservation of this species in the future, long-term studies need to be conducted to determine whether released sea lions survive and eventually reproduce.

Lander, M. E., Logsdon, M. L., Loughlin, T. R., & Van Blaricom, G. R. (2011). Spatial Patterns and Scaling Behaviors of Steller Sea Lion (*Eumetopias Jubatus*) Distributions and Their Environment. *Journal* of Theoretical Biology, 274(1), 74-83. <u>https://doi.org/10.1016/j.jtbi.2011.01.015</u>

Fractal geometry and other multi-scale analyses have become popular tools for investigating spatial patterns of animal distributions in heterogeneous environments. In theory, changes in patterns of animal distributions with changes in scale reflect transitions between the controlling influences of one environmental factor or process over another. In an effort to find linkages between Steller sea lions (Eumetopias jubatus) and their environment, the objective of this study was to determine if the spatial distribution of Steller sea lions at sea displayed similar scaling properties to the variation of two environmental features, including bathymetry and sea surface temperature (SST). Additionally, distributions of Steller sea lion point patterns were examined with respect to measurements of bathymetric complexity. From February 2000 to May 2004, satellite transmitters were deployed on 10 groups of juvenile Steller sea lions (n=52) at eight different locations within the Aleutian Islands and Gulf of Alaska. Indices of fractal dimension were calculated for each group of sea lions using a unit square box-counting method, whereas indices of bathymetry and SST patchiness were derived by conducting a variance ratio analysis over the same scales. Distributions of Steller sea lions at sea displayed self-similar fractal patterns, suggesting that individuals were distributed in a continuous hierarchical set of clumps within clumps across scales, and foraging behavior was likely influenced by a scale invariant mechanism. Patterns of bathymetric variability also were self-similar, whereas patterns of SST variability were scale

dependent and failed to retain self-similar spatial structure at larger scales. These results indicate that the distributions of Steller sea lions at sea were more influenced by bathymetry than SST at the scales examined, but scale-dependent patterns in the distribution of Steller sea lions at sea or linkages with SST may have been apparent if analyses were conducted at finer spatial scales.

Lew, D. K., Layton, D. F., & Rowe, R. D. (2010). Valuing Enhancements to Endangered Species Protection under Alternative Baseline Futures: The Case of the Steller Sea Lion. *Marine Resource Economics*, 25(2), 133-154. <u>https://doi.org/10.5950/0738-1360-25.2.133</u>

This article presents results from a stated preference survey of U.S. households intended to value the public's preferences for enhancements to the protection of the western stock of Steller sea lions, which is listed as endangered under the Endangered Species Act. To account for the uncertainty of future populations under current programs without additional protection efforts, three survey versions were implemented that each present different, yet plausible, baseline futures for Steller sea lions. Stated preference choice experiment data from each survey are analyzed using repeated, rank ordered random parameters logit models, and welfare estimates are calculated and compared for each baseline for a variety of possible improvements. The willingness to pay (WTP) results reflect positive, but diminishing, marginal utility for improvements until the population greatly exceeds the current population, at which point the WTP for additional improvements levels off Similarly, as would be expected, WTP for improvements to the western stock population decreases as the future baseline population forecast improves.

Lian, M., Johnson, S., Gelatt, T., O'Hara, T. M., Beckmen, K. B., & Rea, L. D. (2018). Field Anesthesia of Juvenile Steller Sea Lions (*Eumetopias Jubatus*) Using Inhalation Anesthesia. *Marine Mammal Science*, 34(1), 125-135. <u>https://doi.org/10.1111/mms.12445</u>

Between 1998 and 2008, 621 Steller sea lions (*Eumetopias jubatus*, SSL) were captured underwater by SCUBA divers and anesthetized with isoflurane (n = 602) or sevoflurane (n = 19). We found significantly faster induction time ((X) over bar +/- SD) for sevoflurane (11 +/- 6 min) compared to isoflurane (14 +/- 6 min), as well as an interaction between anesthetists using the isoflurane protocol. Severe hypothermia with temperatures <35 degrees C were measured in 22% of all animals, and had significant associations with month, length of anesthesia, and sex. Mortality rate was low (0.33%). We conclude that both isoflurane and sevoflurane anesthesia were effective for field anesthesia to safely handle and sample SSL.

Loughlin, T. R. (1997). Using the Phylogeographic Method to Identify Steller Sea Lion Stocks. *Molecular Genetics of Marine Mammals, Special Publication.* 3, 159-171.

This paper is a review of available information relevant to distinguishing stocks of Steller sea lions (*Eumetopias jubatus*) in the United States. The review is based on the phylogeographic method (Dizon et al. 1992), which uses information on distribution, population response, phenotype, and genotype to define a stock. The strongest evidence for stock separation in Steller sea lions is based on mtDNA studies, which suggest an eastern and western stock, with the division at about Prince William Sound, Alaska. Analysis of population demography supports this thesis, and tagging and branding studies

suggest that Steller sea lions are reproductively faithful to their birth sites and that immigration rates are low. On the basis of this review, I recommend that Steller sea lions be considered as two stocks that are geographically separated at the 144°W meridian (Cape Suckling, Alaska).

Loughlin, T. R., & Spraker, T. (1989). Use of Telazol to Immobilize Female Northern Sea Lions (*Eumetopias Jubatus*) in Alaska. *Journal of Wildlife Diseases, 25*(3), 353-358. <u>https://doi.org/10.7589/0090-3558-25.3.353</u>

Twenty-nine female northern sea lions (*Eumetopias jubatus*) were immobilized using Telazol in dosages ranging from 1.8 to 8.1 mg/kg. Best results were achieved with Telazol dosages ranging between 1.8 and 2.5 mg/kg which resulted in smooth induction and recovery. Optimal injection location was in the muscle mass of the lower back and hip. Dosages greater than 3.5 mg/kg resulted in a tendency toward hypothermia. Six mortalities occurred which were partially caused by the location of drug injection and perhaps the high dosage.

Mangel, M. (2010). Scientific Inference and Experiment in Ecosystem Based Fishery Management, with Application to Steller Sea Lions in the Bering Sea and Western Gulf of Alaska. *Marine Policy*, *34*(5), 836-843. <u>https://doi.org/10.1016/j.marpol.2010.01.005</u>

Learning about ecosystem processes and patterns is an essential component of Ecosystem Based Fishery Management and the sustainable use of natural resources. Currently, such learning is usually done through adaptive management (passive or active) or Management Strategy Evaluation, which are explained. An example of adaptive management in northwestern Australia shows the strengths and limitations of management experiments and raises the question of how to learn if an experiment is not practicable. Both adaptive management and Management Strategy Evaluation are examples of scientific inference, an idea introduced by Sir Harold Jeffreys nearly 80 years ago. With sufficient variation, even if it is not through controlled experiments, scientific inference is possible by combining mechanistic models with statistical methods; the recently proposed paradigm of 'adaptive monitoring' is another case of scientific inference. The decline of Steller sea lions in the Bering Sea and Aleutian Islands is reviewed, including the only work in which 10 hypotheses concerning the decline were simultaneously compared. It is concluded that scientific inference using mechanistic models and fine scale data at the level of the rookery can provide useful information about the interactions of fisheries, fish populations, and Steller sea lions.

Mansfield, B., & Haas, J. (2006). Scale Framing of Scientific Uncertainty in Controversy over the Endangered Steller Sea Lion. *Environmental Politics*, *15*(1), 78-94. <u>https://doi.org/10.1080/09644010500418795</u>

Political debate about the endangered Steller sea lion turns on uncertainty about the cause of decline and lack of recovery of this marine mammal of the North Pacific Ocean. To shift the political terrain, different groups tried to shift the scale at which problems are framed. US regulators focused on localised interactions, environmental organisations highlighted the entire fishery management regime and the fishing industry focused on natural climate change within the North Pacific region. Because debate is about supposedly objective, scientific realities, these practices of scale framing take on particular significance in this case. Scientific understandings of individual problems are not outside the frame of scale practices, but instead there is a politics of scale around science. This case shows that using scale as a framing device is a powerful political strategy for dealing with uncertainty, because focusing on a particular scale presupposes certain kinds of solutions while foreclosing others.

McAllister, D. C., Calkins, D. G., & Pitcher, K. W. (2001). Underwater Capture of Juvenile Steller Sea Lions with Scuba: A Narrated Video Presentation. In *Coldwater Diving for Science*. S. C. Jewett (Ed.), (pp. 4-56): University of Alaska Sea Grant Retrieved from <u>http://archive.rubicon-foundation.org/xmlui/bitstream/handle/123456789/4721/AAUS_2001cold_12.pdf?sequence=1</u>

The western population of Steller sea lions (*Eumetopias jubatus*) in Alaska declined by approximately 85% over the past 30 years and is classified as "endangered" under the U.S. Endangered Species Act. Data collected during the 1980s strongly suggested that nutritional stress played a role in the declining population (Calkins et al. 1998, Pitcher et al. 1998). Studies conducted during the mid-1990s suggested that reproductive females and young pups were in "good" nutritional status, and analyses by York (1994) suggested that low survival of juveniles contributed to the declining population. Because of these findings, it was decided that studies on health and nutritional status of juvenile sea lions were of high priority. However, traditional methods of capture such as darting with immobilizing drugs were inefficient for juvenile sea lions and new capture techniques were needed.

McBeath, J. (2012). Science and Politics in the Conservation of Biodiversity: The Steller Sea Lion Case. Environmental Development, 1(1), 107-121. <u>https://doi.org/10.1016/j.envdev.2011.12.009</u>

The U.S. Endangered Species Act (ESA), adopted by the Congress with virtually no opposition in 1973, is one of the world's most comprehensive biodiversity sustainability measures, because both the listing of species as endangered and plans for their recovery by law must be based only on biological needs. Yet ESA has been one of the most embattled of American environmental laws; critics argue that politics routinely eclipses science in ESA decision-making. This study demonstrates the need to analyze reciprocal effects of scientific knowledge and political decision-making in the sustainability transition. The case concerns crisis in the conservation of Steller sea lions (SSL), whose population in the Bering Sea and Aleutian Islands plummeted more than 80 percent after the 1950s. It examines three early decisions of the National Marine Fisheries Service (NMFS): (1) to list the SSL as threatened in 1990; (2) to upgrade the listing of Western SSL to endangered in 1997; and (3) in its first biological opinions in 1999–2000, to permit continued operation of the greater than \$1 billion bottomfish fishery, notwithstanding the belief of many scientists and most environmentalists that cause of depletion was nutritional stress (the fishery competed with SSL for prey). In discussing NMFS's implementation of ESA policy, the article asks the extent to which decisions were based on scientifically determined characteristics of the species (e.g., cause and degree of endangerment and requisite critical habitat) as compared to non-scientific variables capturing aspects of the mammal's charisma and appeal or political economic value of its habitat. It finds that the boundaries of science and politics are blurred in this case, and then asks why, by briefly comparing the finding to decision-making in protection of other endangered species.

McMahon, C. (2007). Branding the Seal Branders: What Does the Research Say About Seal Branding? *Australian Veterinary Journal, 85*(12), 482-484. <u>https://doi.org/10.1111/j.1751-</u> <u>0813.2007.00237.x</u> Research on seals, especially the use of hot branding, has received considerable high profile coverage.1-4 In some cases this has led to the closure of long term research projects, for example, the elephant seal (Mirounga leonina) demographic program at Macquarie Island, and research on Hooker's sea lions (Phocarctos hookeri) in New Zealand. In another case, criticism of research projects has led to the prosecution of researchers in the USA working on Steller sea lions (*Eumetopias jubatus*).3, 5 The researchers and their studies were, with two notable exceptions,6, 7 universally condemned by the lay and veterinary communities.5, 8 Among all the emotion, (including calls in the general media from the lay public for the researchers themselves to be branded), one consistent theme emerged: a call for a quantitative assessment of the effects of hot branding on various seal species, concentrating on the elephant seal program in Australia as an example of how scientists have taken the criticisms levelled at them seriously. I note that there have been no such attempts by the program's critics to address the many questions raised.

McPhee, J. M., Rosen, D. A. S., Andrews, R. D., & Trites, A. W. (2003). Predicting Metabolic Rate from Heart Rate in Juvenile Steller Sea Lions *Eumetopias Jubatus*. *Journal of Experimental Biology*, 206(11), 1941-1951. <u>https://doi.org/10.1242/jeb.00369</u>

The validity of using heart rate to estimate energy expenditure in free-ranging Steller sea lions *Eumetopias jubatus* was investigated by establishing whether there is a relationship between heart rate (f(H)) and oxygen consumption rate ((V) over dot O-2) in captive sea lions while swimming and resting. Four trained Steller sea lions (2 males and 2 females; mass 87.4-194.4 kg; age 16 months-3 years) were each equipped with a datalogger and two dorsal subcutaneous electrodes to record electrocardiograms from which f(H) was calculated. (V) over dot O-2 (measured using open-circuit respirometry) was simultaneously recorded while the previously fasted animals were at rest within an enclosed dry metabolic chamber or while they swam in an enclosed swim mill against water currents of various speeds (0-1.5 m s(-1)). The mean regression equation describing the relationship between f(H) (beats min(-1)) and (V) over dot O-2 (ml h(-1) kg(-0.60)) for all four animals was (V) over dot O-2=(71.3fH+/-4.3)-(1138.5+/-369.6) (means +/- S.E.M.) (r(2)=0.69, P<0.01). The relationship demonstrated between f(H) and (V) over dot O-2 while fasting suggests that heart rate can potentially be used to monitor energy consumption in free-ranging Steller sea lions. However, a short-term feeding experiment revealed no significant increase in heart rate following a 6 kg or 12 kg meal to match the observed increase in rate of oxygen consumption. This suggests that heart rate may not accurately reflect energy consumption during digestion events. Additional research should be conducted to further elucidate how the relationship between heart rate and oxygen consumption is affected by such factors as digestive state, stress and age.

Meek, C. L. (2009). Comparing Marine Mammal Co-Management Regimes in Alaska: Three Aspects of Institutional Performance. University of Alaska Fairbanks, Retrieved from <u>http://hdl.handle.net/11122/9013</u>

Arctic marine mammals and the communities that depend on them for subsistence are facing unprecedented rates of environmental change. Comparative studies of policy implementation are necessary in order to identify key mechanisms of successful environmental governance under challenging conditions. This study compares two federal agencies responsible for the conservation of Arctic marine mammals. Drawing on multiple methods, I develop indepth case studies of the policy implementation process for managing bowhead whale and polar bear subsistence hunting. I examine how and why agency approaches to conservation differ and assess policy effectiveness. The analysis focuses on three aspects of institutional performance as drivers of policy outcomes: historical events, organizational culture, and structural relationships with stakeholders. The study begins by tracing the development of marine mammal management in Alaska through time. I find that definitions of subsistence developed under previous eras continue to shape debates over wildlife management in Alaska, confounding ecologically relevant policy reform. I next examine the roles of agency culture, policy history, and relationships with stakeholders in influencing how agencies implement contemporary harvest assessment programs. Findings suggest that the internal orientation of the U.S. Fish & Wildlife Service makes it more likely to retain control over management programs than the more externally oriented National Marine Fisheries Service. Furthermore, these policy approaches affect the development of social norms at the local level. Through a social network analysis, I demonstrate that the extent to which policy programs are integrated into the existing social networks of a village affects policy success. Hunter participation in and support for policies is stronger when there are local centers of coordination and meaningful policy deliberation. Finally, I assess existing policies regarding both species to examine whether or not contemporary policy approaches address key drivers of system change and provide effective feedback channels. Findings demonstrate that both agencies have focused on regulating harvests; I argue that in order to foster resilience of the system into the future, policy actors must reconfigure management approaches and policies towards the protection of functional seascapes. I propose two strategies in order to govern for recovery (polar bears) and resistance (bowhead whales).

Mellish, J. A., Hennen, D., Thomton, J., Petrauskas, L., Atkinson, S., & Calkins, D. (2007). Permanent Marking in an Endangered Species: Physiological Response to Hot Branding in Steller Sea Lions (*Eumetopias Jubatus*). Wildlife Research, 34(1), 43-47. <u>https://doi.org/10.1071/wr06073</u>

Identification of individual animals is important in order to evaluate age-specific survival rates, onset of sexual maturity and reproductive rates in wildlife populations. Of the various methods available to researchers, hot branding is the most effective, although somewhat controversial, tool available. The physiological effects of hot-iron branding (n = 7) were assessed using temporarily captive juvenile Steller sea lions (*Eumetopias jubatus*) (n = 22). Sea lions showed statistically significant increases in white blood cell count, platelet levels, globulin and haptoglobin concentration up to two weeks after branding. No significant differences were found in serum cortisol levels. The changes in health parameters we saw after branding were consistent with minor tissue trauma and indistinguishable from baseline levels after 7-8 weeks.

Mellish, J. A., Thomton, J., & Horning, M. (2007). Physiological and Behavioral Response to Intra-Abdominal Transmitter Implantation in Steller Sea Lions. *Journal of Experimental Marine Biology* and Ecology, 351(1-2), 283-293. <u>https://doi.org/10.1016/j.jembe.2007.07.015</u>

The absence of a direct, long-term measure of individual Steller sea lion survival led to the development of implanted, delayed transmission satellite tags specifically for this species (Life History Transmitter, LHX). To assess possible effects of implant procedures and LHX tags, we undertook a two-stage approach to monitor: 1) immediate physiological response under controlled conditions in temporary captivity, and 2) post-release movernent and dive behavior via externally mounted satellite data recorders (SDR). Six juvenile sea lions were monitored up to 8 weeks post-implant for physiological indications of post-surgical effects. Overall, mass, body condition and blood parameters did not change during the study period. There was limited white blood cell elevation and acute-phase reaction in the first 2 weeks post-implant. During the 3 months of post-release tracking, all sea lions returned to their respective capture haul-outs. Shorter and shallower dives during the first week post-release suggested a possible recovery period similar to other non-LHX individuals released from temporary captivity. For all subsequent weeks, dive depth, duration, frequency and dispersal distances of LHX animals were comparable to free-ranging individuals. All physiological and behavioral responses noted were temporary in nature, supporting LHX implantation as a viable alternative for long-term survival monitoring of free-ranging sea lions.

Merrick, R. L., Calkins, D. G., Loughlin, T. R., & Alaska Fisheries Science, C. (1996). *Hot Branding: A Technique for Long-Term Marking of Pinnipeds*. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-68. Retrieved from https://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-68.pdf

Long-term studies of pinniped population dynamics, behavior, and movements require a sample of uniquely identified, permanently marked animals from the population. The mark must be large enough for animals to be identified from a distance and the marking process should subject the animal to minimal stress. Hot branding provides a marking technique which meets these criteria. Using hot branding equipment and techniques developed for studies of Steller sea lions, 1,489 pups were branded in 1987-89 at rookeries in Alaska and Russia. Survival in the month following branding was high (99.8 %). Observed returns of branded pups (through their eighth month) at Marmot Island, Alaska, may be different from returns of unmarked pups, but the differences are difficult to confirm because of possible immigration of unmarked pups from other rookeries. Most (95.8 %) of 142 brands observed 5-8 months after branding were legible, and 92.3 % of 26 brands seen 6-7 years after branding were legible. Of 751 pups branded at Marmot Island in 1987-88, 151 (20.1%) have been resighted at least once. Most resightings (56.9 %) occurred at Marmot Island, but animals have been resighted up to 1,700 km away.

Merrick, R. L., Loughlin, T. R., Antonelis, G. A., & Hill, R. (1994). Use of Satellite-Linked Telemetry to Study Steller Sea Lion and Northern Fur-Seal Foraging. *Polar Research*, *13*(1), 105-114. <u>https://doi.org/10.1111/j.1751-8369.1994.tb00441.x</u>

One explanation for recent declines in some Alaskan pinniped populations is that ecosystem changes may have reduced the availability of preferred prey. Part of our evaluation of this hypothesis involves the use of satellite-linked telemetry to study Steller sea lion (Eumetopias *jubatus*) and northern fur seal (Callorhinus ursinus) foraging. Data on dives (depth and duration) and water temperatures arc collected by satellite-linked time-depth recorders (SLTDR) glued to the backs of sea lions and fur seals. These data are then summarized and stored for later transmission. Data are relayed back to land through NOAA Tiros-series satellites and are processed by Service-Argos (a U.S.-French consortium). These transmissions are also used to calculate at-sea and on-land locations of the animals through use of Doppler shifts of the frequency of received transmissions. Ultimately, diving and temperature can be reconciled with at-sea locations to compare foraging areas with locations of known prey stocks.

Monamy, V. (2007). Hot Iron Branding of Seals and Sea Lions: Why the Ban Will Remain. *Australian Veterinary Journal*, *85*(12), 485-486. <u>https://doi.org/10.1111/j.1751-0813.2007.00239.x</u>

In March 2000, the Federal Minister for the Environment and Heritage banned hot iron branding of pinnipeds on Macquarie Island and other sub-Antarctic islands, invoking powers under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999. It appears that widespread media coverage of welfare issues associated with the use of this technique on newly weaned southern elephant seal pups (Mirounga leonina) prompted this ministerial intervention. Since that decision was made, many technical articles and letters to editors have been published, discussing the merits of various wildlife identification techniques and the practicalities and ethical aspects of conducting of conservation research.

 Mulsow, J., Reichmuth, C., Gulland, F., Rosen, D. A. S., & Finneran, J. J. (2011). Aerial Audiograms of Several California Sea Lions (Zalophus Californianus) and Steller Sea Lions (*Eumetopias Jubatus*) Measured Using Single and Multiple Simultaneous Auditory Steady-State Response Methods. *Journal of Experimental Biology, 214*(7), 1138-1147. <u>https://doi.org/10.1242/jeb.052837</u>

Measurements of the electrophysiological auditory steady-state response (ASSR) have proven to be efficient for evaluating hearing sensitivity in odontocete cetaceans. In an effort to expand these methods to pinnipeds, ASSRs elicited by single and multiple simultaneous tones were used to measure aerial hearing thresholds in several California sea lions (Zalophus californianus) and Steller sea lions (*Eumetopias jubatus*). There were no significant differences between thresholds measured using the single and multiple ASSR methods, despite the more rapid nature of data collection using the multiple ASSR method. There was a high degree of variability in ASSR thresholds among subjects; thresholds covered a range of ~40 dB at each tested frequency. As expected, ASSR thresholds were elevated relative to previously reported psychophysical thresholds for California and Steller sea lions. The features of high-frequency hearing limit and relative sensitivity of most ASSR audiograms were, however, similar to those of psychophysical audiograms, suggesting that ASSR methods can be used to improve understanding of hearing demographics in sea lions, especially with respect to high-frequency hearing. Thresholds for one Steller sea lion were substantially elevated relative to all other subjects, demonstrating that ASSR methods can be used to detect hearing loss in sea lions.

Myers, M. J., Litz, B., & Atkinson, S. (2010). The Effects of Age, Sex, Season and Geographic Region on Circulating Serum Cortisol Concentrations in Threatened and Endangered Steller Sea Lions (*Eumetopias Jubatus*). *General and Comparative Endocrinology*, *165*(1), 72-77. <u>https://doi.org/10.1016/j.ygcen.2009.06.006</u>

The role of stress in the decline of Steller sea lions has become of interest in the identification of factors leading to their drastic decline and subsequent failure to recover. Serum cortisol was validated as a potential indicator of stress in three sub-populations inhabiting the majority of the Steller sea lions range (n = 941). Additionally. seasonal variability in serum cortisol measured in captive animals (n = 9) of different age classes and sex was investigated. Significant interactions were found between region and year, as well as year and sex (p = 0.001 and p = 0.005, respectively). Samples from pups in Russia (151.5 +/- 3.2 ng ml(-1)) and southeast Alaska (152.7 +/- 2.7 ng ml(-1)) were consistently higher than concentrations measured in pups from southwest Alaska (133.0 +/- 3.2 ng ml(-1)). Serum cortisol concentrations measured in 2001 (134.9 +/- 2.0 ng ml(-1)) were significant interactions between age, year and sex (p = 0.011). Serum cortisol was elevated in months associated with the breeding season

and annual molt (86.5 +/- 5.0 and 92.4 +/- 5.1 ng ml(-1), respectively) compared to the other seasons. Our results suggest that cortisol concentrations in Steller sea lions can be a useful diagnostic tool to compare the physiology between groups of sea lions, but factors such as animal sex, age, season and year must be considered.

National Marine Fisheries Service. (2005). Environmental Assessment of the Effects of Permit Issuance for Research and Recovery Activities on Steller Sea Lions. Retrieved from https://repository.library.noaa.gov/view/noaa/19189

The National Marine Fisheries Service (NMFS) proposes to issue permits and permit amendments for scientific research on Steller sea lions (Eumetopias jubatus) in the wild, pursuant to the Marine Mammal Protection Act of 1972, as amended (MMPA; 16 U.S.C. 1361 et seq.), and the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 et seq.). The purpose of the proposed permits and amendments is to allow an exemption to the moratoria on takes established under the MMPA and ESA. The permits would allow for takes of threatened and endangered Steller sea lions for scientific research purposes. The need for the research is related to monitoring the population status and better understanding the cause(s) of the population decline in order to develop conservation and protective measures to ensure Steller sea lion recovery. The objective of the proposed research is to collect information on life history, foraging behavior, habitat use, physiology, population status and trends, survival and reproductive rates, and condition of Steller sea lions in the North Pacific. Scientific research permits are generally categorically excluded from the National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. 4321 et seq.) requirements to prepare an environmental assessment (EA) or environmental impact statement (EIS) (NAO 216-6). However, when the activities that would be authorized in a scientific research permit would have uncertain environmental impacts or unique or unknown risks, would establish a precedent or decision in principle about future proposals, may result in cumulatively significant impacts, or may have any adverse effects upon endangered or threatened species and their habitats, the preparation of an EA or EIS is required. Because some of the proposed research may result in adverse effects on threatened and endangered Steller sea lions, NMFS determined that further environmental review was warranted to determine whether significant impacts could result from issuance of the proposed permits. Therefore, this document evaluates the relevant effects of a variety of scientific research activities on Steller sea lions under several alternative permitting options.

National Marine Fisheries Service. (2008). Recovery Plan for the Steller Sea Lion : Eastern and Western Distinct Population Segments (Eumetopias Jubatus): Revision. Retrieved from https://repository.library.noaa.gov/view/noaa/15974

Section 4(f) of the ESA directs the responsible agency to develop and implement a Recovery Plan, unless such a plan will not promote the conservation of a species. NMFS has determined that a Recovery Plan would promote the conservation of the eastern and western distinct population segments of Steller sea lion. NMFS completed the first recovery plan for Steller sea lions in December 1992. At that time, the entire species was listed as threatened under the ESA. Because that recovery plan became obsolete after the reclassification of Steller sea lions into two distinct population segments (DPS) in 1997, and because nearly all of the recovery actions contained in the first plan had been completed, NMFS assembled a new Steller Sea Lion Recovery Team (Team) in 2001 to assist NMFS in revising the Plan to promote the conservation of the Steller sea lion. The first draft of the revised plan was written by the Team at the request of the Assistant Administrator for Fisheries. The recovery team included: experts

on marine mammals from the private sector, academia, and government; experts on endangered species conservation; and representatives of the commercial fishing industry, the Alaska Native Steller sea lion subsistence hunting community, and the environmental community.

National Marine Fisheries Service. (2009). Endangered Species Act Section 7 Re-Initiated Consultation Biological Opinion for Proposed Full Implementation of the Preferred Alternative of the Programmatic Environmental Impact Statement (PEIS) for Research on Steller Sea Lions and Northern Fur Seals. National Marine Fisheries Service Office of Protected Resources.

The Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531-1544), amended in 1988, establishes a national program for the conservation of threatened and endangered species of fish, wildlife, plants, and the habitat on which they depend. Section 7(a)(2) of the ESA, requires that each federal agency shall insure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered species or threatened species, or destroy or adversely modify critical habitat of such species. When a federal agency's action "may affect" a protected species, that agency is required to consult formally with the National Marine Fisheries Service (NMFS) or the U.S. Fish and Wildlife Service, depending upon the endangered species, threatened species, or designated critical habitat that may be affected by the action (50 CFR 402.14(a)). Federal agencies are exempt from this general requirement to formally consult if they have concluded that an action "may affect but is not likely to adversely affect" endangered species, threatened species, or designated critical habitat and NMFS or the U.S. Fish and Wildlife Service concur with that conclusion (50 CFR 402.14(b)). 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 Marine Fisheries Service Alaska Fisheries Science Center. (2007). *Coordination of Proposed Steller Sea Lion Field Research Activities in Alaska, 2007.* Retrieved from <u>https://repository.library.noaa.gov/view/noaa/18781</u>

Until the late 1990s, most research on Steller sea lions in Alaska was conducted by relatively few groups using the Steller Sea Lion Recovery Plan (NMFS 1992) for guidance, and thus coordination was straightforward. Because of a large increase in scientific activity and funding, mostly through Congressional appropriations starting in FY01, a framework for a comprehensive and coordinated research program was created as an organizational tool (Ferrero and Fritz 2002). Studies were also categorized based on which multiple hypotheses proposed for the Steller sea lion decline were being addressed.

National Marine Fisheries Service Alaska Region. (2010). *Revisions to the Steller Sea Lion Protection Measures for the Bering Sea and Aleutian Islands Management Area Groundfish Fisheries*. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/19137</u>

This environmental assessment/regulatory impact review provides decision-makers and the public with an evaluation of the environmental, social, and economic effects of alternatives to the Steller sea lion protection measures for the Bering Sea and Aleutian Islands Management Area groundfish fisheries, in particular the Atka mackerel and Pacific cod fisheries. The western distinct population segment (WDPS) of Steller sea lion is listed as endangered under the Endangered Species Act, and the species population in the Aleutian Islands is declining. Atka mackerel and Pacific cod are principal prey species for Steller sea lions in the Aleutian Islands. This proposed action would revise management of the Atka mackerel and Pacific cod fisheries are not likely to result in jeopardy of extinction or adverse modification or destruction of critical habitat for the WDPS of Steller sea lions. This document addresses the requirements of the National Environmental Policy Act and Executive Order 12866.

National Marine Fisheries Service Office of Protected Resources. (1992). *Final Recovery Plan for Steller Sea Lions Eumetopias Jubatus*. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/17384</u>

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect the species. Plans are prepared by the U.S. Fish and Wildlife Service and the Nationall Marine Fisheries Service, sometimes with the assistance of recovery teams, contractors, state agencies, and others. The Steller Sea Lion Recovery Plan was prepared by a recovery team and approved by the National Marine Fisheries Service. It does not necessarily represent official positions nor approvals of all the 1team members or cooperating agencies, other than the National Marine Fisheries Service, involved in the plan formulation. The plan represents the official position of the National Marine Fisheries Service 9nly after it has been signed by the Assistant Administrator for Fisheries as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status and completion of tasks described in the plan. Goals and objectives will be attained and funds expended contingent upon agency appropriations and priorities. This final plan incorporates the new format that has become standard in recovery plans in recent years. It is intended to serve as a guide that delineates and schedules those actions believed necessary to restore the Steller sea lion as a viable self-sustaining element of its ecosystem. It is recognized that some of the tasks described in the plan are 'already undetway. The inclusion of these ongoing tasks represents an awareness of their importance,. and offers support for their continuation.

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

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. (2008). *Recovery Plan for the Steller Sea Lion (Eumetopias Jubatus). Revision.* Retrieved from https://repository.library.noaa.gov/view/noaa/15974

Congress passed the Endangered Species Act of 1973 (16 USC 1531 et seq.) (ESA) to protect species of plants and animals endangered or threatened with extinction. The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (FWS) share responsibility for the administration of the Act. NMFS is responsible for most marine mammals including the Steller sea lion. Section 4(f) of the ESA directs the responsible agency to develop and implement a Recovery Plan, unless such a plan will not promote the conservation of a species. NMFS has determined that a Recovery Plan would promote the conservation of the eastern and western distinct population segments of Steller sea lion. NMFS completed the first recovery plan for Steller sea lions in December 1992. At that time, the entire species was listed as threatened under the ESA. Because that recovery plan became obsolete after the reclassification of Steller sea lions into two distinct population segments (DPS) in 1997, and because nearly all of the recovery actions contained in the first plan had been completed, NMFS assembled a new Steller Sea Lion Recovery Team (Team) in 2001 to assist NMFS in revising the Plan to promote the conservation of the Steller sea lion. The first draft of the revised plan was written by the Team at the request of the Assistant Administrator for Fisheries. The recovery team included: experts on marine mammals from the private sector, academia, and government; experts on endangered species conservation; and representatives of the commercial fishing industry, the Alaska Native Steller sea lion subsistence hunting community, and the environmental community.

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 <u>https://repository.library.noaa.gov/view/noaa/17160</u>

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.

Noren, D. P., Rea, L. D., & Loughlin, T. R. (2009). A Model to Predict Fasting Capacities and Utilization of Body Energy Stores in Weaned Steller Sea Lions (*Eumetopias Jubatus*) During Periods of Reduced Prey Availability. *Canadian Journal of Zoology-Revue Canadienne De Zoologie*, 87(10), 852-864. <u>https://doi.org/10.1139/z09-074</u>

The population decline of Steller sea lions (*Eumetopias jubatus* (Schreber, 1776)) may be linked to a decline in juvenile survivorship. Limitations in prey availability may contribute to the decline, thus it is important to understand fasting capacities of Steller sea lions. For most mammals, fat catabolism is the preferred energetic pathway to ensure that protein is spared. However, marine mammals also have a conflicting requirement to conserve fat because the main site of fat storage is the blubber layer, which is also their primary thermal barrier when at sea. We developed a dynamic state variable model to demonstrate how protein and fat reserve utilization and maximum fasting duration are influenced by body condition and time spent foraging. This model was parameterized with respect to conditions faced by juvenile and subadult Steller sea lions foraging unsuccessfully during a period of reduced prey availability. The model accurately predicted changes in fat and protein mass of juvenile and subadult Steller sea lions fasting in captivity. Furthermore, the model demonstrated that body lipid content, body mass, and the proportion of time spent in water influence energy reserve catabolism and maximum fasting durations. Consequently, small, lean individuals are particularly susceptible to reductions in prey availability.

Petrauskas, L., Tuomi, P., & Atkinson, S. (2006). Noninvasive Monitoring of Stress Hormone Levels in a Female Steller Sea Lion (*Eumetopias Jubatus*) Pup Undergoing Rehabilitation. *Journal of Zoo and Wildlife Medicine*, 37(1), 75-78. https://doi.org/10.1638/04-108.1

Steller sea lions (*Eumetopias jubatus*) rarely strand in areas monitored by humans, and there is little published data on the diseases, parasites, nutritional state, and stress levels of Steller sea lions in the wild. In May 2002, a female Steller sea lion pup (EJS-02-01) was sighted separated from her mother after strong storms in Southeast Alaska. After 5 days of observations, EJS-02-01 was transferred to the Alaska SeaLife Center (ASLC) in Seward, Alaska. During 11 mo of rehabilitation at ASLC, body weight was monitored and opportunistic fecal samples (n = 86) were analyzed for corticosterone concentrations. Fecal corticosterone concentrations ranged from 15 to 3,805 ng/g for EJS-02-01. Peak corticosterone values reflected responses to acute stressors during rehabilitation. EJS-02-01 was successfully released at Gran Point, Alaska, in April 2003. Fecal corticosterone assay monitoring provided a valuable tool to monitor various stressors and is useful in monitoring long-term situations like rehabilitation.

Punt, A. E., & Fay, G. (2006). Can Experimental Manipulation Be Used to Determine the Cause of the Decline of Western Stock of Steller Sea Lions (Eumetopias Jubatus)? In Sea Lions of the World.
A.W. Trites, S.K. Atkinson, D.P. DeMaster, L.W. Fritz, T.S. Gelatt, L.D. Rea, and K.M. Wynne (Eds.) Sea Grant Alaska. <u>https://doi.org/10.4027/slw.2006.28</u>

A variety of reasons have been postulated for the decline of Steller sea lions (Otariidae: *Eumetopias jubatus*) in the Northeast Pacific. To date, however, it has proved impossible to distinguish among these

reasons given the available data. In principle, experimental management based on spatial replication of treatments could be used to discriminate among some of these hypotheses. A simulation protocol was developed and applied to evaluate the power of a set of potential experiments to distinguish between whether the cause of the decline was fishing-induced or due to other factors. The simulations are based on an operating model that is individual-based and spatially explicit, and can be parameterized to represent the implications of a range of possible causes for the decline. This model can be used to generate the types of data typically available for the western stock of Steller sea lions. Experiments based on splitting four of the regions identified for past analyses of population dynamics information into sectors that are either open to some fishing or completely closed are considered. The performance of these experiments is, however, poor, owing to the impact of movement, different historical trends in different areas, demographic stochasticity, and the likely size of the effect that the experiments are attempting to detect. These results suggest that the currently available information imply that large-scale experimental manipulation by means of additional spatial closures, where the results are analyzed by examining trends in pup counts, is unlikely to provide an effective means of discriminating among alternative hypotheses for the decline in Steller sea lions in Alaska.

Rosen, D., Fahlman, A., Hastie, G., & Trites, A. (2007). Laboratory Studies in Wildlife Conservation: The Case of the Steller Sea Lion. *Comparative Biochemistry & Physiology Part A: Molecular & Integrative Physiology, 146*, S84-S84. <u>https://doi.org/10.1016/j.cbpa.2007.01.111</u>

The use of large captive vertebrates to address wildlife conservation issues raises at least two concerns: ethics of captivity and scientific relevance. To some degree the former is mitigated by the efficacy of the latter. For the past decade, laboratory studies with captive Steller sea lions (*Eumetopias jubatus*) have been central in efforts to understand the reasons for their precipitous population decline in the North Pacific, particularly in relation to the Nutritional Stress hypothesis. Research has concentrated on areas deemed most appropriate to the laboratory setting: physiology, bioenergetics, nutrition, and the development of techniques to study animals in the wild. Studies to date have quantified the nutritional value of prey items, the physiological response (and adaptive limitations) to changes in food intake (quality and availability), the energetic costs of various behaviours (including construction of a bioenergetic model), the energetic effects of changes in the physical environment, the hierarchy of bioenergetic and nutritional priorities, the cost of diving and foraging, the interaction between prey fields and diving behaviour, and the physiological constraints affecting concurrent bioenergetic demands. Experiments have taken place with trained sea lions both in an Aquarium and at an Open Water facility where animals can perform without unnatural physical constraints. These studies have yielded novel data that have permitted scientists to make inroads into the reasons for the Steller sea lion population decline. This is an example where controlled empirical experiments in an artificial setting have allowed researchers to test specific relationships hypothesised or observed to occur among their wild counterparts.

Shuert, C., Horning, M., & Mellish, J. A. (2015). The Effect of Novel Research Activities on Long-Term Survival of Temporarily Captive Steller Sea Lions (*Eumetopias Jubatus*). *PLoS ONE, 10*(11) <u>https://doi.org/10.1371/journal.pone.0141948</u>

Two novel research approaches were developed to facilitate controlled access to, and long-term monitoring of, juvenile Steller sea lions for periods longer than typically afforded by traditional fieldwork. The Transient Juvenile Steller sea lion Project at the Alaska SeaLife Center facilitated

nutritional, physiological, and behavioral studies on the platform of temporary captivity. Temporarily captive sea lions (TJs, n = 35) were studied, and were intraperitoneally implanted with Life History Transmitters (LHX tags) to determine causes of mortality post-release. Our goal was to evaluate the potential for long-term impacts of temporary captivity and telemetry implants on the survival of study individuals. A simple open-population Cormack-Jolly-Seber mark-recapture model was built in program MARK, incorporating resightings of uniquely branded study individuals gathered by several contributing institutions. A priori models were developed to weigh the evidence of effects of experimental treatment on survival with covariates of sex, age, capture age, cohort, and age class. We compared survival of experimental treatment to a control group of n = 27 free-ranging animals (FRs) that were sampled during capture events and immediately released. Sex has previously been show to differentially affect juvenile survival in Steller sea lions. Therefore, sex was included in all models to account for unbalanced sex ratios within the experimental group. Considerable support was identified for the effects of sex, accounting for over 71% of total weight for all a priori models with delta AICc < 5, and over 91% of model weight after removal of pretending variables. Overall, most support was found for the most parsimonious model based on sex and excluding experimental treatment. Models including experimental treatment were not supported after post-hoc considerations of model selection criteria. However, given the limited sample size, alternate models including effects of experimental treatments remain possible and effects may yet become apparent in larger sample sizes.

Shuert, C., Mellish, J., & Horning, M. (2015). Physiological Predictors of Long-Term Survival in Juvenile Steller Sea Lions (*Eumetopias Jubatus*). *Conservation Physiology*, 3 <u>https://doi.org/10.1093/conphys/cov043</u>

This study builds on a continued effort to document potential long-term research impacts on the individual, as well as to identify potential markers of survival for use in a field framework. The Transient Juvenile Steller sea lion (TJ) project was developed as a novel framework to gain access to wild individuals. We used three analyses to evaluate and predict long-term survival in temporarily captive sea lions (n = 45) through Cormack-Jolly-Seber open population modelling techniques. The first analysis investigated survival in relation to the observed responses to handling stress through changes in six principal blood parameters over the duration of captivity. The second analysis evaluated survival compared with body condition and mass at entry and exit from captivity. Finally, the third analysis sought to evaluate the efficacy of single-point sampling to project similar survival trends for use in field sampling operations. Results from a priori models ranked through Akaike information criterion model selection methods indicated that mass gains (4.2 +/- 12%) over captivity and increases in leucocytes (WBC, 1.01 +/- 3.54 x 10(3)/mm(3)) resulted in a higher average survival rate (> 3 years). Minor support was identified for the single-point measures of exit mass and entry WBC. A higher exit mass predicted a higher survival rate, whereas a higher WBC predicted a lower survival rate. While changes in mass and WBC appear to be the best predictors of survival when measured as a change over time, single-point sampling may still be an effective way to improve estimates of population health.

Shuert, C. R., Skinner, J. P., & Mellish, J. E. (2015). Weighing Our Measures: Approach-Appropriate Modeling of Body Composition in Juvenile Steller Sea Lions (*Eumetopias Jubatus*). Canadian Journal of Zoology, 93(3), 177-180. <u>https://doi.org/10.1139/cjz-2014-0174</u>

While many approaches to modeling body condition exist, ranging from arbitrary morphometric indices to sophisticated cone modeling, few approaches have attempted to develop a standardized, simplified

method for determining total body fat and protein in otariids. Our goal was to develop a method for predicting the body condition of juvenile Steller sea lions (Eumetopias *jubatus* (Schreber, 1776)) using simple morphometrics such as measurements of girth, length, mass, and blubber depth. We compared a candidate set of models to determine which metrics best predicted total body water (TBW) measures obtained by deuterium isotope dilution. Furthermore, we used AICc (Akaike's information criterion corrected for small sample size) model selection methods and cross-validation to choose and validate the best suite of predictors. TBW was best predicted by a model that included mass, standard length, axial girth with the addition of blubber depths on the lateral side of the neck and dorsal surface of the hip. The results presented here show that blubber depth is an important addition to modeling body composition and may improve upon nonlethal, population-level estimates of nonisotopically derived values of TBW in juvenile Steller sea lions. Additionally, our models present a model development framework for other research efforts for use in determining body condition in otariids.

Siess, K. (2014). Variability in Delta13c and Delta 15n Values of Steller Sea Lion Pup Vibrissae: Implications for Diet and Foraging Studies (Eumetopias Jubatus, Alaska). Alaska Pacific University. Retrieved from <u>https://search.proquest.com/docview/1687687039</u>

During the 1970s to the 1990s, Steller sea lions (*Eumetopias jubatus*) in Alaska declined severely, resulting in the western stock's listing as endangered under the United States Endangered Species Act. The localized depletion of their main food source around rookeries and haul out sites was the primary cause of their depletion. The western stock has still not recovered to historical levels. Therefore, scientists have continued to study Steller sea lions diet and foraging habits. One approach has been through stable isotope analysis of their various tissues. Analysis of their vibrissae, or whiskers, provides an exact record of an individual's diet from birth to the present. However, scientists so far have only measured stable isotope values of a single vibrissa from an individual, assuming no significant difference among vibrissae within or between cheeks. They have not accounted for the possibility of variable stable isotope accumulation in an individual's different vibrissae. In this study, delta tested the assumption of no significant individual variability among vibrissae by examining the delta super(13)C and delta super(15)N values in all of the vibrissae on five Steller sea lion pups recovered in Alaska. delta super(15)N values did not differ between vibrissae on a cheek or between vibrissae from left and right cheeks. The delta super(13)C values did not differ between vibrissae within cheeks; however, delta super(13)C values were significantly different between the left and right cheeks of Lowrie Island Pup and PWS 29 Pup. This between cheek variation is most likely due to small sample size rather than different stable isotope incorporation. The lack of delta super(15)N value variation within or between cheeks, as well as the lack of delta super(13)C variation within cheeks, supports the assumption that stable isotope accumulation is similar between all vibrissae and validates sampling protocols of previous studies collecting just the longest, thick vibrissa from a Steller sea lion. More studies similar to this one are needed to verify these findings and to look at variability in stable isotope incorporation of juvenile and adult Steller sea lion vibrissae as well as other mammal species.

Skinner, J. P., Norberg, S. E., & Andrews, R. D. (2009). Head Striking During Fish Capture Attempts by Steller Sea Lions and the Potential for Using Head Surge Acceleration to Predict Feeding Behavior. *Endangered Species Research*, 10, 61-69. <u>http://dx.doi.org/10.3354/esr00236</u>

After declining by over 80% in the last 30 yr, Steller sea lion *Eumetopias jubatus* (SSL) populations in Alaska remain low with no sign of recovery. To better examine the potential effects of nutritional stress,

foraging studies are needed. Currently available biotelemetry techniques are either incapable of precisely quantifying prey captures or have not been validated for SSLs. Our objectives were to (1) determine whether SSL fish-capture attempts (FCAs) produce a head surge acceleration signal; (2) determine whether acceleration of the head relative to the body (differential) produces a more distinct signal than head acceleration alone (dynamic); and (3) develop a method for predicting FCAs using accelerometry. We attached accelerometers to the head and torso of 2 captive SSLs at the Alaska SeaLife Center and allowed them to feed on live fish. For the first SSL, we used video to classify FCAs during foraging trials and modeled the association between FCAs and parameters created using both dynamic and differential acceleration. Model coefficients were used to predict FCAs for a second SSL, and the results were compared with video. Head acceleration spikes were found in all FCAs. The dynamic model performed slightly better than the differential model at correctly predicting FCAs. Although the model did not perform exceptionally at identifying individual FCAs, it did predict at least 1 FCA in 96% of fish-chasing events and made only 1 false FCA prediction during 392 min of non-foraging. This study demonstrates that head accelerometry is useful for estimating SSL foraging effort.

Small, R. J., & DeMaster, D. P. (2006). Uncertain Management or Management of Uncertainty: Steller Sea Lion - a Case Study. https://doi.org/10.4027/slw.2006.32

The abundance of Steller sea lions (sea lions) declined similar to 15% per year during the 1980s in the Bering Sea, Aleutian Islands, and Gulf of Alaska regions, resulting in a threatened listing under the Endangered Species Act (ESA) in 1990. Numerous factors may have contributed to the decline, and there has been substantial uncertainty regarding the relative impact of these factors when management actions were implemented to promote recovery. One key hypothesis for the continued decline in the 1990s (similar to 5%/year) has been a reduction in sea lion prey biomass and quality caused by either commercial fishing or an "oceanographic regime shift" resulting in substantial changes in the abundance or availability of dominant prey species, which may have subsequently resulted in nutritional stress on the sea lion population. Following the 1997 ESA endangered listing of the western population and the determination that competition with commercial groundfish fisheries in Alaska was likely, additional fishery management restrictions were implemented. Counts of sea lions in 2002 and 2004 indicate the decline of sea lions may have begun to cease. The evidence for nutritional stress, especially post-1990, is somewhat contradictory and equivocal which contributes to continued uncertainty. Given the ESA's mandate to U.S. federal regulatory agencies to manage in a strongly precautionary manner, greater uncertainty can be translated to mean more precautionary management. To address ongoing uncertainty about causal factors and the efficacy of conservation actions, we believe that a research strategy with four primary components should be pursued: (1) population monitoring and fundamental sea lion ecological research, (2) fishery interaction studies designed to test the localized depletion hypothesis, (3) determining the mechanism by which changes in prey biomass or nutritional quality of the prey species may result in chronic nutritional stress that results in decreased sea lion survival and reproduction, and (4) adaptive management experiments to assess the impact of fisheries on the sea lion prey field and subsequently sea lion demography. In addition, recently suggested modifications to conservation policy should be pursued: (a) establishing a specific quantitative standard for risk of extinction (under the ESA), (b) defining jeopardy and adverse modification of critical habitat (under the ESA) in terms of risk of extinction, and (c) establishing a quantitative standard for ecosystem protection in developing recovery strategies for ESA listed species. Implementation of these research and conservation policy recommendations could substantially decrease uncertainty and increase the probability of effective conservation of sea lions.

Snyder, G. M., Pitcher, K. W., Perryman, W. L., & Lynn, M. S. (2001). Counting Steller Sea Lion Pups in Alaska: An Evaluation of Medium-Format, Color Aerial Photography. *Marine Mammal Science*, 17(1), 136-146. <u>https://doi.org/10.1111/j.1748-7692.2001.tb00984.x</u>

Estimates of Steller sea lion (*Eumetopias jubatus*) pup production are valuable for estimating population trend and size. Currently in Alaska, pups are counted by visiting rookeries, driving older animals into the water, then walking through the rookeries and counting the pups, a highly disruptive procedure. At smaller rookeries, with good vantage points, pups are occasionally counted from the periphery of rookeries without disturbing the sea lions. We evaluated counts made from medium-format, color, aerial photographs as an alternative to drive counts and peripheral counts. Neither the peripheral counts nor the aerial photographic counts disturbed animals on the rookeries. There were strong 1:1 linear relationships between photographic counts and drive counts (r(2) = 0.966, P < 0.001) and between photographic counts (r(2) = 0.999, P < 0.001). Precision was similar for all three methods of counting. We suggest that medium-format, color, aerial photography is appropriate for routine surveys of Steller sea lion pups in Alaska because it is not disruptive to the hauled-out sea lions and provides comparable estimates with similar precision to drive and peripheral counts. Large areas can be rapidly surveyed during periods of good weather with a minimum of manpower.

Steller Sea Lions and Proposed Fishery Management Changes in the Aleutian Islands. (2014). *Marine Pollution Bulletin, 82*(1-2), 5-5. <u>https://doi.org/10.1016/j.marpolbul.2014.04.025</u>

Proposed changes to fishing restrictions in the Aleutian Islands are not likely to jeopardize the continued existence of the endangered western population of Steller sea lions or adversely modify Steller sea lion critical habitat, according to a biological opinion issued by the National Oceanic and Atmospheric Administration (NOAA) Fisheries under the Endangered Species Act. The agency estimates that the proposed fishery management changes would relieve roughly two-thirds of the economic burden imposed on Aleutian Islands' fishermen by sea lion protection measures that took effect in 2011. Fishermen could see new regulations in place by January 2015. Finding a way to protect endangered sea lions while minimizing costs to the fishing industry is a real challenge. The new biological opinion was developed based on the best available scientific information and notes that considerable changes have occurred in the Aleutian Islands fisheries, coupled with new data and analyses that help give the agency a better picture of the potential for commercial fisheries to compete with sea lions for Pacific cod, Atka mackerel and pollock. NOAA Fisheries remains concerned that large fishery harvests from important areas in the Aleutians over a short amount of time has the potential to deplete concentrations of fish that Steller sea lions depend upon. However, the proposed measures would limit and spread out the catch enough to meet the requirements of the Endangered Species Act, and are consistent with NOAA Fisheries' views on dispersing the harvest in space and time to avoid localized depletion of fish that are prey species for Steller sea lions.

Taylor, R. L. (2009). A Multistate Mark Recapture Analysis to Estimate Reproductive Rate in the Steller Sea Lion (Eumetopias Jubatus), an Endangered Species. (Doctor of Philosophy), Montana State University-Bozeman, College of Letters & Science, Montana. Retrieved from <u>https://scholarworks.montana.edu/xmlui/handle/1/2403</u> The Steller sea lion is an endangered species whose reproductive rate estimates need to be updated. The species is divided into two populations: the endangered western population has declined over 80% from historical levels, while the threatened eastern population has been increasing at approximately 3% for the past three decades. The statistically most compelling reproductive rate estimates for this species are based on now out of date population dynamics, and hence are not applicable to current concerns. Extensive recent branding and resighting efforts by the Alaska Department of Fish and Game in Southeast Alaska make possible an updated estimation of eastern population Steller sea lion reproductive rates. However, the complexity of these data required a different statistical approach than is typically used to estimate reproduction in marked and resighted animals. I developed a novel statistical analysis, based upon a multistate mark recapture likelihood function, specifically to analyze the Southeast Alaska Steller sea lion data. The likelihood function estimates a reproductive rate when only adult females (not pups) are marked, female sightability is correlated with reproductive status, state classification uncertainty is present and the population is open to births during many of the resighting intervals. I apply this analysis to the Southeast Alaska Steller sea lion data and estimate a reproductive rate of 0.66 (0.55, 0.77). Not only does this provide a reproductive rate estimate for the eastern population, which is important for monitoring its health, but it also provides a basis for comparison to the endangered western population. Furthermore, the Alaska Department of Fish and Game continues to have an active branding and resighting program. The methods developed here can be applied to future data collected in either population.

Tollit, D. J., Schulze, A. D., Trites, A. W., Olesiuk, P. F., Crockford, S. J., Gelatt, T. S., . . . Miller, K. M. (2009). Development and Application of DNA Techniques for Validating and Improving Pinniped Diet Estimates. *Ecological Applications*, 19(4), 889-905. <u>https://doi.org/10.1890/07-1701.1</u>

Polymerase chain reaction techniques were developed and applied to identify DNA from >40 species of prey contained in fecal (scat) soft-part matrix collected at terrestrial sites used by Steller sea lions (Eumetopias jubatus) in British Columbia and the eastern Aleutian Islands, Alaska. Sixty percent more fish and cephalopod prey were identified by morphological analyses of hard parts compared with DNA analysis of soft parts (hard parts identified higher relative proportions of Ammodytes sp., Cottidae, and certain Gadidae). DNA identified 213 prey occurrences, of which 75 (35%) were undetected by hard parts (mainly Salmonidae, Pleuronectidae, Elasmobranchii, and Cephalopoda), and thereby increased species occurrences by 22% overall and species richness in 44% of cases (when comparing 110 scats that amplified prey DNA). Prey composition was identical within only 20% of scats. Overall, diet composition derived from both identification techniques combined did not differ significantly from hard-part identification alone, suggesting that past scat-based diet studies have not missed major dietary components. However, significant differences in relative diet contributions across scats (as identified using the two techniques separately) reflect passage rate differences between hard and soft digesta material and highlight certain hypothesized limitations in conventional morphological-based methods (e.g., differences in resistance to digestion, hard part regurgitation, partial and secondary prey consumption), as well as potential technical issues (e.g., resolution of primer efficiency and sensitivity and scat subsampling protocols). DNA analysis of salmon occurrence (from scat soft-part matrix and 238 archived salmon hard parts) provided species-level taxonomic resolution that could not be obtained by morphological identification and showed that Steller sea lions were primarily consuming pink (Oncorhynchus gorbuscha) and chum (Oncorhynchus keta) salmon. Notably, DNA from Atlantic salmon (Salmo salar) that likely originated from a distant fish farm was also detected in two scats from one site in the eastern Aleutian Islands. Overall, molecular techniques are valuable for identifying prey in the fecal remains of marine predators. Combining DNA and hard-part identification will effectively alleviate

certain predicted biases and will ultimately enhance measures of diet richness, fisheries interactions (especially salmon-related ones), and the ecological role of pinnipeds and other marine predators, to the benefit of marine wildlife conservationists and fisheries managers.

Tollit, D. J., Steward, M. J., Thompson, P. M., Pierce, G. J., Santos, M. B., & Hughes, S. (1997). Species and Size Differences in the Digestion of Otoliths and Beaks: Implications for Estimates of Pinniped Diet Composition. *Canadian Journal of Fisheries and Aquatic Sciences*, 54(1), 105-119. https://doi.org/10.1139/f96-264

We examined the digestion of hard remains of between one and four different size ranges of nine key North Sea prey taxa fed to seven captive harbour seals (Phoca vitulina). Percentage length reduction (mean 27.5%) and recovery rates (mean 42%) of experimental otoliths varied between species and were positively correlated to fish size and otolith robustness (mass/length). Mean length reduction of egested otoliths increased systematically with increasing size of ingested whiting and sandeel otoliths (p <0.001), indicating that the size of larger fish may be underestimated. Intraspecific variation in otolith digestion was high (CV = 0.48-1.30), and to control for the artificial conditions of a captive study, external morphological features of otoliths were used to grade the degree of digestion and provide grade-specific correction factors. Bootstrap simulations were used to estimate 95% confidence intervals around correction factors and when partitioned indicated that calculation errors were in general less important than resampling errors. The application of species-, size-, and grade-specific correction factors progressively improved reconstructed estimates of prey biomass fed. As a consequence, estimates of prey size and diet composition require otoliths from faeces to be graded and more complex correction factors applie

Trites, A. W., Hunt, K. E., Wynne, K., & Wasser, S. K. (2003, Dec). Noninvasive Assessment of Possible Nutritional Stress in Steller Sea Lions (Eumetopias Jubatus) Using Fecal Glucocorticoid and Dietary Analyses. Paper presented at the Annual Meeting of the Society for Integrative and Comparative Biology. Retrieved from http://www.sicb.org/meetings/2004/schedule/abstractdetails.php3?id=962

The western population of the Steller sea lion (*Eumetopias jubatus*) experienced a pronounced population decline in the 1970's-90's. The initial decline is thought to have involved reduced quantity or quality of prey, but it is unclear what factors are now preventing population recovery. To enable noninvasive assessment of physiologic stress of free-living sea lions, we validated a fecal glucocorticoid assay using ACTH (adrenocorticotropic hormone) injections in four captive Steller sea lions. All four showed pronounced elevations in fecal glucocorticoids after ACTH injection, indicating that assay results reflect adrenal activity. We assayed 206 scats from Steller sea lion haul-outs in the declining (Gulf of Alaska) population, and 265 scats from the stable (Southeast Alaska) population. Diet was determined from hard parts recovered from scats, and dietary energy content was estimated from known caloric densities of prey. Both populations had significantly higher fecal glucocorticoid concentrations and significantly lower dietary energy density in winter compared to summer. During winter, sea lions in the declining population. No significant differences were seen between glucocorticoid levels of the two populations in summer. Glucocorticoid differences were noted in summer between mature males, mature females and immature animals. Though many questions remain to be answered, these results
suggest that the Gulf of Alaska population is not currently suffering from nutritional stress, and that other factors such as orca predation may now be more important in preventing population recovery.

Trites, A. W., & Joy, R. (2005). Dietary Analysis from Fecal Samples: How Many Scats Are Enough? Journal of Mammalogy, 86(4), 704-712. <u>https://doi.org/10.1644/1545-1542(2005)086[0704:DAFFSH]2.0.CO;2</u>

Diets of mammals are increasingly being inferred from identification of hard parts from prey eaten and recovered in fecal remains (scats). Frequencies with which particular prey species occur among collections of scats are easily compiled to describe the average diet, and can be used to compare diets between and within geographic regions, and across years and seasons. Important to these analyses is the question of statistical power. In other words, how many scats should be collected to compare the diet among and between species? We addressed this problem by using Monte Carlo simulations and frequency of occurrence methods to analytically determine the consequence of sample size on the dietary analysis of scats. We considered 2 questions. First, how is the statistical power affected by sample size? Second, what is the likelihood of not identifying a prey species? We randomly sampled predetermined numbers of scats (n ¼ 10–200) from computer-generated populations of scats containing prey of known species and frequencies of occurrences. We also randomly sampled a large database of field-collected scats from Steller sea lions (Eumetopias jubatus). We then used standard contingency table tests such as chi-square and Fisher's exact test to determine whether differences between our samples and populations were statistically significant. We found that a minimum size of 59 scats is necessary to identify principal prey remains occurring in .5% of scats. However, 94 samples are required when comparing diets to distinguish moderate effect sizes over time or between areas. These findings have significant implications for the interpretation of published dietary data, as well as for the design of future scat-based dietary studies for pinnipeds and other species.

Viviant, M., Trites, A. W., Rosen, D. A. S., Monestiez, P., & Guinet, C. (2010). Prey Capture Attempts Can Be Detected in Steller Sea Lions and Other Marine Predators Using Accelerometers. *Polar Biology*, 33(5), 713-719. <u>https://doi.org/10.1007/s00300-009-0750-y</u>

We attached accelerometers to the head and jaw of a Steller sea lion (*Eumetopias jubatus*) to determine whether feeding attempts in a controlled setting could be quantified by acceleration features characteristic of head and jaw movements. Most of the 19 experimental feeding events that occurred during the 51 dives recorded resulted in specific acceleration patterns that were clearly distinguishable from swimming accelerations. The differential acceleration between the head-mounted and jaw-mounted accelerometers detected 84% of prey captures on the vertical axis and 89% on the horizontal axis. However, the jaw-mounted accelerometer alone proved to be equally effective at detecting prey capture attempts. Acceleration along the horizontal (surge)-axis appeared to be particularly efficient in detecting prey captures, and suggests that a single accelerometer placed under the jaw of a pinniped is a promising and easily implemented means of recording prey capture attempts.

Waite, J. N., & Horning, M. (2000). 3d Photogrammetry as a Tool for Assessing Morphometrics and Estimating Body in Steller Sea Lions. *FASEB Journal*, *14*(4), A551-A551. Retrieved from <u>http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch_&qid=26&SID=8AKBSJ5RixL6hagr5Wp&page=1&doc=1</u>

[NO ABSTRACT AVAILABLE]

Waite, J. N., & Mellish, J. A. E. (2009). Inter- and Intra-Researcher Variation in Measurement of Morphometrics on Steller Sea Lions (*Eumetopias Jubatus*). *Polar Biology*, 32(8), 1221-1225. <u>https://doi.org/10.1007/s00300-009-0649-7</u>

Substantial effort has been made to increase the accuracy of photogrammetric measurement techniques, especially on marine mammals. However, accuracy of the physical measurements is rarely considered when calculating the photogrammetric accuracy. We examined inter- and intra-researcher variation in the measurement of physical morphometrics of Steller sea lions (*Eumetopias jubatus*) to assess their potential effects on photogrammetric accuracy and body mass predictions based on photogrammetrically derived morphometrics. Significant differences were found inter-researcher in median standard length and axillary girth and intra-researcher when measuring axillary girth of the same animals. Photogrammetrically derived estimates of these parameters are comparable to physical measurements when taking into account the inherent inter- and intra-researcher variation.

Waite, J. N., Schrader, W. J., Mellish, J. A. E., & Horning, M. (2007). Three-Dimensional Photogrammetry as a Tool for Estimating Morphometrics and Body Mass of Steller Sea Lions (*Eumetopias Jubatus*). Canadian Journal of Fisheries and Aquatic Sciences, 64(2), 296-303. <u>https://doi.org/10.1139/f07-014</u>

A technique was developed to estimate morphometrics and body mass of Steller sea lions (*Eumetopias jubatus*) using three-dimensional (3D) photogrammetry. 3D photogrammetry reduces many of the problems associated with camera and body position encountered with two-dimensional photogrammetric techniques, allowing body mass estimation of free-ranging, active sea lions, without sedation, heavy weighing equipment, and disturbance. 3D computer wireframes of 53 Steller sea lions of various age classes were generated from multiple time-synchronous digital photos and used to estimate length, girth, and volume. Average estimates of standard length and axillary girth were within +/- 2.5% and +/- 4.0% of physically measured dimensions, respectively. Average estimates of standard length and axillary girth using only wireframes based on ideal body postures were within +/- 1.7% and +/- 3.1% of physically measured dimensions, respectively. Regressions of physically measured mass on photogrammetrically estimated body volume yielded a predictive model. Body mass estimates using this model were on average within 9.0% (95% confidence interval = +/- 1.7%) of the physically measured mass. This technique was also successfully applied to reptiles and fish.

Willis, K., & Horning, M. (2005). A Novel Approach to Measuring Heat Flux in Swimming Animals. Journal of Experimental Marine Biology and Ecology, 315(2), 147-162. <u>https://doi.org/10.1016/j.jembe.2004.09.019</u>

We present a design for long-term or removable attachment of heat flux sensors (HFSs) to stationary or swimming animals in water that enables collection of heat flux data on both captive and free-ranging pinnipeds. HFSs were modified to allow for independent, continuous, and long-term or removable attachment to study animals. The design was tested for effects of HFSs and the attachment mechanism on resultant heat flux. Effects were insulative and consistent across water temperatures and flow

speeds, resulting in a correction factor of 3.42. This correction factor was applied to all measurements of heat flux from animal experiments to account for the thermal resistance of HFSs and insulative effects of the attachment mechanism. Heat flux and skin temperature data were collected from two captive Steller sea lions (*Eumetopias jubatus*) as they swam in a large habitat tank over time periods ranging from approximately 4 to 9 min. Of the 72 HFSs deployed using the attachment mechanism, data were successfully retrieved from 70. The HFS attachment mechanism was also used on two wild free-ranging Weddell seals (Leptonychotes weddellii) off Ross Island, Antarctica, for up to 7 days. Heat flux data were retrieved from all eight sensors deployed. These results, along with those from Steller sea lions, suggest that HFSs can be deployed with success on captive and wild animals using the designed attachment mechanism.

Yamamura, O., Hattori, K., & Isono, T. (2016). Steller Sea Lion: From Conservation to Management. *Aquabioloy/Kaiyo to Seibutsu, 38*(3), 232-237. Retrieved from <u>https://search.proquest.com/earthatmosphericaquatic/docview/1846421744/26262B0B2FD942</u> <u>8EPQ/1?accountid=28258</u>

Steller sea lions Eumetopias jubatus (SSL) originated from Okhotsk rookeries experienced an acute population decline by half from the 1960s to the 1980s partly due to hunting in Japan, on which virtually no regulation had been enforced. A provisional annual quota of 116 animals was mandated in the early 1990s, and then the SSL began to rebound at the rate of 4% a year. However, fishing damages due to SSLs has been serious accounting for >1 billion JPY yr super(-1) for the last 20 yrs. Hunting has been one of the mitigating measures of the damages, and has been regulated by means of PBR during 2008-2013. After the degrading of SSL in the Red Lists (IUCN and Japan Ministry of Environment) in 2012, the management has been requested to be revised. The revision intended to control the number of SSLs mitigating to the western coast of the Hokkaido Island, and a virtual population comprising the migrators has been assumed. In the purpose of fishing damage mitigation, the target level of the migrators in 2024 was set to be 60% of the present level (i.e. 40% depletion). We constructed a simple population model to describe the dynamics of the population based on the catch history and aerial surveys, and an annual harvest level including by-catch was calculated. This is one of the first implementations of the 'from conservation to management' volte-face in the pinniped around the Pacific Rim, and should be followed by a careful monitoring of the SSL and precautions and adaptive management revisions, to avoid its fall below the endangered level again.

Zhao, L. Y., & Schell, D. M. (2004). Stable Isotope Ratios in Harbor Seal Phoca Vitulina Vibrissae: Effects of Growth Patterns on Ecological Records. *Marine Ecology Progress Series, 281*, 267-273. <u>https://doi.org/10.3354/meps281267</u>

Growth rates and patterns of vibrissae (whiskers) in captive harbor seals Phoca vitulina were examined by intravenous infusion of N-15-labeled amino acid tracers to mark their keratinous tissues. The use of vibrissa segmental isotopic analysis as diet indicators was evaluated during controlled feeding trials. Harbor seals shed their vibrissae annually. Replacement of new vibrissae started in May or June, depending on individual seals. Growth rates of new vibrissae were very fast at up to 0.78 mm d(-1) during summer and fall, and then changed to a much slower growth rate throughout winter and early spring. An average growth rate of 0.075 mm d(-1) was obtained from 1 vibrissa from December to May. delta(13)C and delta(15)N values in vibrissae co-varied and reflected temporal variations of diet or habitat changes of seals, particularly over a rapid growth period from late spring to fall. Compared with other tissues such as blood components, vibrissae can be sampled less invasively and archive ecological records over a longer period. Vibrissa segmental isotopic analysis provides a more flexible tool for studying foraging ecology of wild seals, despite the varying seasonal growth rates and annual replacements.

Section XIII: Survival Rates

Altukhov, A. V., Andrews, R. D., Calkins, D. G., Gelatt, T. S., Gurarie, E. D., Loughlin, T. R., . . . Burkanov, V. N. (2015). Age specific survival rates of Steller sea lions at rookeries with divergent population trends in the Russian Far East. *PLoS ONE*, 10(5). <u>https://doi.org/10.1371/journal.pone.0127292</u>

After a dramatic population decline, Steller sea lions have begun to recover throughout most of their range. However, Steller sea lions in the Western Aleutians and Commander Islands are continuing to decline. Comparing survival rates between regions with different population trends may provide insights into the factors driving the dynamics, but published data on vital rates have been extremely scarce, especially in regions where the populations are still declining. Fortunately, an unprecedented dataset of marked Steller sea lions at rookeries in the Russian Far East is available, allowing us to determine age and sex specific survival in sea lions up to 22 years old. We focused on survival rates in three areas in the Russian range with differing population trends: the Commander Islands (Medny Island rookery), Eastern Kamchatka (Kozlov Cape rookery) and the Kuril Islands (four rookeries). Survival rates differed between these three regions, though not necessarily as predicted by population trends. Pup survival was higher where the populations were declining (Medny Island) or not recovering (Kozlov Cape) than in all Kuril Island rookeries. The lowest adult (> 3 years old) female survival was found on Medny Island and this may be responsible for the continued population decline there. However, the highest adult survival was found at Kozlov Cape, not in the Kuril Islands where the population is increasing, so we suggest that differences in birth rates might be an important driver of these divergent population trends. High pup survival on the Commander Islands and Kamchatka Coast may be a consequence of less frequent (e.g. biennial) reproduction there, which may permit females that skip birth years to invest more in their offspring, leading to higher pup survival, but this hypothesis awaits measurement of birth rates in these areas.

Altukhov, A. V., Permyakov, P. A., Andrews, R. D., Burkanov, V. N., Calkins, D. G., Trukhin, A. M., & Gelatt, T. S. (2012). Adult Steller sea lion mortality on rookeries in the Russian Far East, 2002– 2010. *Russian Journal of Marine Biology*, 38(6), 442-447 https://doi.org/10.1134/s106307401206003x

We used visual observations during nine field seasons to determine the causes and death rate of Steller sea lions older than 1 year on eight rookeries in the Russian Far East. The average annual death rate was 0.48% of the total recorded Steller sea lions on shore and varied among rookeriesy. The mortality did not exceed 0.29% in six rookeries, but reached 0.80–1.19% in two rookeries. Individuals of all age and sex groups were recorded among dead animals. Bulls died as a result of territorial conflicts, and cows and young lions were crushed or suffocated by bulls during copulation. The death of nearly half of the females was attributed to 11 bulls.

Burdin, A., R. Hennen, D., G. Calkins, D., Burkanov, V., S. Nikulin, V., & Yu. Lisitsina, T. (2009). Can we see a cohort effect on survival of Steller sea lions (*Eumetopias jubatus*) at Kozlova Cape rookery (eastern Kamchatka, Russia)? *Marine Mammal Science*, 25, 888-901 <u>https://doi.org/10.1111/j.1748-7692.2009.00294.x</u>

Steller sea lions (*Eumetopias jubatus*) have experienced a decline in Russia as well as the United States. The causes for the decline of the Russian population may or may not overlap the causes of the decline in Alaska. The demographics of the Russian population are not well understood and are an area of interest for scientists wishing to compare and contrast the Alaskan and Russian stocks. This study uses a unique observational system to assess survival by age at a small rookery on the Kamchatka Peninsula, Kozlova Cape. We proceeded under the hypothesis that changes in environmental conditions between years would produce noticeable differences in survival of pups born in those years. We found no evidence to support our hypothesis, but did find some differences from the Alaskan population in estimated survival for the juvenile stage class. This study also provides some of the history of Steller sea lions in Russia for context.

Fritz, L. W., Chumbley, K., Towell, R. G., Luxa, K., & Cutler, J. (2018). Short-term survival rates of branded Steller sea lion pups. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-368. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/14855</u>

Survival rates of western Steller sea lion (*Eumetopias jubatus*) pups (total N = 621) were estimated during 2000, 2002, and 2004 at one rookery on Marmot Island and during 2003 and 2005 at two rookeries on Ugamak Island for up to 73 days following hot-iron branding. Estimated daily apparent survival rates increased and standard errors of the estimates decreased with increasing durations of inseason monitoring. An asymptotic apparent survival rate ([phi] alpha) of 0.9995 d⁻¹ was estimated from sightings of marked pups on 7-30 occasions between 1 and 73 days after branding, as well as in subsequent years through 2015. Sex and pup mass at the time of branding were not strong factors affecting survival. Extrapolations of [phi] beyond the in-season period yielded 12-week and 1-year survival rates of 0.960 and 0.837, respectively. During six of the seven in-season monitoring periods, numbers of dead pups counted by observers following branding were less than those estimated to have died based on our calculated survival rate. Two more dead pups were counted than predicted at Marmot in 2000, but the actual cause(s) of any of the pup deaths are not known.

- Fritz, L. W., Towell, R., Gelatt, T. S., Johnson, D. S., & Loughlin, T. R. (2014). Recent increases in survival of western Steller sea lions in Alaska and implications for recovery. *Endangered Species Research*, 26(1), 13-24 Retrieved from <u>https://www.int-res.com/abstracts/esr/v26/n1/p13-24/</u>
- Survival rates of endangered western stock Steller sea lions *Eumetopias jubatus* east of Samalga Pass (~170°W) have rebounded to nearly the same levels estimated for the 1970s prior to their decline in abundance. We estimated survival of sea lions hot-branded as pups (N = 1449) in 2000-2005 using Cormack-Jolly-Seber mark-recapture models and sighting data collected through 2011. Survivorship to Age 7 yr was greater for females (range: 0.352-0.386) than males (0.228-0.275), but was similar for each sex across the study area. Survival was lowest in the first year and increased through Age 4+ yr for both sexes in the eastern Gulf of Alaska (144-150°W).

However, to the west, first-year survivorship was greater or equal to that of Year 2, and the difference was generally greater for males than females. Regional differences in the pattern of early survival could reflect spatial variability in early life history (e.g. duration of maternal care, growth rate) or habitat characteristics (e.g. prey availability, rates of predation). Population models indicate that natality of the increasing population east of Samalga Pass in 2000-2012 may not be significantly different from rates estimated for the 1970s prior to the decline in overall western abundance. Given current information, western Steller sea lions may satisfy the stock-wide demographic down-listing (to threatened status) criterion by 2015. However, due to continued abundance declines west of Samalga Pass, where no survival data are currently available, it is less certain that the western stock's regional down-listing criteria will be achieved.

Hastings, K. K. (2017). Survival of Steller sea lion (*Eumetopias jubatus*) pups during the first months of life at the Forrester Island complex, Alaska. *Journal of Mammalogy*, 98(2), 397-409 https://doi.org/10.1093/jmammal/gyw182

Mark-recapture models and a sample of 607 Steller sea lion (SSL, Eumetopias jubatus) pups born to individually marked, known-aged females were used to estimate pup survival probabilities from birth to approximately 2 months of age over 8 years (2007-2014) at the Forrester Island complex, the largest rookery in Alaska. Survival of pups was lowest (0.846/week) early in the season when pupping areas were less dense than after the time of maximum counts of adults (>= 18 June, 0.972/week). Survival was lowest in the first 2 weeks of life and then consistently high after 2 weeks of age. After including age effects, survival was lowest for pups born < 9 June and for pups of 5-7-year-old mothers than 8-20-yearold mothers. Compared to average survival over 6 other years, pup survival to 3 weeks of age was similar to 20% lower in 2010, due to a prolonged storm during the middle of the active pupping period, and in 2013, for unknown reasons but not storm-related. Average survival to 3 weeks of age was 0.79, suggesting neonatal mortality was significant and likely important to population dynamics at this stable rookery and in shaping reproductive strategies of females. To prevent disturbance of very young pups and their mothers, SSL pups are first marked for long-term mark-recapture studies at approximately 3 weeks of age throughout their range. When the high neonatal mortality rate observed in this study was ignored, the positively biased model-based population trend estimate (2.3%/year) was triple the estimate produced when the 1st-year survival estimate included neonatal mortality (0.7%/year).

Hastings, K. K., Gelatt, T. S., Jemison, L. A., Pitcher, K., Laake, J., Rea, L. D., & Pendleton, G. (n.d.). *Regional variation in Steller sea lion vital rates in Alaska*. Alaska Department of Fish and Game.

From 2000-2005, nearly 2,500 Steller sea lion (Eumetopias jubatus) pups and juveniles were branded throughout Alaska at rookeries or during dive captures by the Alaska Department of Fish and Game. Over 25,000 resights of these individuals were collected from 20012007 to assess vital rates. We examined population processes responsible for greater rates of population growth in northern vs. southern rookeries in Southeast Alaska.

Hastings, K. K., Gelatt, T. S., & King, J. C. (2009). Postbranding Survival of Steller Sea Lion Pups at Lowrie Island in Southeast Alaska. *Journal of Wildlife Management*, 73(7), 1040-1051 <u>https://doi.org/10.2193/2007-208</u> Steller sea lion (*Eumetopias jubatus*) pups (n = 366) were hot-branded at Lowrie Island, Southeast Alaska, USA, in June 2001 and 2002 for vital-rates studies. To assess potential mortality following branding, we estimated weekly survival to 12 weeks postbranding using mark-recapture models. Survival estimates ranged from 0.984/week to 0.988/week, or 0.868 over the 12-week period; varied little with sex, year, and capture area; and were higher for larger than smaller male pups and unexpectedly lower for larger than smaller female pups. Inclusion of resights at 1-3 years of age prevented a 24.5% bias in cumulative survival to 12 weeks postbranding by accounting for pups that survived but permanently emigrated from Lowrie Island during the 12-week survey. Data from doublemarked pups (i.e., branded and flipper-tagged) indicated the low brand-misreading probability of 3.1% did not bias survival estimates. Assuming survival differences between the first 2 weeks postbranding and later weeks were due entirely to the branding event, potential postbranding mortality of branded pups attributable to the branding event was 0.5-0.7%, or one pup for every 200 marked. Weekly survival of branded pups was nearly identical to estimates from a control group of undisturbed, unbranded pups born to 10-11-year-old branded adult females in 2005 (0.987-0.988/week) and similar to pup survival estimates from other otariid studies. Available data did not indicate substantial mortality to 12 weeks postbranding resulting from the branding disturbance, suggesting branding of Steller sea lion pups can be used effectively for investigations of population declines without significantly affecting population health or study goals.

Hastings, K. K., Jemison, L. A., Gelatt, T. S., Laake, J. L., Pendleton, G. W., King, J. C., . . . Pitcher, K. W. (2011). Cohort effects and spatial variation in age-specific survival of Steller sea lions from southeastern Alaska. *Ecosphere*, 2(10), <u>https://doi.org/10.1890/es11-00215.1</u>

Information concerning mechanistic processes underlying changes in vital rates and ultimately population growth rate is required to monitor impacts of environmental change on wildlife. We estimated age-specific survival and examined factors influencing survival for a threatened population of Steller sea lions (Eumetopias jubatus) in southeastern Alaska. We used mark-recapture models and data from 1,995 individuals marked at approximately one month of age at four of five rookeries in southeastern Alaska, and resignted from Oregon to the Bering Sea. Average annual survival probability for females was 0.64 for pups and 0.77 for yearlings, and increased from 0.91 to 0.96 from age 3–7 yrs. Annual survival probability of males averaged 0.60 for pups and 0.88 by 7 yrs, resulting in probability of survival to age 7, 33% lower for males compared to females. Pups from northern southeastern Alaska (including an area of low summer population size but rapid growth) were twice as likely to survive to age 7 compared to pups from southern rookeries (including a large, historical, stable rookery). Effects of early conditions on future fitness were observed as (1) environmental conditions in the birth year equally affected first- and secondyear survival, and (2) effects of body mass at approximately one month of age were still apparent at 7 yrs. Survival from 0–2 yrs varied among five cohorts by a maximum absolute difference of 0.12. We observed survival costs for long-distance dispersal for males, particularly as juveniles. However, survival was higher for non-pups that dispersed to northern southeastern Alaska, suggesting that moving to an area with greater productivity, greater safety, or lower population size may alleviate a poor start and provide a mechanism for spatial structure for sea lion populations.

Hastings, K. K., Jemison, L. A., & Pendleton, G. W. (2018). Survival of adult Steller sea lions in Alaska: senescence, annual variation and covariation with male reproductive success. *Royal Society Open Science*, <u>https://doi.org/10.1098/rsos.170665</u> Population dynamics of long-lived vertebrates depend critically on adult survival, yet factors affecting survival and covariation between survival and other vital rates in adults remain poorly examined for many taxonomic groups of longlived mammals (e.g. actuarial senescence has been examined for only 9 of 34 extant pinniped species using longitudinal data). We used mark–recapture models and data from 2795 Steller sea lion (Eumetopias jubatus) pups individually marked at four of five rookeries in southeastern Alaska (SEAK) and resighted for 21 years to examine senescence, annual variability and covariation among life-history traits in this long-lived, sexually dimorphic pinniped. Sexes differed in age of onset (approx. 16–17 and approx. 8–9 years for females and males, respectively), but not rate (–0.047 and –0.046/year of age for females and males) of senescence. Survival of adult males from northern SEAK had greatest annual variability (approx. ±0.30 among years), whereas survival of adult females ranged approximately ±0.10 annually. Positive covariation between male survival and reproductive success was observed. Survival of territorial males was 0.20 higher than that of non-territorial males, resulting in the majority of males alive at oldest ages being territorial.

Kaplan, C. C., White, G. C., & Noon, B. R. (2008). Neonatal survival of Steller sea lions (*Eumetopias jubatus*). *Marine Mammal Science*, 24(3), 443-461 <u>https://doi.org/10.1111/j.1748-7692.2008.00203.x</u>

Neonatal survival of Steller sea lions (*Eumetopias jubatus*) are often considered inconsequential to their population dynamics. However, observations of dead animals on rookeries and in surrounding waters suggest that early mortality is not uncommon. This study used the natural markings of adult females in a mark and resighting framework to estimate the apparent survival (phi) of pups with the Cormack-Jolly-Seber model at two sites on Lowrie Island, Alaska from birth to 3 wk old. Estimates varied greatly by site and year; 2002 Area 5: (phi) over cap = 0.423 (95% CI: 0.199, 0.684; n = 21), 2002 Area 1: (phi) over cap = 0.744 (0.437, 0.916; n = 21), 2003 Area 5: (phi) over cap = 0.585 (0.414, 0.738; n = 56), and 2003 Area 1: (phi) over cap = 0.679 (0.569, 0.772). Survival was lowest on the first day of life and then leveled off at a higher rate. None of the four environmental covariates we considered (swell height, interaction of tide and swell heights, density, or birth date) were significantly related to neonatal survival. Our results suggest that estimates of first-year survival that do not account for mortality prior to dispersal from the natal rookery may significantly overestimate survival rate.

Loughlin, T. R., & York, A. E. (2000). An accounting of the sources of Steller sea lion, *Eumetopias jubatus*, mortality. *Marine Fisheries Review*, 62(4), 40-45 Retrieved from http://aquaticcommons.org/9764/

During 1991-2000, the western stock of Steller sea lions, *Eumetopias jubatus*, declined at 5.03% (SE = 0.25%) per year, statistically significant rates (P < 0.10) in all but the eastern Aleutian Islands region. The greatest rates of declines occurred in the eastern and central Gulf of Alaska and the western Aleutian Islands (> 8.2% per year). Using a published correction factor, we estimated the total non-pup population size in Alaska of the western stock of Steller sea lions to be about 33,000 animals. Based on a published life table and the current rate of decline, we estimate that the total number of mortalities of non-pup Steller sea lions during 1991-2000 was about 6,383 animals; of those, 4,718 (74%) are mortalities that would have occurred if the population were stable, and 1,666 (26%) are additional mortalities that fueled the decline. We tabulated the levels of reported anthropogenic sources of mortality (subsistence, incidental take in fisheries, and research), estimated another (illegal shooting),

then approximated levels of predation (killer whales and sharks). We attempted to partition the various sources of "additional" mortalities as anthropogenic and as additional mortality including some predation. We classified 436 anthropogenic mortalities and 769 anthropogenic plus some predation mortalities as "mortality above replacement"; this accounted for 26% and 46% of the estimated total level of "mortality above replacement", respectively. The remaining mortality (74% and 54%, respectively) was not attributed to a specific cause and may be the result of nutritional stress.

Mamaev, E. G., & Burkanov, V. N. (1996). The state of the breeding group of Steller's sea lions Eumetopias jubatus (Pinnipedia, Otariidae) on the southeastern rookery of Medny Island (Commodore I.): TINRO Tsentr. Retrieved from <u>https://search.proquest.com/earthatmosphericaquatic/docview/16294229/28C57EBF6BAB49E8</u> <u>PQ/1?accountid=28258</u>

The paper presents data on the abundance of different sex-age groups of the sea lion (E. jubatus) present on the rookery during the summer seasons of 1991, 1992 and 1993. The abundance of the breeding animals and the birth rate did not change over the observation period, and the newborn mortality did not exceed the rate normal for the species. The observed decreasing trend in the abundance of juveniles on the rookery suggests low juvenile survival, however their movement to other rookeries is also possible.

Maniscalco, J. M. (2014). The effects of birth weight and maternal care on survival of juvenile Steller sea lions (*Eumetopias jubatus*). *PLoS ONE*, 9(5), e96328 <u>https://doi.org/10.1371/journal.pone.0096328</u>

Steller sea lions were listed as endangered following a collapse of the western distinct population beginning in the late 1970s. Low juvenile survival has been implicated as a factor in the decline. I conducted a multistate mark-recapture analysis to estimate juvenile survival in an area of the western population where sea lions are showing signs of recovery. Survival for males and females was 80% between 3 weeks and 1 year of age. Approximately 20% of juveniles continued to be nursed by their mothers between ages 1 and 2 and 10% between ages 2 and 3. Survival for juveniles that suckled beyond 1 year was 88.2% and 89.9% to ages 2 and 3, respectively. In contrast, survival for individuals weaned by age 1 was 40.6% for males and 64.2% for females between ages 1 and 2. Birth mass positively influenced survival for juveniles weaned at age 1 but had little effect on individuals continuing to suckle. Cumulative survival to age 4 was double that estimated during the population decline in this region. Evidence suggests that western Steller sea lions utilize a somewhat different maternal strategy than those in the eastern distinct population. Western adult females generally invest more in their pups during the first year but wean offspring by age 1 more often. This results in better survival to age 1, but greater mortality between ages 1 and 3 compared to the eastern population. Different maternal strategies may reflect density dependent pressures of populations at opposite levels of abundance.

Maniscalco, J. M., Calkins, D. G., Parker, P., & Atkinson, S. (2008). Causes and Extent of Natural Mortality Among Steller Sea Lion (*Eumetopias jubatus*) Pups. *Aquatic Mammals*, 34(3), 277-287 <u>https://doi.org/10.1578/am.34.3.2008.277</u> The authors studied the causes and extent of mortality in endangered Steller sea lion (*Eumetopias jubatus*) pups at a small rookery in the northern Gulf of Alaska over seven consecutive summers (2001 to 2007). Mortality among pups up to 2.5 mo post-partum (n = 69) averaged 15.4% (range = 3.8 to 27.8%) and was not dependent on number of pups born. The causes of mortalities varied greatly from year to year, although high surf conditions and killer whale predation accounted for more than half of all deaths. Stillbirths, traumatic injury, and maternal abandonment were individually relatively minor sources of mortality. Causes of mortality were age-dependent. Pups greater than 2 wks old were not washed away by high surf conditions or killed by traumatic injury; whereas pups less than 1 mo old were not subject to predation. The authors also summarize historical observations of pup mortality in this species to compare similarities over time and differences between regions. Current and historic evidence suggests that rates of pup mortality have been higher in the eastern/increasing population of Steller sea lions compared to the western/decreasing population. Therefore, an increase in pup mortality was probably not a major cause of the overall population decline or current lack of recovery.

Maniscalco, J. M., Springer, A. M., Adkison, M. D., & Parker, P. (2015). Population trend and elasticities of vital rates for Steller sea lions (*Eumetopias jubatus*) in the eastern Gulf of Alaska: a new lifehistory table analysis. *PLoS ONE*, 10(10), e0140982 https://doi.org/10.1371/journal.pone.0140982

Steller sea lion (*Eumetopias jubatus*) numbers are beginning to recover across most of the western distinct population segment following catastrophic declines that began in the 1970s and ended around the turn of the century. This study makes use of contemporary vital rate estimates from a trend-site rookery in the eastern Gulf of Alaska (a sub-region of the western population) in a matrix population model to estimate the trend and strength of the recovery across this region between 2003 and 2013. The modeled population trend was projected into the future based on observed variation in vital rates and a prospective elasticity analysis was conducted to determine future trends and which vital rates pose the greatest threats to recovery. The modeled population grew at a mean rate of 3.5% per yr between 2003 and 2013 and was correlated with census count data from the local rookery and throughout the eastern Gulf of Alaska. If recent vital rate estimates continue with little change, the eastern Gulf of Alaska population could be fully recovered to pre-decline levels within 23 years. With density dependent growth, the population would need another 45 years to fully recover. Elasticity analysis showed that, as expected, population growth rate (lambda) was most sensitive to changes in adult survival, less sensitive to changes in juvenile survival, and least sensitive to changes in fecundity. A population decline could be expected with only a 6% decrease in adult survival, whereas a 32% decrease in fecundity would be necessary to bring about a population decline. These results have important implications for population management and suggest current research priorities should be shifted to a greater emphasis on survival rates and causes of mortality.

Maniscalco, J. M., Springer, A. M., & Parker, P. (2010). High Natality Rates of Endangered Steller Sea Lions in Kenai Fjords, Alaska and Perceptions of Population Status in the Gulf of Alaska. *PLoS ONE*, 5(4), 1-9 <u>https://doi.org/10.1371/journal.pone.0010076</u>

Steller sea lions experienced a dramatic population collapse of more than 80% in the late 1970s through the 1990s across their western range in Alaska. One of several competing hypotheses about the cause holds that reduced female reproductive rates (natality) substantively contributed to the decline and continue to limit recovery in the Gulf of Alaska despite the fact that there have been very few attempts to directly measure natality in this species. We conducted a longitudinal study of natality among individual Steller sea lions (n = 151) at a rookery and nearby haulouts in Kenai Fjords, Gulf of Alaska during 2003–2009. Multi-state models were built and tested in Program MARK to estimate survival, resighting, and state transition probabilities dependent on whether or not a female gave birth in the previous year. The models that most closely fit the data suggested that females which gave birth had a higher probability of surviving and giving birth in the following year compared to females that did not give birth, indicating some females are more fit than others. Natality, estimated at 69%, was similar to natality for Steller sea lions in the Gulf of Alaska prior to their decline (67%) and much greater than the published estimate for the 2000s (43%) which was hypothesized from an inferential population dynamic model. Reasons for the disparity are discussed, and could be resolved by additional longitudinal estimates of natality at this and other rookeries over changing ocean climate regimes. Such estimates would provide an appropriate assessment of a key parameter of population dynamics in this endangered species which has heretofore been lacking. Without support for depressed natality as the explanation for a lack of recovery of Steller sea lions in the Gulf of Alaska, alternative hypotheses must be more seriously considered.

Parker, P., Harvey, J. T., Maniscalco, J. M., & Atkinson, S. (2008). Pupping-site fidelity among individual Steller sea lions (*Eumetopias jubatus*) at Chiswell Island, Alaska. *Canadian Journal of Zoology*, 86(8), 826-833 <u>https://doi.org/10.1139/z08-058</u>

Pupping-site fidelity (defined as pupping within 5.8 m of a previous location in >= 2 years) in Steller sea lions (*Eumetopias jubatus* (Schreber. 1776)) was investigated during the breeding seasons from 2001 to 2005 at Chiswell Island, a small rookery in the Gulf of Alaska. Density of females was minimal with 54-80 pups born. Photo-identification of individuals and GPS points, including elevation of the rookery, were used to determine locations of 297 births. Sixty-four percentage (35/55) of the females exhibited pupping-site fidelity, and mean frequency of site fidelity was greater for females that gave birth >3 times. Fifty percentage of the births occurred at 22% of the locations for all years, indicating that multiple births occurred at some locations throughout the breeding season. Competition or aggression among females for specific pupping locations before birth was not observed, and there was no temporal order of pupping locations used, indicating that the rookery was not overcrowded and that many suitable pupping locations existed. Multiparous females gave birth at significantly greater distances from the surf zone than primiparous females. Long-term monitoring of pupping-site fidelity in combination with other measures of maternal care will ultimately determine which factors have the greatest effect on pup survival.

Pendleton, G. W., Hastings, K. K., Rea, L. D., Jemison, L. A., O'Corry-Crowe, G. M., & Beckmen, K. B. (2016). Short-term survival of Steller sea lion (*Eumetopias jubatus*) pups: Investigating the effect of health status on survival. *Marine Mammal Science*, 32(3), 931-944 <u>https://doi.org/10.1111/mms.12308</u>

We estimated survival probabilities for Steller sea lion (*Eumetopias jubatus*) pups from 3 wk to 6 wk old and from 6 wk to 1 yr at three rookeries in southeastern Alaska. We also investigated the effect of mass, body condition, health variables, and the genetic origin on 3-6 wk survival. Survival differed substantially among rookeries and between sexes, with survival lowest at Hazy Islands, intermediate at White Sisters, and highest at Graves Rocks and survival lower for males than females. Body mass, body condition, and hematocrit were positively related to survival and blood % H2O and haptoglobin level (for females; no relationship for males) were negatively related to survival. Taking predictor variables collectively, sea lion pups at Hazy Islands, which had the lowest survival probability, had the lowest mass, hematocrit, and hemoglobin, and had high levels of blood % H2O, and hookworm infection. Values from Graves Rocks, which had the highest survival, were the opposite of those from Hazy Island (e.g., high mass, body condition, hematocrit, and hemoglobin), while those from White Sisters (intermediate survival) had varying means (e.g., high hematocrit and hemoglobin and low hookworms, but also low body condition); these patterns suggest that physiological factors potentially underlie rookery differences in survival.

Pendleton, G. W., Pitcher, K. W., Fritz, L. W., York, A. E., Raum-Suryan, K. L., Loughlin, T. R., . . . Gelatt, T. S. (2006). Survival of Steller sea lions in Alaska: a comparison of increasing and decreasing populations. *Canadian Journal of Zoology*, 84(8), 1163-1172 https://doi.org/10.1139/z06-103

Steller sea lion (Eumetopias jubatus (Schreber, 1776)) populations have had differing dynamics in different regions of Alaska over the past 30 years. The western population (west of 1448W, near Cape Suckling) declined by approximately 85% between the 1970s and 2000, while the eastern population has increased at a rate of over 3%/year. Past research has indicated that the decline in the western population likely resulted from decreased juvenile survival and smaller declines in adult female survival and reproduction. Based on repeated observations (1987–2003) of sea lions branded as pups at Marmot Island (58.2168N, 151.8408W; western population; branded in 1987–1988) and at the Forrester Island rookery complex (54.8598N, 133.5398W; eastern population; branded in 1994–1995), we used markresight analyses to estimate age-specific survival probabilities. Juvenile sea lion survival probability at Marmot Island from 1988 to 1991 was lower than survival estimates at that location in the 1970s (assumed stable population) and lower than juvenile survival at Forrester Island from 1995 to 1998 (increasing population). Adult female survival at Marmot Island from 1992 to 2003 was only slightly reduced compared with that in the 1970s but was substantially lower than that at Forrester Island (1999–2003). In addition, and contrary to the typical pattern (e.g., Forrester Island), adult female survival probabilities at Marmot Island were indistinguishable from adult male survival probabilities. This suggests that regardless of which factors altered the dynamics of the western Steller sea lion population, they differentially affected females.

Trukhin, A. M. (2008). Survival and reproduction of indigenous Steller sea lions (*Eumetopias jubatus*) at the reproductive rookery Raykoke Island. *Transactions of the Pacific Research Fisheries Centre*, 152, 121-131 Retrieved from <u>https://cyberleninka.ru/article/v/vyzhivaemost-i-uchastie-v-</u> <u>razmnozhenii-aborigennyh-sivuchey-eumetopias-jubatus-na-reproduktivnom-lezhbische-o-</u> <u>raykoke</u>

Survival rate for Steller sea lions of both sexes born in 1989, 1996-1999 is estimated by tagging at Raykoke Island (the Kurils) in 2001-2004. The rate was different for different generations probably because of year-to-year changes in environmental conditions. The number of sea lions having reached the age of five years could vary in twice. Moreover, the rate depended on sex. It was approximately the same up to the age of 7-8 years, but mortality of males became higher after physical growth completion. The highest survival was registered for the males in the phase of pubescence and physical maturing (< 7 years old) and for the middle-aged females (12-15 years old). At the age of 15 years the number of females was approximately tenfold higher then that of males. No one of 30 males had reached the age of 7-8 years in 2003-2004 owned a plot in harem territory of the rookery and took part in reproduction.

The age of 15 years is probably close to critical for males, but they were active in reproduction in this age, too. Females can calve for a first time at the age of 4 years, but such females were no more than 8.8 % in the rookery. As a whole, the females reached pubescence at the age of 4-5 years. Among 5 years old females, 51.7 % of animals had puppies. Rate of dry females was rather high in the age group 5-8 years, but elder females took part in reproduction regularly. The highest level of reproductive value was noted for middle-aged females, who brought the most significant contribution in reproduction of population. The Steller sea lions number at the Raykoke Island rookery held stable by means of internal resources of the local aggregation formed mainly by aboriginal sea lions. Immigrants had minor contribution in breeding here (approximately 3 %), although the immigrant sea lions were 35 % among tagged animals registered at the Raykoke Island in 2001-2004. The immigrant females were originated only from the rookeries at Lovushki Rock and Sredny Islands.

Section XIV: Threats

Akamatsu, T., Nakamura, K., Nitto, H., & Watabe, M. (1996). Effects of Underwater Sounds on Escape Behavior of Steller Sea Lions. *Fisheries Science*, *62*(4), 503-510. https://doi.org/10.2331/fishsci.62.503

The reactions of 10 captive Steller sea lions *Eumetopias jubatus*, including one adult male, four adult females and five juvenile animals to underwater sounds, with and without the presence of a baited fishing net, were observed. Two narrow spectrum sounds, an 8 kHz pure tone and a 1 kHz to 4 kHz frequency sweep, three broad spectrum sounds, two mechanically generated impulse sounds, and the recorded vocalization of a killer whale were used. The reactions of Steller sea lions were divided into three categories. Category O: Both adult and juvenile Steller sea lions landed on a side of their pool during a one-minute period timed from the start of the sound projection. Category a: More than two juvenile Steller sea lions landed. Category X:A single juvenile Steller sea lion or no animals landed. Impulsive sounds transmitted at high source level (210 dB re 1 mu Pa at 1 m) or pure tone sounds (165 dB source level) were found to repel adult Steller sea lions. Broad band spectrum sounds did not repel adult and juvenile Steller sea lions after successive sound projections. The male Steller sea lion was only deterred from eating the fish entangled in the net by the high source level impulsive sound. The acoustic characteristics required to repel Steller sea lions are thought to be narrow spectrum within the sensitive range of a Steller sea lion's audible frequency and above 165 dB sound pressure level. However, Steller sea lions appear to acclimatize to repeated sound projections, and a sound pressure level below 165 dB does not appear to be enough to repel Steller sea lions from a fishing net.

Alava, J. J., Lambourn, D., Olesiuk, P., Lance, M., Jeffries, S. J., Gobas, F. A. P. C., & Ross, P. S. (2012).
Pbde Flame Retardants and Pcbs in Migrating Steller Sea Lions (*Eumetopias Jubatus*) in the Strait of Georgia, British Columbia, Canada. *Chemosphere*, *88*(7), 855-864.
https://doi.org/10.1016/j.chemosphere.2012.03.094

Polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) were measured in blubber biopsy samples from 22 live-captured Steller sea lions (*Eumetopias jubatus*) that had just entered the Strait of Georgia, British Columbia, Canada, for their overwintering feeding season. PBDE ranged from 50µgkg-1 (lipid weight) in adult females to 3780µgkg-1 in subadult individuals. PCBs ranged from 272µgkg–1 in adult females to 14280µgkg–1 in subadult individuals. While most PBDE and PCB congeners were transferred through milk to pups, PCBs with logKOW>7.0 (PCBs 206, 207, 208 and 209) appeared constrained, resulting in a lighter mixture in pups compared to adult females. The ratio of individual PCB congeners by metabolic group (Groups I, II, III, IV and V) to PCB-153 regressed against length of males suggested poor biotransformation of these compounds (slopes did not differ from zero, p>0.05). PBDE congeners 49, 99, 153 and 183 appeared bioaccumulative (slopes of ratio BDE/PCB 153 versus length were higher than zero, p<0.05), but the dominance of the single congener, BDE-47 (64% of total PBDEs), likely due in part to debromination pathways, reduced our ability to explore congener-specific dynamics of PBDEs in these pinnipeds. With 80% of our Steller sea lions exceeding a recent toxicity reference value for PCBs, the fasting-associated mobilization of these contaminants raises concerns about a heightened vulnerability to adverse effects during annual migrations.

Allen, B. M., Helker, V. T., & Jemison, L. A. (2014). Human-Caused Injury and Mortality of NMFS-Managed Alaska Marine Mammal Stocks, 2007-2011. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC 274. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/4687</u>

This report consists of records of human-caused mortality and injury for cetaceans and pinnipeds occurring in Alaska and assessed within the Alaska Marine Mammal Stock Assessment Reports (SARs). I f deaths or injuries to marine mammal s assessed in the U.S. Pacific Marine Mammal SARs are reported in Alaska waters, the records are sent to the Southwest Fisheries Science Center (SWFSC) for inclusion in the report summarizing mortality and injury for U.S. Pacific west coast marine mammal stocks (Carretta et al. 2013). Sources of marine mammal injury and mortality data include, but are not limited to, marine mammal stranding network responders, fishery observer programs, disentanglement network teams, opportunistic observations, and self-reporting of entanglements and vessel collisions. Most humancaused marine mammal deaths and injuries result from entanglements in commercial and recreational fishing gear, entanglements in marine debris, and vessel collision. Additionally, other incidental or intentional injuries are also reported. Deaths and injuries resulting from subsistence hunts and harvests are not reported in this document but are available in the SARs (Allen and Angliss in prep). Humancaused mortality and injury data for the 5-year period from 2007 to 2011 were compiled, and each injury record assessed to determine whether it was a non- serious injury (NSI) or serious injury (SI). All information pertinent to decisions of NSI and SI is presented in this report and tabulated for each stock. Mortality and serious injury data were summarized by stock, source, and year for estimates reported in the 2013 SARs (Allen and Angliss in prep.)

Ando, N., Isono, T., & Sakurai, Y. (2005). Trace Elements in the Teeth of Steller Sea Lions (*Eumetopias Jubatus*) from the North Pacific. *Ecological Research, 20*(4), 415-423. https://doi.org/10.1007/s11284-005-0037-x

The occurrence of trace elements in the teeth of Steller sea lions (*Eumetopias jubatus*) collected from the North Pacific from 1968 to 1999 is described. Using particle-induced X-ray emission analysis, we detected eight trace elements: Ca. Mn, Fe, Cu, Zn, Br, Sr and Pb. We used a general linear model to evaluate long-term trends of trace element accumulation. Zn (Zn/Ca) and Fe (Fe/Ca) levels both varied during the last three decades, and showed significant differences between animals of different age (Fe/Ca), season (Zn/Ca and Fe/Ca), and sex (Zn/Ca); both Zn/Ca and Fe/Ca ratios were higher in young males than older males. Pb was detected in 39% of the samples from Hokkaido (Japan) and 22% of those

from Alaska. The high levels of Pb recorded in 1975 were thought to be related to the use of leaded gasoline during the 1970s. Our results indicate that the levels of trace elements in the teeth of Steller sea lions can be used as indicators of temporal and spatial variations of trace element pollution.

Balsiger, J. W. (2018). Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion for Construction at the City Dock and Ferry Terminal in Tenakee Springs, Alaska and Issuance of Incidental Harassment Authorization under 101(a)(5)(D) of the Marine Mammal Protection Act. National Marine Fisheries Service Office of Protected Resources. AKR-2018-9756. Retrieved from https://repository.library.noaa.gov/view/noaa/17858

For the actions described in this document, the action agencies are the NMFS Office of Protected Resources Permits and Conservation Division (PR1), which proposes to permit Marine Mammal Protection Act (MMPA) Level B take of the endangered western Distinct Population Segment (WDPS) Steller sea lion (*Eumetopias jubatus*) and the threatened Mexico Distinct Population Segment (DPS) humpback whale (Megaptera novaeangliae) in conjunction with construction activities at the Tenakee Springs Ferry Terminal (see Figure 1-2), and the Federal Highway Administration (FHWA), which proposes to fund this project. The environmental review, consultation, and other actions required by applicable Federal environmental laws for this project are being carried out by the Alaska Department of Transportation and Public Facilities (ADOT&PF) pursuant to 23 U.S.C. § 326 and a Memorandum of Understanding dated September 18, 2015 and executed by FHWA and ADOT&PF. The consulting agency for this proposal is NMFS's Alaska Regional Office (AKR). This document represents NMFS's biological opinion (opinion) on the effects of this proposal on endangered and threatened species and designated critical habitat for those species.

Barron, M. G., Heintz, R., & Krahn, M. M. (2003). Contaminant Exposure and Effects in Pinnipeds: Implications for Steller Sea Lion Declines in Alaska. *Science of The Total Environment, 311*(1-3), 111-133. <u>https://doi.org/10.1016/s0048-9697(03)00140-2</u>

After nearly 3 decades of decline, the western stock of Steller sea lions (SSL; Eumetopias jubatus) was listed as an endangered species in 1997. While the cause of the decline in the 1970s and 1980s has been attributed to nutritional stress, recent declines are unexplained and may result from other factors including the presence of environmental contaminants. SSL tissues show accumulation of butyltins, mercury, PCBs, DDTs, chlordanes and hexachlorobenzene. SSL habitats and prey are contaminated with additional chemicals including mirex, endrin, dieldrin, hexachlorocyclohexanes, tetrachlorodibenzo-pdioxin (TCDD) and related compounds, cadmium and lead. In addition, many SSL haulouts and rookeries are located near other hazards including radioactivity, solvents, ordnance and chemical weapon dumps. PCB and DDT concentrations measured in a few SSL during the 1980s were the highest recorded for any Alaskan pinniped. Some contaminant exposures in SSL appear to be elevated in the Gulf of Alaska and Bering Sea compared to southeast Alaska, but there are insufficient data to evaluate geospatial relationships with any certainty. Based on very limited blubber data, current levels of PCBs may not pose a risk to SSL based on comparison to immunotoxicity tissue benchmarks, but SSL may have been at risk from pre-1990 PCB exposures. While exposure to PCBs and DDTs may be declining, SSL are likely exposed to a multitude of other contaminants that have not been monitored. The impacts of these exposures on SSL remain unknown because causal effects have not been established. Field studies with SSL have been limited in scope and have not yet linked contaminant exposures to adverse animal health or population effects. Several biomarkers may prove useful for monitoring exposure and additional

research is needed to evaluate their utility in SSL. We conclude that there are insufficient data to reject the hypothesis that contaminants play a role in the continued decline of SSL, and suggest that a coordinated monitoring program be developed which can be related to key biological, ecological and laboratory toxicity data.

 Beckmen, K. B., Blake, J. E., Ylitalo, G. M., Stott, J. L., & O'Hara, T. M. (2003). Organochlorine Contaminant Exposure and Associations with Hematological and Humoral Immune Functional Assays with Dam Age as a Factor in Free-Ranging Northern Fur Seal Pups (*Callorhinus Ursinus*). *Marine Pollution Bulletin*, 46(5), 594-606. https://doi.org/10.1016/S0025-326X(03)00039-0

Potential effects of organochlorine contaminant (OC) exposure on humoral immune function and health of free-ranging northern fur seals were investigated. Forty-two "neonates" were captured for blood sample collection and re-sampled as "pups" 29–51 days later. OCs were extracted from whole blood to identify polychlorinated biphenyl congeners and chlorinated pesticides by high performance liquid chromatography. Humoral immune function was assessed by antibody responses to vaccination and immunoglobulin concentrations. Additional health status indicators included leukocyte counts and haptoglobin concentrations. Mean OC concentrations were higher in neonates than at recapture. Neonates of young dams had higher mean OC concentrations than neonates of older dams. A higher proportion of old dam's pups developed a twofold or greater increase in antigen-specific antibodies compared to young dam's pups. Higher OC exposure and poor immune responses in first-born pups may indicate a higher risk of secondary morbidity and mortality than pups of multiparous dams.

Beckmen, K. B., Duffy, L. K., Zhang, X. M., & Pitcher, K. W. (2002). Mercury Concentrations in the Fur of Steller Sea Lions and Northern Fur Seals from Alaska. *Marine Pollution Bulletin*, 44(10), 1130-1135. <u>https://doi.org/10.1016/s0025-326x(02)00167-4</u>

We compared total mercury (THg) concentrations in the fur of northern fur seals (Callorhinus ursinus) from the depleted Pribilof Islands population with those of both declining and thriving populations of Steller sea lions (*Eumetopias jubatus*) from Prince William Sound (PWS) and Southeast Alaska (SEA), respectively. Relatively low wet weight concentrations (ranges) of THg were detected in the fur of Steller sea lion (SSL) pups (0.90-3.14 mug/g) and juveniles (0,56 6.75 mug/g) from both area, in 1998 and 2000 compared to northern fur seal (NFS) pups (3.15-8.14 mug/g) in 2000. The mean concentration +/- SD fur SSLs sampled were 1.46 +/- 0.64 mug/g for pups (n = 22) and 2.74 +/- 2.89 mug/g for juveniles (n = 6). Analyses indicated higher THg concentrations from SSL pups from PWS compared to the SEA. Mean +/- SD. THg in the NFS pups was 4.9 +/- 1.42 mug/g (n = 34) and for post-partum dams was 7.84 +/- 1.78 mug/g (n = 12).

Beckmen, K. B., Keogh, M. J., Burek-Huntington, K. A., Ylitalo, G. M., Fadely, B. S., & Pitcher, K. W. (2016).
Organochlorine Contaminant Concentrations in Multiple Tissues of Free-Ranging Steller Sea
Lions (*Eumetopias Jubatus*) in Alaska. *Science of The Total Environment, 542*, 441-452.
https://doi.org/10.1016/j.scitotenv.2015.10.119

The relationships of selected organochlorine (OC) contaminants between blubber, blood, feces, and milk of young, free-ranging Steller sea lions (*Eumetopias jubatus*) were examined. Both between and within each tissue there was considerable individual variation. In spite of the variation, similar patterns were

observed across the tissues for most of the selected PCB congeners. In all four tissues, the major PCB congeners were PCB101, PCB118, PCB138, and PCB153. The most prominent congener, both as a weight (ng/g lipid) and as a percentage of summed PCBs (Σ PCBs), was PCB 153. Comparisons between paired tissues showed that Σ DDTs in blubber samples were related to concentrations in blood, feces, and milk. The Σ PCBs in blubber were related to concentrations in milk and fecal samples, though the relationship with feces was weak. Our findings show milk samples, in particular, are useful for assessing OCs in young sea lions. Blubber concentrations of PCB101, PCB118, and PCB138 were an order of magnitude higher than those in milk, supporting the biomagnification of these PCB congeners in SSL tissues. The findings indicate alternative tissues may be used as indicators of relative contaminant exposure in lieu of surgical blubber biopsy.

Braune, B. M., Outridge, P. M., Fisk, A. T., Muir, D. C. G., Helm, P. A., Hobbs, K., . . . Stirling, I. (2005). Persistent Organic Pollutants and Mercury in Marine Biota of the Canadian Arctic: An Overview of Spatial and Temporal Trends. *Science of The Total Environment, 351-352*, 4-56. <u>https://doi.org/10.1016/j.scitotenv.2004.10.034</u>

This review summarizes and synthesizes the significant amount of data which was generated on mercury (Hg) and persistent organic pollutants (POPs) in Canadian Arctic marine biota since the first Canadian Arctic Contaminants Assessment Report (CACAR) was published in 1997. This recent body of work has led to a better understanding of the current levels and spatial and temporal trends of contaminants in biota, including the marine food species that northern peoples traditionally consume. Compared to other circumpolar countries, concentrations of many organochlorines (OCs) in Canadian Arctic marine biota are generally lower than in the European Arctic and eastern Greenland but are higher than in Alaska, whereas Hg concentrations are substantially higher in Canada than elsewhere. Spatial coverage of OCs in ringed seals, beluga and seabirds remains a strength of the Arctic contaminant data set for Canada. Concentrations of OCs in marine mammals and seabirds remain fairly consistent across the Canadian Arctic although subtle differences from west to east and south to north are found in the proportions of various chemicals. The most significant development since 1997 is improvement in the temporal trend data sets, thanks to the use of archived tissue samples from the 1970s and 1980s, longterm studies using archeological material, as well as the continuation of sampling. These data cover a range of species and chemicals and also include retrospective studies on new chemicals such as polybrominated diphenyl ethers. There is solid evidence in a few species (beluga, polar bear, blue mussels) that Hg at some locations has significantly increased from pre-industrial times to the present; however, the temporal trends of Hg over the past 20–30 years are inconsistent. Some animal populations exhibited significant increases in Hg whereas others did not. Therefore, it is currently not possible to determine if anthropogenic Hg is generally increasing in Canadian Arctic biota. It is also not yet possible to evaluate whether the recent Hg increases observed in some biota may be due solely to increased anthropogenic inputs or are in part the product of environmental change, e.g., climate warming. Concentrations of most "legacy" OCs (PCBs, DDT, etc.) significantly declined in Canadian Arctic biota from the 1970s to the late 1990s, and today are generally less than half the levels of the 1970s, particularly in seabirds and ringed seals. Chlorobenzenes and endosulfan were among the few OCs to show increases during this period while ∑HCH remained relatively constant in most species. A suite of new-use chemicals previously unreported in Arctic biota (e.g., polybrominated diphenyl ethers (PBDEs), short chain chlorinated paraffins (SCCPs), polychlorinated naphthalenes (PCNs), perfluoro-octane sulfonic acid (PFOS) and perfluorocarboxylic acids (PFCAs)) has recently been found, but there is insufficient information to assess species differences, spatial patterns or food web dynamics for these compounds. Concentrations of these new chemicals are generally lower than legacy OCs, but there is

concern because some are rapidly increasing in concentration (e.g., PBDEs), while others such as PFOS have unique toxicological properties, and some were not expected to be found in the Arctic because of their supposedly low potential for long-range transport. Continuing temporal monitoring of POPs and Hg in a variety of marine biota must be a priority.

 Burek, K. A., Gulland, F. M., Sheffield, G., Beckmen, K. B., Keyes, E., Spraker, T. R., ... Trites, A. W. (2005). Infectious Disease and the Decline of Steller Sea Lions (*Eumetopias Jubatus*) in Alaska, USA: Insights from Serologic Data. *Journal of Wildlife Diseases, 41*(3), 512-524. https://doi.org/10.7589/0090-3558-41.3.512

Serologic data were examined to determine whether infectious disease may have played a role in the decline of Steller sea lions (Eumetopias jubatus) in the Gulf of Alaska and Aleutian Islands, USA. Available published data, unpublished data, and recent collections (1997-2000) were compared and reviewed. Data were stratified by geography to compare the declining western Alaskan population in the Aleutian Islands through eastern Prince William Sound to the increasing population in southeastern Alaska. Prevalences of antibodies from the 1970s to the early 1990s were noted for Leptospira interrogans, Chlamydophila psittaci, Brucella spp., phocid herpesvirus-1, and calciviruses. Serum samples collected from 1997-2000 were tested for antibodies to these agents as well as to marine mammal morbilliviruses, canine parvovirus, and canine adenovirus-1 and -2. Conclusions could not be drawn about changes in antibody prevalence to these agents during the decline of Steller sea lions, however, because data were incomplete or not comparable as a result of inconsistencies in testing techniques. Despite these shortcomings, results provided no convincing evidence of significant exposure of Steller sea lions to morbilliviruses, Brucella spp., canine parvovirus, or L. interrogans. Steller sea lions have been exposed to phocid herpesviruses, caliciviruses, canine adenovirus, and C. psittaci or to cross-reactive organisms in regions of both increasing and decreasing sea lion abundance. Based on similar antibody prevalence estimates from the increasing and decreasing populations, these agents are unlikely to have been the primary cause of the population decline. They may have contributed to the decline or impeded population recovery, however, because of undetected mortality and morbidity or reductions of fecundity and body condition in animals under other stresses. Systematic monitoring for disease agents and their effects is needed to determine whether infectious disease currently plays a role in the decline and lack of recovery of Steller sea lions.

Carrasco, S. E., Burek, K. A., Beckmen, K. B., Oaks, J. L., Davis, M. A., Baker, K. N. K., & Mazet, J. A. K. (2011). Aerobic Oral and Rectal Bacteria of Free-Ranging Steller Sea Lion Pups and Juveniles (*Eumetopias Jubatus*) in Alaska. *Journal of Wildlife Diseases*, 47(4), 807-820. https://doi.org/10.7589/0090-3558-47.4.807

Bacteriologic cultures from oral, rectal, and lesion samples from free-ranging Steller sea lion (SSL, *Eumetopias jubatus*) pups and juveniles in Alaska (2001-2005) were examined to determine frequency of infection by a specific subset of common and pathogenic aerobic bacteria. Associations between isolated bacteria and age, sex, body condition, location, and sampling season were investigated. Salmonella spp. isolates were further evaluated to determine spatial dust :ring (n=48) and to identify serovars (n=13) and antimicrobial susceptibility patterns (n=11) We sampled 356 SSL pups (n=272) and juveniles (n=84), and identified 988 isolates of 13 bacterial genera of specific interest. Pasteurella spp. (43.8%), beta-hemolytic Streptococcus spp. (30.6%), and Mannheimia spp. (18.2%) were the most commonly isolated oral bacteria (n=499 isolates), whereas Escherichia coli (47.6%), beta-hemolytic E.

coli (32.4%), Salmonella spp. (10.4%). and Campylobacter spp. (7.8%) were the most frequently, isolated rectal bacteria (n=460 isolates). Salmonella was most commonly found in pups from western stocks and in samples collected during fall/winter seasons. A significant Salmonella cluster was detected at the Perry Island haulout. Five serovars were isolated: Enteritidis, Infant's, Newport, Reading, and Stanley. Pulsed-field gel electrophoresis provided evidence that Salmonella isolates were most likely being maintained within the SSL population in Alaska.

Castellini, J. M., Rea, L. D., Lieske, C. L., Beckmen, K. B., Fadely, B. S., Maniscalco, J. M., & O'Hara, T. M. (2012). Mercury Concentrations in Hair from Neonatal and Juvenile Steller Sea Lions (*Eumetopias Jubatus*): Implications Based on Age and Region in This Northern Pacific Marine Sentinel Piscivore. *Ecohealth*, 9(3), 267-277. https://doi.org/10.1007/s10393-012-0784-4

Mercury is a global contaminant of concern for the fetus and the neonate of piscivores. Methylmercury, produced within marine ecosystems, is of particular concern as a readily absorbed neurotoxicant transported across the blood brain barrier and transplacentally. In the North Pacific Ocean, Steller sea lions are broadly distributed apex predators and, as such, integrate complex food webs and the associated exposure and possible adverse effects of toxic and infectious agents. Hair, including lanugo, was examined using regional and age groupings to assess mercury concentrations in young Alaskan Steller sea lions. The highest concentrations of mercury occurred in the youngest animals, likely via in utero exposure. Based on the adverse developmental outcomes of methylmercury toxicity this specific cohort is of concern. Regionally, higher concentrations of mercury were observed in the endangered western population of Steller sea lions and mirrored patterns observed in human biomonitoring studies of Alaskan coastal communities. These data have broader implications with respect to human and ecosystem health as Steller sea lions rely on similar prey species and foraging areas as those targeted by commercial fisheries and subsistence users and are therefore valuable sentinels of marine ecosystem health.

Correa, L., Rea, L. D., Bentzen, R., & O'Hara, T. M. (2014). Assessment of Mercury and Selenium Tissular Concentrations and Total Mercury Body Burden in 6 Steller Sea Lion Pups from the Aleutian Islands. *Marine Pollution Bulletin, 82*(1), 175-182. <u>https://doi.org/10.1016/j.marpolbul.2014.02.022</u>

Concentrations of total mercury ([THg]) and selenium ([TSe]) were measured in several tissue compartments in Steller sea lion (*Eumetopias jubatus*) pups; in addition we determined specific compartment and body burdens of THg. Compartmental and body burdens were calculated by multiplying specific compartment fresh weight by the [THg] (summing compartment burdens equals body burden). In all 6 pup tissue sets (1) highest [THg] was in hair, (2) lowest [THg] was in bone, and (3) pelt, muscle and liver burdens contributed the top three highest percentages of THg body burden. In 5 of 6 pups the Se:Hg molar ratios among compartments ranged from 0.9 to 43.0. The pup with the highest hair [THg] had Se:Hg molar ratios in 9 of 14 compartments that were ≤0.7 potentially indicating an inadequate [TSe] relative to [THg].

Dailey, M. D., Demaree, R. S., & Critchfield, R. L. (2002). Galactosomum Stelleri Sp N. (Trematoda : Heterophyidae) from the Northern Sea-Lion, *Eumetopias Jubatus* (Schreber, 1776) (Carnivora : Otariidae). *Comparative Parasitology, 69*(1), 58-61. <u>https://doi.org/10.1654/1525-2647(2002)069[0058:Gssnth]2.0.Co;2</u>

Galactosomum stelleri sp. n. (Trematoda: Heterophyidae), a new trematode from the small intestine of the Steller's or northern sea-lion Eumetopias *jubatus* is described. An adult female specimen of E. jubatus collected from Indian Beach, Oregon, U.S.A., harbored over 100 specimens of these trematodes. The new species most closely resembles Galactosomum ubelakeri (Dailey, 1969) Pearson, 1977, and Galactosomum humbargari Park, 1936 but differs in body shape and size, lack of tegumental spines, length of esophagus, and ventral genital complex configuration. This is the third report of a species of Galactosomum from a marine mammal.

de Swart, R. L., Ross, P. S., Vos, J. G., & Osterhaus, A. D. (1996). Impaired Immunity in Harbour Seals (*Phoca Vitulina*) Exposed to Bioaccumulated Environmental Contaminants: Review of a Long-Term Feeding Study. *Environmental Health Perspectives*, 104(suppl 4), 823-828. <u>https://doi.org/10.1289/ehp.96104s4823</u>

Mass mortalities among seals and dolphins inhabiting contaminated marine regions have led to speculation about a possible involvement of immunosuppression associated with environmental pollution. To evaluate whether contaminants at ambient environmental levels can affect immune function of seals, we carried out an immunotoxicological study under semifield conditions. Two groups of 11 harbour seals (Phoca vitulina) originating from a relatively uncontaminated area were fed herring from either the highly polluted Baltic Sea or the relatively uncontaminated Atlantic Ocean. Changes in immune function were monitored over a 2 1/2-year period. The seals that were fed contaminated Baltic herring developed significantly higher body burdens of potentially immunotoxic organochlorines and displayed impaired immune responses as demonstrated by suppression of natural killer cell activity and specific T-cell responses. During a 2-week fasting experiment performed at the end of the feeding study, mobilization of organochlorines from the blubber did not lead to a strong increase of contaminant levels in the blood, and no enhancement of the existing immunosuppression was observed. These results demonstrate that chronic exposure to environmental contaminants accumulated through the food chain affects immune function in harbour seals, whereas short-term fasting periods, which are normal for seals, do not seem to pose an additional risk. The seals of this study were not exposed perinatally to high levels of environmental chemicals, and body burdens of organochlorines measured near the end of the study were lower than those generally observed in free-ranging seals inhabiting many contaminated regions. Therefore, it may be expected that environmental contaminants adversely affect immune function of free-ranging seals inhabiting contaminated regions at least as seriously as observed in these studies.

DeLong, R. L., Gilmartin, W. G., & Simpson, J. G. (1973). Premature Births in California Sea Lions: Association with High Organochlorine Pollutant Residue Levels. . *Science*, *181*, 1168–1170. <u>https://doi.org/10.1126/science.181.4105.1168</u>

Premature pupping in California sea lions has been noted on the breeding islands since 1968. Organochlorine pesticides and polychlorinated biphenyl residues were two to eight times higher in tissues of premature parturient females and pups than in similar tissues of full-term parturient females and pups collected on San Miguel Island in 1970. Deming, A. C., Colegrove, K. M., Duignan, P. J., Hall, A. J., Wellehan, J. F. X., & Gulland, F. M. D. (2018).
Prevalence of Urogenital Carcinoma in Stranded California Sea Lions (*Zalophus Californianus*) from 2005–15. *Journal of Wildlife Diseases, 54*(3), 581-586. <u>https://doi.org/10.7589/2017-08-208</u>

Urogenital carcinoma is common in wild California sea lions (Zalophus californianus) along the west coast of the US. From 1979 to 1994, this cancer was observed in 18% (66/370) of necropsied subadult and adult sea lions at The Marine Mammal Center in Sausalito, California. A retrospective review of records from 1 January 2005 to 31 December 2015 was performed to characterize prevalence and characteristics of cancer over this decade. Fourteen percent (263/ 1917) of necropsied sea lions had cancer, of which 90% (237/263) were urogenital carcinoma. The prevalence of urogenital carcinoma was significantly higher in adults compared to juveniles and subadults. Advanced-stage disease with metastases was identified histologically in 78% (182/232) of cases and was the cause of death in 95% (172/ 182) of these cases. Metastases were most common in lung and lymph nodes, and hydronephrosis, secondary to ureter obstruction by metastases, was identified in 62% (114/185) of animals with advanced disease. No significant temporal change in prevalence was detected over the decade, and this highly aggressive, fatal cancer remains common in stranded California sea lions.

Doney, S. C., Ruckelshaus, M., Duffy, J. E., Barry, J. P., Chan, F., English, C. A., . . . Talley, L. D. (2012). Climate Change Impacts on Marine Ecosystems. *Annual Reviews in Marine Science*, *4*, 11-37. https://doi.org/10.1146/annurev-marine-041911-111611

In marine ecosystems, rising atmospheric CO2 and climate change are associated with concurrent shifts in temperature, circulation, stratification, nutrient input, oxygen content, and ocean acidification, with potentially wideranging biological effects. Population-level shifts are occurring because of physiological intolerance to new environments, altered dispersal patterns, and changes in species interactions. Together with local climate-driven invasion and extinction, these processes result in altered community structure and diversity, including possible emergence of novel ecosystems. Impacts are particularly striking for the poles and the tropics, because of the sensitivity of polar ecosystems to sea-ice retreat and poleward species migrations as well as the sensitivity of coral-algal symbiosis to minor increases in temperature. Midlatitude upwelling systems, like the California Current, exhibit strong linkages between climate and species distributions, phenology, and demography. Aggregated effects may modify energy and material flows as well as biogeochemical cycles, eventually impacting the overall ecosystem functioning and services upon which people and societies depend.

Dorn, M. W., Cunningham, C. J., Dalton, M., Fadely, B. S., Gerke, B. L., Hollowed, A. B., ... Palsson, W. A. (2017). A Climate Science Regional Action Plan for the Gulf of Alaska. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-376. <u>https://doi.org/10.7289/V5/TM-AFSC-376</u>

Large changes in climate are expected in the U.S. Gulf of Alaska (GOA) in the coming decades. Projected changes include warming of ocean waters, decreases in ocean pH, sea level rise, changes in ocean circulation and stratification, and potential concomitant changes in species distributions, ecosystem productivity, and food-web structure. While the nature of physical changes is clear, such as warming and ocean acidification, ecosystem responses to changing physical conditions are uncertain because it is

unknown which of several forcing factors will be dominant. Directed research is needed to assess the degree of climate-driven change to critical ecosystem components, evaluate potential effects on marine species, and to determine risks to the ecosystem and fishing communities. This research will guide policies to reduce climate impacts, to manage human involvement in changed ecosystems, and to capitalize on any novel opportunities that may arise for marine resource-dependent human communities. This Regional Action Plan (RAP) outlines a framework to initiate this process.

Duignan, P. J., Van Bressem, M. F., Baker, J. D., Barbieri, M., Colegrove, K. M., De Guise, S., . . . Wellehan, J. F. X. (2014). Phocine Distemper Virus: Current Knowledge and Future Directions. *Viruses-Basel*, 6(12), 5093-5134. <u>https://doi.org/10.3390/v6125093</u>

Phocine distemper virus (PDV) was first recognized in 1988 following a massive epidemic in harbor and grey seals in north-western Europe. Since then, the epidemiology of infection in North Atlantic and Arctic pinnipeds has been investigated. In the western North Atlantic endemic infection in harp and grey seals predates the European epidemic, with relatively small, localized mortality events occurring primarily in harbor seals. By contrast, PDV seems not to have become established in European harbor seals following the 1988 epidemic and a second event of similar magnitude and extent occurred in 2002. PDV is a distinct species within the Morbillivirus genus with minor sequence variation between outbreaks over time. There is now mounting evidence of PDV-like viruses in the North Pacific/Western Arctic with serological and molecular evidence of infection in pinnipeds and sea otters. However, despite the absence of associated mortality in the region, there is concern that the virus may infect the large Pacific harbor seal and northern elephant seal populations or the endangered Hawaiian monk seals. Here, we review the current state of knowledge on PDV with particular focus on developments in diagnostics, pathogenesis, immune response, vaccine development, phylogenetics and modeling over the past 20 years.

Environmental Protection Agency Region 10. (2009). *Authorization to Discharge under the National Pollutant Discharge Elimination System for Offshore Seafood Processors in Alaska*. AK-G52-4000. Retrieved from <u>https://www.epa.gov/sites/production/files/2017-10/documents/r10-npdes-ak-offshore-seafood-akg524000-final-permit-2010.pdf</u>

In compliance with the provisions of the Clean Water Act, 33 U.S.C.A. ' 1251 et seq. (hereafter, CWA or the Act), the owners and operators of the seafood processing facilities that are described in Part I of this general National Pollutant Discharge Elimination System (NPDES) permit are authorized to discharge seafood processing wastes and the concomitant wastes set out in Part II of this Permit to waters of the United States, except those excluded from authorization of discharge in Part III of this Permit, in accordance with effluent limitations, monitoring requirements and other conditions set forth herein. The discharge of wastes not specifically set out in Part II of this Permit are not authorized under this Permit. Upon the effective date of this Permit, it is the controlling document for regulation of seafood processing wastes and other designated wastewaters in Federal Waters off the State of Alaska discharged by authorized facilities in accordance with this Permit.

 Goldstein, T., Johnson, S., Phillips, A., Hanni, K., & Fauquier, D. (1999). Human-Related Injuries Observed in Live Stranded Pinnipeds Along the Central California Coast 1986-1998. *Aquatic Mammals, 25*, 43-51. Retrieved from https://www.aquaticmammalsjournal.org/share/AquaticMammalsIssueArchives/1999/Aquatic Mammals 25-01/25-01 Johnson.pdf

From January 1986 to September 1998, of a total of 6196 live stranded pinnipeds including California sea lions (Zalophus californianus), Pacific harbor seals (Phoca vitulina), northern elephant seals (Mirounga angustirostris), northern fur seals (Callorhinus ursinus), Guadalupe fur seals (Arcto-cephalus townsendi) and Steller sea lions (Eumeto-pias jubatus) admitted to a rehabilitation center on the central California coast, 464 (7.5%) had human-related injuries. Three hundred and six (5%) had lesions caused by gunshots, I 07 (1.7%) had lesions caused by entanglement with manmade marine debris (includes active or discarded fishing nets and monofilament line, packing straps, plastic bags, rope and rubber o-rings), 46 (0.7%) had injuries caused by fishing tackle and 5 (0.1%) had boat propeller damage. The majority of human-inter-action injuries seen in these pinnipeds involved yearling California sea lions that stranded in Monterey Bay. June was the peak month for admis-sion of animals with these injuries. Wounds caused by gunshots cases was by radiography.

Greig, D. J., Gulland, F. M. D., & Kreuder, C. (2005). A Decade of Live California Sea Lion (Zalophus Californianus) Strandings Along the Central California Coast: Causes and Trends, 1991-2000. Aquatic Mammals, 31(1), 11-22. <u>https://doi.org/10.1578/am.31.1.2005.11</u>

Stranded marine mammals offer a unique sample of relatively inaccessible wild animals that are more likely to represent the diseased segment of the population and are easy to examine thoroughly. Examination of these animals, therefore, offers a method to detect novel diseases in free-living aquatic mammals. Diseases in marine mammals may reflect environmental changes such as ocean pollution, prey shifts, and global warming. To detect spatial and temporal trends in prevalence of such diseases, we reviewed records for 3,707 California sea lions (Zalophus californianus) that stranded live between 1991 and 2000 along the central California coast. Reasons for stranding were determined from a combination of clinical examinations, hematology and serum biochemistry, radiography, gross necropsy, histopathology, microbiology, and biotoxin assays. Over the ten years, 74% of sea lions stranded in Santa Cruz, Monterey and San Luis Obispo Counties, and 83% of these were admitted between May and October each year. Malnutrition was the most common reason for stranding (32%), followed by leptospirosis (27%), trauma (18%), domoic acid intoxication (9%), and cancer (3%). Strandings caused by malnutrition were greatest during the El Niño events of 1992, 1993, and 1998, while strandings caused by leptospirosis accounted for over 60% of strandings in 1991, 1995, and 1999. Although domoic acid was first reported in California sea lions in 1998, there was a small stranding event in 1992 that, based on clinical examinations and histopathology, was probably also caused by domoic acid. The observed prevalence of cancer among stranded animals remained constant over the past ten years at 3%.

 Guenette, S., Heymans, S. J. J., Christensen, V., & Trites, A. W. (2006). Ecosystem Models Show Combined Effects of Fishing, Predation, Competition, and Ocean Productivity on Steller Sea Lions (*Eumetopias Jubatus*) in Alaska. *Canadian Journal of Fisheries and Aquatic Sciences*, 63(11), 2495-2517. <u>https://doi.org/10.1139/f06-136</u>

Steller sea lions (*Eumetopias jubatus*) increased in the eastern portion of their range while declining in the Gulf of Alaska and Aleutian Islands from the late 1970s to late 1990s. We constructed ecosystem models of the central and western Aleutians and of southeast Alaska to simultaneously evaluate four

hypotheses explaining sea lion dynamics: killer whale (Orcinus orca) predation, ocean productivity, fisheries, and competition with other species. Comparisons of model predictions with historical time series data indicate that all four factors likely contributed to the trends observed in sea lion numbers in both ecosystems. Changes in ocean productivity conveyed by the Pacific Decadal Oscillation influenced the abundance trajectory of several species. Fishing could have affected the ecosystem structure by influencing the abundance of Atka mackerel (Pleurogrammus monopterygius) in the Aleutians and Pacific herring (Clupea pallasii) in southeast Alaska. Pacific halibut (Hippoglossus stenolepis) in the Aleutians and arrowtooth flounder (Atheresthes stomias) in southeast Alaska appear to impede sea lion population growth through competitive interactions. Predation by killer whales was important when sea lions were less abundant in the 1990s in the Aleutians and in the 1960s in Southeast Alaska, but appear to have little effect when sea lion numbers were high.

Gulland, F., Trupkiewicz, J., Spraker, T., & Lowenstine, L. (1996). Metastatic Carcinoma of Probable Transitional Cell Origin in 66 Free-Living California Sea Lions (*Zalophus Californianus*), 1979 to 1994. *Journal of Wildlife Diseases*, *32*(2), 250-258. <u>https://doi.org/10.7589/0090-3558-32.2.250</u>

Sixty-six (18%) cases of widely metastatic carcinoma of probable transitional cell origin were identified in 370 California sea lions (Zalophus californianus) stranded alive along the central California (USA) coast, between January 1979 and December 1994. Live animals were usually emaciated and anorectic, with perineal edema and occasionally hind-flipper paralysis or paresis. Large yellow caseous masses were observed in the sub-lumbar lymph nodes, often extending around the ureters resulting in hydroureter. Histologically, metastases were usually widespread, and the primary neoplastic focus undetectable. This is the highest reported prevalence among necropsied animals of neoplasia in a pinniped population to date.

Haynes, T. L., & Mishler, C. (1991). *The Subsistence Harvest and Use of Steller Sea Lions in Alaska*. Alaska Department of Fish and Game Division of Subsistence. Retrieved from <u>http://www.subsistence.adfg.state.ak.us/TechPap/tp198.pdf</u>

Subsequent to the classification of the Steller sea lion as a threatened species in 1990, a Sea Lion Recovery Team was created and charged with preparing a population recovery plan. This report examines the historical literature on subsistence uses, reviews Native oral traditions, and summarizes the limited amount of available information on contemporary harvests and uses of sea lions over a wide range of 25 coastal Alaskan communities. The report is designed to assist in creation of a recovery plan sensitive to subsistence uses. Further research and data needs are identified for consideration in the development of a long-range sea lion management plan. Various strategies of hunting sea lions are described, along with hunting technologies, methods of butchering sea lions, and traditional ways of cooking and serving them. Evidence gathered from prehistoric sites is summarized, and the pervasive symbolic role of Steller sea lions in Koniag and Aleut folktales, folk songs, and folk beliefs is examined in some detail. Judging from recent village harvest surveys, subsistence uses of sea lions appear to have declined rather dramatically in all Kodiak Island villages, although resident Kodiak hunters insist they see more sea lions around the villages than ever before. The number of animals harvested and used in Prince William Sound, Lower Cook Inlet, and the Lower Alaska Peninsula, on the other hand, appears to be fairly stable. Other coastal regions where sea lions are harvested, such as the Aleutian Islands and the Pribilof Islands, have not been studied adequately enough to determine trends.

Helker, V. T., Allen, B. M., & Jemison, L. A. (2015). Human-Caused Injury and Mortality of NMFS-Managed Alaska Marine Mammal Stocks, 2009-2013. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-300. <u>https://doi.org/10.7289/V50G3H3M</u>

The National Marine Fisheries Service (NMFS) is required under the Marine Mammal Protection Act (MMPA) to estimate the annual human-caused mortality and serious injury of marine mammal stocks by source. Revisions to NMFS' guidelines and methods for distinguishing serious from non-serious injuries pursuant to the MMPA were implemented in 2013. Data from documented interactions between humans and Alaska pinnipeds and cetaceans under the jurisdiction of the NMFS were compiled for the 5-year period from 2009 through 2013. Details regarding each human-marine mammal interaction were reviewed for evidence of human-caused injury or mortality, and criteria were applied in order to assign injuries to categories and determine the severity (serious or non-serious). A total of 603 unique interactions with potential evidence of human-caused injury and mortality were closely reviewed and are summarized in this report. Injury determination details regarding the injury source, type, and severity are presented, along with the injury category and criteria supporting the determination. Mortality and injury values were assigned (0, 1, or prorated) to each event for comparison with the calculated Potential Biological Removal levels for each stock.

Helker, V. T., M. M. Muto, K. Savage, S. Teerlink, L. A. Jemison, K. Wilkinson, & Jannot, J. (2017). *Human-Caused Mortality and Injury of NMFS-Managed Alaska Marine Mammal Stocks, 2011-2015.* National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-354. Retrieved from https://repository.library.noaa.gov/view/noaa/14444

Section 117 of the Marine Mammal Protection Act (MMPA) requires the National Marine Fisheries Service (NMFS) to estimate human-caused marine mammal mortality and serious injury. Data from documented interactions between human activities and pinnipeds or cetaceans belonging to stocks which appear in the Alaska Marine Mammal Stock Assessment Reports (SARs) were compiled for the 5year period from 2011 through 2015. A total of 839 unique interactions with potential evidence of human-caused mortality or injury were reviewed and are summarized in this report. Details regarding each interaction were assessed for evidence of human-caused injury to the marine mammal. Injury severity determinations were made for those injuries likely to be human-caused. Injury determination details regarding the injury source, type, severity, and criteria supporting the determination are presented in the appendices. Records of mortality are also included in this report, and assigned to source. Mortality and injury values were assigned to each interaction for comparison with the potential biological removal (PBR) levels for each stock calculated under the MMPA and appearing within the Alaska SARs. The mortality and serious injury values included in this report are derived solely from documented interactions. Since not all human-caused mortality and serious injury to marine mammals is documented, this report represents a minimum count of human-caused mortality and serious injury to Alaska marine mammal stocks.

Helker, V. T., Muto, M. M., & Jemison, L. A. (2016). Human-Caused Injury and Mortality of NMFS-Managed Alaska Marine Mammal Stocks, 2010-2014. National Marine Fisheries Service Alaska Fisheries Science Center. NMFS-AFSC-315. <u>https://doi.org/10.7289/V5/TM-AFSC-315</u>

Section 117 of the Marine Mammal Protection Act (MMPA) requires the National Marine Fisheries Service (NMFS) to estimate human-caused marine mammal mortality and serious injury. Data from

documented interactions between human activities and pinnipeds or cetaceans belonging to stocks which appear in the Alaska Marine Mammal Stock Assessment Reports (SARs) were compiled for the 5year period from 2010 through 2014. A total of 818 unique interactions with potential evidence of human-caused mortality or injury were reviewed and are summarized in this report. Details regarding each interaction were assessed for evidence of human-caused injury to the marine mammal and injury severity determinations were made for those injuries likely to be human-caused. Records of mortality are also included in this report, and assigned to source. Injury determination details regarding the injury source, type, severity, and criteria supporting the determination are presented in the appendices. Mortality and injury values were assigned to each interaction for comparison with the potential biological removal (PBR) levels for each stock calculated under the MMPA and appearing within the Alaska SARs.

Hollowed, A. B., Barange, M., Beamish, R. J., Brander, K., Cochrane, K., Drinkwater, K., . . . Yamanaka, Y. (2013). Projected Impacts of Climate Change on Marine Fish and Fisheries. *ICES Journal of Marine Science*, 70(5), 1023-1037. <u>https://doi.org/10.1093/icesjms/fst081</u>

Projected impacts of climate change on marine fish and fisheries. – ICES Journal of Marine Science, 70: 1023–1037. This paper reviews current literature on the projected effects of climate change on marine fish and shellfish, their fisheries, and fishery-dependent communities throughout the northern hemisphere. The review addresses the following issues: (i) expected impacts on ecosystem productivity and habitat quantity and quality; (ii) impacts of changes in production and habitat on marine fish and shellfish species including effects on the community species composition, spatial distributions, interactions, and vital rates of fish and shellfish; (iii) impacts on fisheries and their associated communities; (iv) implications for food security and associated changes; and (v) uncertainty and modelling skill assessment. Climate change will impact fish and shellfish, their fisheries, and fisherydependent communities through a complex suite of linked processes. Integrated interdisciplinary research teams are forming in many regions to project these complex responses. National and international marine research organizations serve a key role in the coordination and integration of research to accelerate the production of projections of the effects of climate change on marine ecosystems and to move towards a future where relative impacts by region could be compared on a hemispheric or global level. Eight research foci were identified that will improve the projections of climate impacts on fish, fisheries, and fishery-dependent communities.

Holmes, A. L., Wise, S. S., Goertz, C. E. C., Dunn, J. L., Gulland, F. M. D., Gelatt, T., . . . Wise, J. P. (2008). Metal Tissue Levels in Steller Sea Lion (*Eumetopias Jubatus*) Pups. *Marine Pollution Bulletin*, 56(8), 1416-1421. <u>https://doi.org/10.1016/j.marpolbul.2008.05.007</u>

The endangered Western population of the Steller sea lion declined for three decades for uncertain reasons. We present baseline data of metal concentrations in pups as a first step towards investigating the potential threat of developmental exposures to contaminants. Seven metals were investigated: arsenic, cadmium, silver, aluminum, mercury, lead and vanadium. Vanadium was detected in only a single blubber sample. Mercury appears to be the most toxicologically significant metal with concentrations in the liver well above the Current action level for mercury in fish. The concentrations of aluminum, arsenic, silver, cadmium and lead were present in one-fourth to two-thirds of all samples and were at either comparable or below concentrations previously reported. Neither gender nor region had

a significant effect on metal burdens. Future work should consider metal concentrations in juveniles and adults and toxicological studies need to be performed to begin to assess the toxicity of these metals.

Hoopes, L. A., Rea, L. D., Christ, A., & Worthy, G. A. J. (2014). No Evidence of Metabolic Depression in Western Alaskan Juvenile Steller Sea Lions (*Eumetopias Jubatus*). *PLoS ONE*, 9(1) <u>https://doi.org/10.1371/journal.pone.0085339</u>

Steller sea lion (Eumetopias jubatus) populations have undergone precipitous declines through their western Alaskan range over the last four decades with the leading hypothesis to explain this decline centering around changing prey quality, quantity, or availability for this species (i.e., nutritional stress hypothesis). Under chronic conditions of reduced food intake sea lions would conserve energy by limiting energy expenditures through lowering of metabolic rate known as metabolic depression. To examine the potential for nutritional stress, resting metabolic rate (RMR) and body composition were measured in free-ranging juvenile Steller sea lions (N = 91) at three distinct geographical locations (Southeast Alaska, Prince William Sound, Central Aleutian Islands) using open-flow respirometry and deuterium isotope dilution, respectively. Average sea lion RMR ranged from 6.7 to 36.2 MJ d(-1) and was influenced by body mass, total body lipid, and to a lesser extent, ambient air temperature and age. Sea lion pups captured in the Aleutian Islands (region of decline) had significantly greater body mass and total body lipid stores when compared to pups from Prince William Sound (region of decline) and Southeast Alaska (stable region). Along with evidence of robust body condition in Aleutian Island pups, no definitive differences were detected in RMR between sea lions sampled between eastern and western populations that could not be accounted for by higher percent total body lipid content, suggesting that that at the time of this study, Steller sea lions were not experiencing metabolic depression in the locations studied.

Horning, M., & Mellish, J. A. E. (2014). In Cold Blood: Evidence of Pacific Sleeper Shark (Somniosus Pacificus) Predation on Steller Sea Lions (*Eumetopias Jubatus*) in the Gulf of Alaska. *Fishery Bulletin*, 112(4), 297-310. <u>https://doi.org/10.7755/fb.112.4.6</u>

Temperature data received post mortem in 2008-13 from 15 of 36 juvenile Steller sea lions (*Eumetopias jubatus*) that had been surgically implanted in 2005-11 with dual life history transmitters (LHX tags) indicated that all 15 animals died by predation. In 3 of those 15 cases, at least 1 of the 2 LHX tags was ingested by a cold-blooded predator, and those tags recorded, immediately after the sea lion's death, temperatures that corresponded to deepwater values. These tags were regurgitated or passed 5-11 days later by predators. Once they sensed light and air, the tags commenced transmissions as they floated at the ocean surface, reporting temperatures that corresponded to regional sea-surface estimates. The circumstances related to the tag in a fourth case were ambiguous. In the remaining 11 cases, tags sensed light and air immediately after the sea lion's death and reported temperatures that corresponded to estimates of regional sea-surface temperatures. In these 11 cases, circumstances did not allow for inferences on the species of predator. Among reported poikilotherm predators of Steller sea lions, only the Pacific sleeper shark (Somniosus pacificus) is known to have body core temperatures that are near ambient. The data from this study indicate that Pacific sleeper sharks need to be considered as a possible source of mortality of juvenile Steller sea lions in the region of the Gulf of Alaska.

Hoshino, H., Fujita, S., Goto, Y., Isono, T., Ishinazaka, T., Burkanov, V. N., & Sakurai, Y. (2006). Organochlorines in Steller Sea Lions (Eumetopias Jubatus) from the Western North Pacific. https://doi.org/10.4027/slw.2006.01

The population of Steller sea lions, *Eumetopias jubatus*, has declined in the western North Pacific since the late 1960s. Recently, the Sea of Okhotsk was reported to be polluted by organochlorine contaminants (OCs) including polychlorinated biphenyls (PCBs) and agrochemicals. OCs are known to have toxic effects on phocid species; thus, studies of OCs in sea lions are important for sea lion conservation. In this study, sea lion blubber samples were collected from the Kuril islands and Olyutorsky Bay in Russia and Hokkaido in Japan from 1997 to 2004, and OC concentrations in blubber were measured. 1,1'-(2,2,2-trichloroethylidene)bis(4-chiorobenzene) and its metabolites (DDTs) and PCBs were found to be the dominant compounds accumulated in sea lions of the western North Pacific. The DDT and PCB levels were higher in Steller sea lions from Hokkaido than in sea lions from Olyutorsky Bay. The ratio of DDTs to PCBs in sea lions from Hokkaido exceeded the 2,2',3,4,4',5,5'-heptachlorobiphenyl level reported to decrease circulating thyroid hormone in ribbon seals than sea lions from Olyutorsky Bay. DDTs and PCBs were the predominant OCs accumulated in Steller sea lions of the western North Pacific measured in this study. in particular, Steller sea lions from Hokkaido may have higher DDT accumulation than sea lions in the western Bering Sea and may have higher risks of toxicity.

Hoshino, H., Fujita, S., Goto, Y., Isono, T., Ishinazaka, T., Sakurai, Y., . . . Tanabe, S. (2003).
Organochlorine Compound Accumulation in Steller Sea Lion *Eumetopias Jubatus* Migrating Along the Coast of Hokkaido in Northern Japan. *Japanese Journal of Environmental Toxicology*, 6(1), 1-10. Retrieved from https://www.jstage.jst.go.jp/article/jset/6/1/6_1_1/pdf/-char/en

To clarify the levels of organochlorine compounds (OCs) and the metabolism of OCs in the body of Steller sea lion *Eumetopias jubatus* migrating along the coast of Hokkaido, OCs in the sea lion's blubbers for each age, sex and reproductive status were determined by gas chromatography linked to ion trap mass spectrometer. In sea lions, the compounds accumulated in the highest concentrations are DDT and its metabolites (DDTs) suggesting these animals are still exposed to DDTs from the surrounding land. The levels of DDTs and polychlorinated biphenyls (PCBs) in sea lions may cause small effects such as the induction of drug metabolizing enzymes. The concentrations of DDTs, PCBs, hexachlorocyclohexanes and chlordanes in the old female sea lions were lower than those in the males and young females. This is most likely due to the loss of these compounds during nursing. In addition, the concentrations of each compound differed in the degree of difference between the young and the old females. This result may reflect ecological and physiological difference between the young and the old females. The proportions of tetrachlorinated biphenyl concentrations were found to be higher in older animals implying low "phenobarbital inducible type" enzyme activity.

Issac, J. L. (2009). Effects of Climate Change on Life History: Implications for Extinction Risk in Mammals. Endangered Species Research, 7(2), 115-123. <u>https://doi.org/10.3354/esr00093</u>

Global climate change is predicted to result in the decline and/or extinction of a large number of animal populations worldwide, and the risk of extinction is likely to be greatest for those species already vulnerable—i.e. those with limited climatic range and/or restricted habitat requirements. To date,

predictive models have failed to take into account the fact that climate change will alter many of the key life history and ecological parameters which determine a species' inherent risk of extinction, such as body mass, size of geographic range and a suite of reproductive traits. Herein, I review contemporary research on the effects of climate change on extinction risk in mammals, focusing on the capacity of climate change to modify those life history traits that inherently alter species' extinction risk. This review finds strong evidence that climate change has already had marked effects on key life history traits in mammals. These changes have resulted in both negative and positive effects on reproductive success and adult and offspring survival, with implications for extinction risk in affected species. While the capacity of climate change to alter life history traits in mammals is clear, there is currently little research to clarify how these changes have influenced population growth and dynamics. Other currently overlooked areas of research are also identified.

Johnson, S., JJ, B., Malme, C., & Davis, R. (1990). *Synthesis of Information on the Effects of Noise and Disturbance on Major Haulout Concentrations of Bering Sea Pinnipeds*. Paper presented at the Information Transfer Meeting. Retrieved from https://catalog.hathitrust.org/Record/008160141

This study investigated the use of terrestrial haulout sites in the eastern Bering Sea by four species of pinnipeds: northern fur seal, northern sea lion, harbor seal, and Pacific walrus. Historical information on the use of each site was summarized and the potential vulnerability to noise and disturbance of each site was evaluated. For a few sites there was little or no information about the number of animals present and consistency of use of the site; we were unable to properly evaluate these sites. The importance and vulnerability to disturbance, i.e., the sensitivii of each haulout site used by each of the four species, was computed and an Inter-site Population Sensitivity Index (IPSI) was generated for each site using a series of eight variables or factors related to: 1) the status, composition, and trend in numbers of the population being considered; 2) the location and major physical characteristics of the haulout sites being considered; and 3) the species being considered and its general response to disturbance (based on the literature). Available information on the effects of airborne and waterborne noise, and human disturbance (from stationary and moving sources) on marine mammals in and/or near terrestrial haulout sites was reviewed. We also conducted a detailed analysis of the acoustic environment of eight haulout sites. These eight sites were representative of others used by each of the four species studied. The analysis included investigations of 1) characteristics of airborne and underwater ambient noise; 2) characteristics of industrial noise sources, including aircraft, small boats, fishing trawlers and commercial cargo traffic; and 3) sound transmission loss in air, water and trough the air-water surface. Ambient noise characteristics for the eight sites were estimated using data obtained from studies of similar areas. The noise source characteristics were obtained from data reported in the literature and from BBN archives. Transmission loss characteristics for airborne and underwater sound were estimated using standard analytical procedures and computer models. An analytical procedure was developed for prediction of transmission of sound from aircraft into shallow water, since an existing procedure was not available.

Keogh, M. J., Maniscalco, J. M., & Atkinson, S. (2009, Feb). Development of Endocrine and Immune Function in Endangered Steller Sea Lion Pups (Eumetopias Jubatus). Paper presented at the Integrative and Comparative Biology. Retrieved from http://www.sicb.org/meetings/2009/schedule/abstractdetails.php3?id=575 Several species of marine mammals and birds in the Northeast Pacific have been in decline since the mid-1970s including the endangered Steller sea lion (SSL; Eumetopias jubatus). A leading theory is the nutritional stress associated with a reduction in prey abundance or quality. The impact of limited resources would be greatest during periods of development and rapid growth. This study seeks to determine if body condition and maternal investment influences the immune and endocrine systems in SSL pups. At Chiswell Island, Alaska, a SSL rookery was monitored by a remote video camera enabling the determination of the age of pups, maternal investment, and survival rates. A total of 61 pups (24 female, 37 male) were sampled during 2005, 2007, and 2008 ranging in age from 5 to 38 days old. Each pup was measured, weighed, and branded. Blood samples were collected for complete blood cell counts, lymphocyte proliferation, serum chemistries and circulating hormone levels. Female pups were significantly smaller than males in mass (F= 26.7 4.1 kg, M=32.2 4.6 kg; F =16.276, p<0.001) and length (F=101.6 4.7 cm, M=108.0 4.9; F =17.331, p<0.001). Age also significantly effected mass (F =49.802, p<0.001) and length (F =17.331, p<0.001) with older pups being larger. While there was a significant difference between male and female pups in body condition these differences were not found in circulating hormones or lymphocyte proliferation. Circulating TT4 (F =6.007, p=0.017), FT4 (F =6.405, p=0.014), and T cell proliferation (F =4.984, p=0.038) decreased while leptin (F =5.679, p=0.020) increased with age. Further analysis will incorporate a body condition index to determine if overall condition significantly affects immune and endocrine parameters.

Keogh, M. J., Maniscalco, J. M., & Atkinson, S. (2010). Steller Sea Lion (*Eumetopias Jubatus*) Pups Undergo a Decrease in Circulating White Blood Cells and the Ability of T Cells to Proliferate During Early Postnatal Development. *Veterinary Immunology and Immunopathology*, 137(3-4), 298-304. https://doi.org/10.1016/j.vetimm.2010.05.008

Postnatal changes in circulating immune components and peripheral blood mononuclear cell (PBMC) proliferation were assessed in Steller sea lion pups (SSL: *Eumetopias jubatus*). Blood samples were collected for complete blood cell counts including total and differential white blood cell (WBC) counts from 46 pups ranging in age from 5 to 38 days old. Total WBC and neutrophil counts decreased in association with increased age of the pups. The ability of PBMC to proliferate was assessed by in vitro exposure to concanavalin A (ConA) or lipopolysaccharide (LPS) in 21 pups ranging in age from 7 to 32 days old. All SSL pups responded to in vitro stimulation with ConA and LPS 055:B5 indicating peripheral T and B cells are capable of responding to an antigenic challenge. ConA-induced T cell proliferation decreased with age while there was no change in spontaneous proliferation of PBMC or B cells exposed to LPS. The decreases in total WBC, neutrophil counts and T cell proliferation indicates that SSL undergo a period of postnatal development in cell-mediated immune function which is comparatively longer than phocid pups and consistent with other otariids.

Kersh, G. J., Lambourn, D. M., Self, J. S., Akmajian, A. M., Stanton, J. B., Baszler, T. V., . . . Massung, R. F. (2010). Coxiella Burnetii Infection of a Steller Sea Lion (*Eumetopias Jubatus*) Found in Washington State. *Journal of Clinical Microbiology*, 48(9), 3428-3431.
https://doi.org/10.1128/jcm.00758-10

A pregnant sea lion stranded in the State of Washington was found to have placentitis caused by a unique strain of Coxiella burnetii. This is the first description of coxiellosis in a sea lion and suggests that exposure to sea lions may be a risk factor for contracting Q fever.

Kim, G. B., Lee, J. S., Tanabe, S., Iwata, H., Tatsukawa, R., & Shimazaki, K. (1996). Specific Accumulation and Distribution of Butyltin Compounds in Various Organs and Tissues of the Steller Sea Lion (*Eumetopias Jubatus*): Comparison with Organochlorine Accumulation Pattern. *Marine Pollution Bulletin*, 32(7), 558-563. <u>https://doi.org/10.1016/0025-326x(96)84576-0</u>

The present study was conducted to elucidate the specific distribution of butyltin (BT) compounds in various tissues and organs of Steller sea ions collected from coastal waters of Hokkaido, Japan. BT concentrations were an order of magnitude higher in the liver than in other tissues and organs except hair, whereas organochlorine (OC) compounds accumulated at two to three orders of magnitude higher in blubber than in other tissues. No relationship was observed between BT concentrations and the lipid content in tissues, while the levels of OCs were positively associated with the lipid content. The levels of BTs in hair (1500 ng g(-1) on a wet weight basis) were the highest of all the tissues analysed. Results also suggested that 25% of the total BT burden in the body was eliminated through shedding. Selective accumulation of BTs in liver and hair is attributed to its protein-binding capacity rather than lipophilicity. The discovery of high concentrations of BTs in hair implies their excretion by shedding in piliferous animals.

Kim, G. B., Tanabe, S., Tatsukawa, R., Loughlin, T. R., & Shimazaki, K. (1996). Characteristics of Butyltin Accumulation and Its Biomagnification in Steller Sea Lion (*Eumetopias Jubatus*). *Environmental Toxicology and Chemistry*, 15(11), 2043-2048. <u>https://doi.org/10.1897/1551-</u> <u>5028(1996)015<2043:Cobaai>2.3.Co;2</u>

The present study was conducted to examine sex difference, age, and temporal trends of butyltin accumulation and its biomagnification in Steller sea lion (*Eumetopias jubatus*) collected from Alaska, USA, during 1976-1985 and from Hokkaido, Japan, during 1994-1995. Average concentration of total butyltin compounds (Sigma BTs) in the liver of Steller sea lion from Alaska (19 ng/g wet weight) was much lower than those from western and eastern Hokkaido, Japan (150 and 220 ng/g), respectively. This result suggests that Japanese coastal waters are contaminated with BTs in comparison with those of Alaska. In most samples, dibutyltin (DBT) residues were retained at higher levels than tributyltin (TBT), suggesting the degradation of TBT to DBT in the liver. Sex difference and age-dependent accumulation of BTs residues were not found in Steller sea lion. Similarly, no prominent temporal trend in BT concentrations was observed between 1976 and 1985. Nevertheless, the annual consumption of organotin compound was doubled in the United States during the same period. These results suggest that the butyltin compounds are degraded faster than the intake from diet in Steller sea lion. The biomagnification factor of BTs in Steller sea lion was low (0.15-4.6; mean, 0.6), indicating that this animal is unlikely to magnify BTs due to rapid degradation and excretion.

Konishi, K., & Shimazaki, K. (1998). Halarachnid Mites Infesting the Respiratory Tract of Steller Sea Lions. Biosphere conservation: for nature, wildlife, and humans, 1(1), 45-48. <u>https://doi.org/10.20798/biospherecons.1.1_45</u>

Steller sea lions (*Eumetopias jubatus*) are infested by many parasites through various routes, including predator-prey relationships and contacts with other sea lions. However, we know little about the life histories of these parasites. This paper discusses a nasal mite (Orthohalarachne attenuata) that infests the respiratory tract of Steller sea lions. Of 22 sea lions sampled around Hokkaido in 1996, the nasal

cavities of 12 were infested with the mites. An average of 23 mites were found in each infested sea lion. There was no correlation between the age of the sea lions and the number of mites they contained. The heads of 9 pups were also examined to determine when first infestation occurred. No pups were infested and none had inflamed nasal cavities.

 Kubo, K., Yamaguchi, K., Ishinazaka, T., Yamada, W., Hattori, K., & Tanaka, S. (2014). Maternal-to-Fetal Transfer and Concentration Profiles of Pcb Congeners for Steller Sea Lions (*Eumetopias Jubatus*) from Hokkaido, Japan. *Marine Pollution Bulletin, 78*(1-2), 165-172. https://doi.org/10.1016/marpolbul.2013.10.047

The concentrations of PCB congeners in the blubber and liver of mother Steller sea lions (*Eumetopias jubatus*; SSLs) and their fetuses from the coast of Hokkaido, Japan in 2008, 2010 and 2012 were analyzed by HRGC-HRMS, in order to elucidate PCB congener profiles and maternal-to-fetal transfer of PCBs in SSLs. Sigma PCBs in the fetuses were 1400 +/- 660 (the mean +/- SD) ng/g-fat in the blubber and 570 +/- 320 ng/g-fat in the liver, respectively. There was a concern that SSLs had been contaminated by PCBs during the fetal period. The concentrations of the major congeners in the blubber and liver were a correlation between the fetus and mother (blubber: r = 0.9934, liver: r = 0.8616; P <= 0.05). The results indicated that PCBs in the fetuses came from the mothers. #177 and #199 showed no correlations between the fetus and the mother in the blubber and liver. This indicated a selective capture by some natural protector such as the placenta.

Kubo, K., Yamaguchi, K., Mitsuhashi, M., Hattori, K., & Tanaka, S. (2013). Concentration Profiles of Pcb Congeners in the Blubber and Liver of Steller Sea Lions (*Eumetopias Jubatus*) from the Coast of Hokkaido, Japan. *Marine Pollution Bulletin, 69*(1-2), 228-232. <u>https://doi.org/10.1016/j.marpolbul.2012.12.012</u>

The concentrations of PCB congeners in the blubber and liver of male and female Steller sea lions (*Eumetopias jubatus*; SSLs) collected from the Shakotan Peninsula and the Nemuro Strait, Hokkaido, Japan in 2008 and 2010 were measured by HRGC-HRMS, in order to express the concentration profiles in SSLs at these regions. #153 predominated in both organs, followed by #138, #99 and #118. In males, #28 and #31 were concentrated particularly in the blubber, while #177 and #199 were accumulated specifically in the liver. The differences in these concentration profiles might be expressed by the differences in the organs and their functions. The concentrations of #99, #118, #138, #153, and #180 in the blubber appeared to correspond significantly with the differences between genders. The details of the surveys on PCB congeners in SSLs could clarify the differences in the residue levels of individual congeners for organs and genders.

Lee, J. S., Tanabe, S., Umino, H., Tatsukawa, R., Loughlin, T. R., & Calkins, D. C. (1996). Persistent Organochlorines in Steller Sea Lion (*Eumetopias Jubatus*) from the Bulk of Alaska and the Bering Sea, 1976–1981. *Marine Pollution Bulletin*, 32(7), 535-544. <u>https://doi.org/10.1016/0025-326X(96)84572-3</u>

Organochlorine pesticides and polychlorinated biphenyls (PCBs) were determined in the blubber and liver of Steller sea lion collected from the bulk of Alaska and the Russian Bering Sea. PCBs were the predominant organochlorines in the blubber, ranging in concentration from 5.7 to 41 μ g g-1 (lipid

weight) in males and from 0.57 to 16 μ g g–1 in females. Concentrations of DDTs (DDT and its metabolites) in the blubber ranged from 2.8 to 17 μ g g–1 in males and from 0.19 to 6.5 μ g g–1 in females. The levels of chlordane compounds (CHLs) and hexachlorocyclohexanes (HCHs) were one to three orders of magnitude lower than those of PCBs and DDTs. The residue levels of PCBs, DDTs and CHLs in males increased with age, whereas in females they decreased sharply after maturity, suggesting the transfer of organochlorines in large quantities during lactation. Transfer rate of organochlorines through lactation was estimated to be 80% for PCBs and 79% for DDTs of the total body of adult female. Concentrations of organochlorines in the liver of the Steller sea lion from Alaska, on a lipid weight basis, were similar to those in the blubber. In addition, liver showed age-dependent accumulation of PCBs, DDTs and CHLs, similar to that in the blubber. The concentrations of all the organochlorines detected in the liver were clearly correlated with those in the blubber, indicating the lipophilic nature of organochlorines in accumulation and movement in the animal body. Residue levels of PCBs and DDTs in the liver of male Steller sea lions from the Bering Sea were significantly lower than those from Alaska, suggesting that Bering Sea animals have different foraging areas from the animals of the bulk of Alaska.

Lee, K., Kim, J. Y., Jung, S. C., Lee, H. S., Her, M., & Chae, C. (2016). First Isolation of Streptococcus Halichoeri and Streptococcus Phocae from a Steller Sea Lion (*Eumetopias Jubatus*) in South Korea. *Journal of Wildlife Diseases*, 52(1), 183-185. <u>https://doi.org/10.7589/2015-05-112</u>

Streptococcus species are emerging potential pathogens in marine mammals. We report the isolation and identification of Streptococcus halichoeri and Streptococcus phocae in a Steller sea lion (*Eumetopias jubatus*) in South Korea.

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 wellbeing 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.

Letcher, R. J., Bustnes, J. O., Dietz, R., Jenssen, B. M., Jorgensen, E. H., Sonne, C., . . . Gabrielsen, G. W. (2010). Exposure and Effects Assessment of Persistent Organohalogen Contaminants in Arctic Wildlife and Fish. Science of The Total Environment, 408(15), 2995-3043. https://doi.org/10.1016/j.scitotenv.2009.10.038

Persistent organic pollutants (POPS) encompass an array of anthropogenic organic and elemental substances and their degradation and metabolic byproducts that have been found in the tissues of exposed animals, especially POPs categorized as organohalogen contaminants (OHCs). OHCs have been of concern in the circumpolar arctic for decades. For example, as a consequence of bioaccumulation and in some cases biomagnification of legacy (e.g., chlorinated PCBs, DDTs and CHLs) and emerging (e.g., brominated flame retardants (BFRs) and in particular polybrominated diphenyl ethers (PBDEs) and perfluorinated compounds (PFCs) including perfluorooctane sulfonate (PFOS) and perfluorooctanic acid (PFOA) found in Arctic biota and humans. Of high concern are the potential biological effects of these contaminants in exposed Arctic wildlife and fish. As concluded in the last review in 2004 for the Arctic Monitoring and Assessment Program (AMAP) on the effects of POPs in Arctic wildlife, prior to 1997, biological effects data were minimal and insufficient at any level of biological organization. The present review summarizes recent studies on biological effects in relation to OHC exposure, and attempts to assess known tissue/body compartment concentration data in the context of possible threshold levels of effects to evaluate the risks. This review concentrates mainly on post-2002, new OHC effects data in Arctic wildlife and fish, and is largely based on recently available effects data for populations of several top trophic level species, including seabirds (e.g., glaucous gull (Larus hyperboreus)), polar bears (Ursus maritimus), polar (Arctic) fox (Vulpes lagopus), and Arctic chart (Salvelinus alpinus), as well as semicaptive studies on sled dogs (Canis familiaris). Regardless, there remains a dearth of data on true contaminant exposure, cause-effect relationships with respect to these contaminant exposures in Arctic wildlife and fish. Indications of exposure effects are largely based on correlations between biomarker endpoints (e.g., biochemical processes related to the immune and endocrine system, pathological changes in tissues and reproduction and development) and tissue residue levels of OHCs (e.g., PCBs, DDTs, CHLs, PBDEs and in a few cases perfluorinated carboxylic acids (PFCAs) and perfluorinated sulfonates (PFSAs)). Some exceptions include semi-field studies on comparative contaminant effects of control and exposed cohorts of captive Greenland sled dogs, and performance studies mimicking environmentally relevant PCB concentrations in Arctic charr. Recent tissue concentrations in several arctic marine mammal species and populations exceed a general threshold level of concern of 1 partper-million (ppm), but a clear evidence of a POP/OHC-related stress in these populations remains to be confirmed. There remains minimal evidence that OHCs are having widespread effects on the health of Arctic organisms, with the possible exception of East Greenland and Svalbard polar bears and Svalbard glaucous gulls. However, the true (if any real) effects of POPs in Arctic wildlife have to be put into the context of other environmental, ecological and physiological stressors (both anthropogenic and natural) that render an overall complex picture. For instance, seasonal changes in food intake and corresponding

cycles of fattening and emaciation seen in Arctic animals can modify contaminant tissue distribution and toxicokinetics (contaminant deposition, metabolism and depuration). Also, other factors, including impact of climate change (seasonal ice and temperatur changes, and connection to food web changes, nutrition, etc. in exposed biota), disease, species invasion and the connection to disease resistance will impact toxicant exposure. Overall, further research and better understanding of POP/OHC impact on animal performance in Arctic biota are recommended. Regardless, it could be argued that Arctic wildlife and fish at the highest potential risk of POP/OHC exposure and mediated effects are East Greenland, Svalbard and (West and South) Hudson Bay polar bears, Alaskan and Northern Norway killer whales, several species of gulls and other seabirds from the Svalbard area, Northern Norway, East Greenland, the Kara Sea and/or the Canadian central high Arctic, East Greenland ringed seal and a few populations of Arctic charr and Greenland shark.

Loughlin, T. R. (1986). Incidental Mortality of Northern Sea Lions in Shelikof Strait, Alaska. *Marine Mammal Science*, *2*(1), 14-33. <u>https://doi.org/10.1111/j.1748-7692.1986.tb00025.x</u>

The incidental catch of northern sea lions (Eumetopias jubatus) in the walleye pollock (Theragra chalcogramma) joint-venture was studied during 1982-1984 to assess the nature and magnitude catch. Data were obtained by placing U.S. observers on foreign processing vessels. Dead sea lions recovered from trawl nets were counted, measured, teeth were removed for age determination incidental fishery in Shelikof Strait, Alaska, of the sexed and by dental laminae; and stomach contents were analyzed. Although the fishery has continued to expand both in number of boats and estimated total catch (74,136 metric tons {t} in 1982 to 171,539 t in 1984), the estimated catch of northern sea lions has declined (ranging from 958 to 1,436 in 1982, 216 to 324 in 1983 and 237 to 355 in 1984). Of the sea lions processed, 73 percent were caught between 2000 and 0500 h, probably during net retrieval. Most caught sea lions were females ranging in age from 1- 25 yr with a mean age of 6.43 yr; 79 percent of the females were sexually mature and probably part of the reproducing population. Males had a mean age of 4.8 yr and only 12 percent were old enough to obtain and defend territories. Analysis of stomach contents showed that the sea lions consumed pollock the same size as that taken by the commercial fishery. The impact of the incidental catch on the Gulf of Alaska sea lion population is unknown.

Lyons, E. T. (2005). Historic Importance of Some Aspects of Research by O. Wilford Olsen on Hookworms (Uncinaria Lucasi) in Northern Fur Seals (Callorhinus Ursinus) and Steller Sea Lions (Eumatopias Jubatus) in 1951 on St. Paul Island, Alaska. *Parasitology Research*, *95*(5), 353-357. https://doi.org/10.1007/s00436-005-1309-7

The purpose of this paper is to disseminate, more widely, certain historically important aspects of research by O. Wilford Olsen on hookworms (Uncinaria lucasi) in northern fur seals (Callorhinus ursinus) and Steller sea lions (Eumatopias jubatus) in 1951 on St. Paul Island, Alaska. Highly meaningful facets of the research were recorded only in a report with limited availability by Olsen in 1952. Portions of his research presented here include measurements of hookworm free-living infective third-stage larvae (L3) and adults, photographs of bursae, and the conclusion that the species of hookworms (U. lucasi) is probably the same in both pinniped hosts. This information is especially important because very little has been published on taxonomy of hookworms in E. jubatus.

 Miller, A. J., DiLorenzo, E., Neilson, D. J., Kim, H. J., Capotondi, A., Alexander, M. A., . . . Hedstrom, K. (2005). Interdecadal Changes in Mesoscale Eddy Variance in The Gulf of Alaska Circulation: Possible Implications for the Steller Sea Lion Decline. *Atmosphere-Ocean*, 43(3), 231-240. https://doi.org/10.3137/ao.430303

A distinct change in the ocean circulation of the Gulf of Alaska after the 1976–77 climate shift is studied in an eddy-permitting primitive equation model forced by observed wind stresses from 1951–99. When the Aleutian Low strengthens after 1976–77, strong changes occur in the mean velocity of the Alaskan Stream and in its associated mesoscale eddy field. In contrast, the Alaska Current and the eddy flows in the eastern Gulf remain relatively unchanged after the shift. Since mesoscale eddies provide a possible mechanism for transporting nutrient-rich open-ocean waters to the productive shelf region, the flow of energy through the food web may have been altered by this physical oceanographic change. This climate-driven mechanism, which has a characteristic eastwest spatial asymmetry, may potentially help to explain changes in forage fish quality in diet diversity of Steller sea lions whose populations have declined precipitously since the mid-1970s in the western Gulf while remaining stable in the eastern Gulf.

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. <u>https://doi.org/10.7589/2012-09-226</u>

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.

Moles, A., & Heintz, R. A. (2007). Parasites of Forage Fishes in the Vicinity of Steller Sea Lion (*Eumetopias Jubatus*) Habitat in Alaska. *Journal of Wildlife Diseases, 43*(3), 366-375. https://doi.org/10.7589/0090-3558-43.3.366

Fish serve as intermediate hosts for a number of larval parasites that have the potential of maturing in marine mammals such as Steller sea lions (*Eumetopias jubatus*). We examined the prevalence of parasites from 229 fish collected between March and July 2002 near two islands used by Steller sea lions in Southeast Alaska and island habitats in the Aleutian Islands. Sea lion populations have remained steady in Southeast Alaska but have been declining over the last 30 yr in the Aleutian Islands. Even though the fish samples near the Southeast Alaska haul-outs were composed of numerous small species
of fish and the Aleutian Islands catch was dominated by juveniles of commercially harvested species, the parasite fauna was similar at all locations. Eleven of the 20 parasite taxa identified were in their larval stage in the fish hosts, several of which have been described from mammalian final hosts. Four species of parasite were more prevalent in Southeast Alaska fish samples, and seven parasite species including several larval forms capable of infecting marine mammals, were more prevalent in fish from the Aleutian Islands. Nevertheless, parasites available to Steller sea lions from common fish prey are not likely to be a major factor in the decline of this marine mammal species.

Morgan, L., Hanni, K., & Lowenstine, L. (1996). Age and Pathological Findings for Two Female Steller Sea Lions Stranded on the Northern California Coast. *California Fish and Game, 82*(2), 81-86. Retrieved from

http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch &qid=27&SID=8AKBSJ5RixL6hagr5Wp&page=1&doc=1

This report details the causes of death of two adult Steller sea lions, *Eumetopias jubatus*, stranded on the north coast of California, In California, as in other areas of their range, Steller sea lion abundance is declining for unknown reasons, Several theories, including death due to fishery interactions, commercial harvest, long-term environmental change, and nutritional stress have been proposed, The Steller sea lions in this report were multiparous-aged females that died from pneumonia, Both animals also had evidence of gunshot wounds.

Myers, M. J. (2009). Organochlorines in Steller Sea Lions (Eumetopias Jubatus). University of Alaska Fairbanks, Retrieved from <u>https://scholarworks.alaska.edu/bitstream/handle/11122/8990/Myers_M_2009.pdf?sequence=</u> <u>1</u>

Existing populations of Steller sea lions (Eumetopias jubatus) have declined precipitously over the last half-century. Investigations into the cause of this downward trend have focused on many different possible factors. Toxicity caused by the accumulation of organochlorines (OCs), such as polychlorinated biphenyls (PCBs) and 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane or dichlorodiphenyltrichloroethane (DDT), has been demonstrated in marine mammals and was considered here as one possible factor that may have contributed to the decline of Steller sea lions or their failure to recover. The focus of this project was to investigate the relationship of contaminant loads to hormone levels, specifically thyroid hormones and cortisol in Steller sea lions. Two approaches were taken to this study. Firstly, baseline hormone concentrations were identified for the thyroid hormones, thyroxine (T sub(4)) and triiodothyronine (T sub(3)), and cortisol. This involves comparison and extrapolation. Secondly, possible risk effects were examined by comparing levels of OCs in captive and free-ranging Steller sea lions to known effects in related species with known physiological thresholds. Serum concentrations of total T sub(4) were highest in Steller sea lions followed by total T sub(3) concentrations. Concentrations of free T sub(4) and free T sub(3) were three to four orders of magnitude lower. Concentrations for all four thyroid hormone measurements tended to a lower level as animals matured beyond the neonatal stage. When thyroid hormones from captive sea lions were evaluated across seasons, all thyroid hormones were highest in the July to September period. Cortisol concentrations were similar in male and female pups. Cortisol varied with age but when considered in regards to time of year when sampled, followed a seasonal pattern. Cortisol was elevated in fall months in captive sea lions (non-pups), which is similar to what is seen in other marine mammals and is likely associated with the annual molt. Male pups from

Alaska had lower levels of PCBs and DDT when compared to male pups from Russia. Female pups from Alaska were significantly lower in PCBs than Russian female pups as were female pups for DDT levels between areas. Anywhere from 12 to 64% (depending on rookery) of Steller sea lion pups investigated for contaminants had concentrations of PCBs that are high enough to cause physiological problems. Concentrations in blood taken monthly for 2 years in three captive Steller sea lions were similar at any given sampling time and followed a seasonal pattern with levels significantly higher in the summer months of July to September and lower in the three month winter period January to March. Concentrations of OCs in blubber samples collected quarterly for the captive females followed an analogous pattern to blood samples but the captive male sea lion was considerably lower and declined over the study period. A significant relationship between blubber contaminants and lipids was noted in the three captive Steller sea lions. Even though OC contamination has not been hypothesized to be the primary factor that precipitated the population decline, there is a potential for these chemicals to have a negative effect on the health of free-ranging Steller sea lions. These data suggest that concentrations of OCs in Steller sea lions may be high enough to cause endocrine or reproductive dysfunction and could potentially impact fertility or fecundity. Therefore, OC contaminants can not be dismissed as a contributing source to either the decline or the failure to recover of the Steller sea lion population.

Myers, M. J., Ylitalo, G. M., Krahn, M. M., Boyd, D., Calkins, D., Burkanov, V., & Atkinson, S. (2008). Organochlorine Contaminants in Endangered Steller Sea Lion Pups (*Eumetopias Jubatus*) from Western Alaska and the Russian Far East. *Science of The Total Environment, 396*(1), 60-69. <u>https://doi.org/10.1016/j.scitotenv.2008.02.008</u>

Investigations into the cause of the Steller sea lion population decline have focused on numerous factors, including exposure to toxic contaminants such as organochlorines (OCs). OCs, such as polychlorinated biphenyls (PCBs), 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane, or dichlorodiphenyltrichloroethane (DDT), have been associated with various biological effects in marine mammals. We measured these compounds in whole blood of free-ranging Steller sea lion pups in order to determine the extent and magnitude of contamination across their geographical range. Of 212 pups analyzed for OCs, 76 pups (36 females and 40 males) were from western Alaska and the other 136 (63 females and 73 males) were from the Russian Far East. Concentrations of Σ PCBs in the whole blood of pups from western Alaska ranged from 0.21 to 13 ng/g wet weight with a mean of 2.1±0.27 ng/g wet weight. In the Russian animals, SPCB concentrations in the whole blood of pups ranged from 0.33 to 36 ng/g wet weight with a mean of 4.3±0.44 ng/g wet weight. ∑DDT concentrations in the whole blood of pups from western Alaska ranged from 0.18 to 11 ng/g wet weight with a mean of 1.6±0.23 ng/g wet weight. In Russia, Σ DDT in the whole blood of pups ranged from undetectable to 26 ng/g wet weight with a mean of 3.3 ± 0.36 ng/g wet weight. Average OC concentrations were significantly higher in the blood of Russian animals compared to western Alaska (for PCBs and DDTs, p<0.001) and in both areas females had higher concentrations than males. Male pups from western Alaska had significantly lower levels of Σ PCBs and Σ DDT when compared to male pups from Russia (for PCBs and DDTs p<0.001). Female pups from western Alaska were significantly lower in SPCBs than Russian female pups (for PCBs p=0.009) as were female pups for Σ DDT levels between areas (for DDTs p=0.026). OC contaminants data indicate that Steller sea lion pups have measurable concentrations of these synthetic chemicals. While any physiological effect and the specific role these chemicals may have in either the decline or the failure of the endangered Steller sea lion population to recover needs to be further investigated, this study indicates specific areas and animals that may be most at risk.

National Research Council. (2003). Ocean Noise and Marine Mammals. Washington, DC: Ocean Study Board, National Academy Press. <u>https://doi.org/10.17226/10564</u>

Scientists and laypersons alike are well aware that human-generated sound in the sea comes from a variety of sources, including commercial ship traffic, oil exploration and production, construction, acoustic research, and sonar use. Underwater sounds are also generated by natural occurrences such as wind-generated waves, earthquakes, rainfall, and marine animals. It is well known that noise levels in the sea began to increase steadily with the onset of industrialization in the mid-nineteenth century. The conventional assumption is that this trend has continued in recent times as well, but there is only limited scientific evidence to support this hypothesis. However, remarkably few details are known about the characteristics of ocean noise, whether it be of human or natural origin, and much less is understood of the impact of noise on the short- and long-term well-being of marine mammals and the ecosystems on which they depend.

Oreskes, N. (2004). The Scientific Consensus on Climate Change. *Science*, *306*(5702), 1686-1686. Retrieved from <u>https://science.sciencemag.org/content/sci/306/5702/1686.full.pdf</u>

Essay on the scientific consensus on climate change.

Pachauri, R. K., & Reisinger, A. (2007). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, li and lii to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* International Panel on Climate Change Retrieved from https://archive.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf

This Synthesis Report is based on the assessment carried out by the three Working Groups of the Intergovernmental Panel on Climate Change (IPCC). It provides an integrated view of climate change as the final part of the IPCC's Fourth Assessment Report (AR4). A complete elaboration of the Topics covered in this summary can be found in this Synthesis Report and in the underlying reports of the three Working Groups.

Randhawa, N., Gulland, F., Ylitalo, G. M., DeLong, R., & Mazet, J. A. (2015). Sentinel California Sea Lions Provide Insight into Legacy Organochlorine Exposure Trends and Their Association with Cancer and Infectious Disease. One Health, 1, 37-43. <u>https://doi.org/10.1016/j.onehlt.2015.08.003</u>

Background: Organochlorine contaminants (OCs), like polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethanes (DDTs), are widespread marine pollutants resulting from massive historical use and environmental persistence. Exposure to and health effects of these OCs in the marine environment may be examined by studying California sea lions (Zalophus californianus), which are long lived, apex predators capable of accumulating OCs. Methods: We evaluated PCB and DDT levels in 310 sea lions sampled between 1992 and 2007: 204 individuals stranded along the coast of central California, 60 healthy males fromWashington State, and 46 healthy females fromsouthern California. Lipid-normalized contaminant concentrations were analyzed using general linear models and logistic regression to ascertain temporal trends; differences between stranded and healthy sea lions; and association of organochlorines with sex, age, and presence of cancer or fatal infectious disease. Results: Concentrations ofthe contaminants in stranded adults decreased over time in the study period (adjusted

for sex, as adult males had higher mean blubber concentrations than adult females and juveniles). Cancer was almost eight and six timesmore likely in animalswithhigher summed PCBs andDDTs, compared to thosewith lower levels (95% CI 5.55–10.51 and 4.54–7.99, respectively). Fatal infectious diseases were similarly seven and five times more likely in animals with higher contaminant burdens (95% CI 4.20–10.89 and 3.27–7.86, respectively). Mean contaminant loads were significantly higher in stranded sea lions than in healthy live captured animals (p b 0.001). Conclusion: Organochlorine contamination has significant associations with health outcomes in California sea lions, raising concerns for humans and other animals eating tainted seafood. While environmental exposure to these organochlorines appears to be decreasing over time based on levels in sea lion tissues, their persistence in the environment and foodweb for all predators, including humans, and the associated serious health risks, warrant monitoring, possibly through sentinel species like marine mammals.

Rea, L. D., Castellini, J. M., Correa, L., Fadely, B. S., & O'Hara, T. M. (2013). Maternal Steller Sea Lion Diets Elevate Fetal Mercury Concentrations in an Area of Population Decline. *Science of The Total Environment*, 454-455, 277-282. <u>https://doi.org/10.1016/j.scitotenv.2013.02.095</u>

Total mercury concentrations ([THg]) measured in western Aleutian Island Steller sea lion pup hair were the highest maximum [THg] documented in this endangered species to date. Some pups exceeded concentrations at which other fish-eating mammals can exhibit adverse neurological and reproductive effects (21% and 15% pups above 20 and $30\mu g/g$ in hair, respectively). Of particular concern is fetal exposure to mercury during a particularly vulnerable stage of neurological development in late gestation. Hair and blood [THg] were highly correlated and 20% of pups sampled in the western Aleutian Islands of Alaska exceeded mammalian risk thresholds established for each of these tissues. Higher nitrogen isotope ratios suggested that pups accumulated the highest [THg] when their dams fed on higher trophic level prey during late gestation.

Rea, L. D., J.M. Castellini, J.P. Avery, B.S. Fadely, V.N. Burkanov, M.J. Rehberg, & O'Hara., T. M. (*In Prep.*). Regional Variations and Drivers of Mercury and Selenium Concentrations in Steller Sea Lions. . *Science of The Total Environment*

[NO ABSTRACT AVAILABLE]

Savage, K. (2018). 2017 Alaska Region Marine Mammal Stranding Summary. National Marine Fisheries Service Alaska Region. Retrieved from <u>https://www.fisheries.noaa.gov/resource/document/2017-alaska-region-stranding-summary</u>

Strandings of cetaceans (whales) and pinnipeds (seals and sea lions) t hat occurred in Alaskan waters and were reported to the National Marine Fisheries Service, Alaska Region (NMFS) in 2017 are summarized here. Stranding events cover animals found dead (floating and beached), and also reports of live stranded, mass stranded, abandoned, sick or injured animals. Strandings include all marine mammals under NMFS jurisdiction. Marine mammal species managed b y the U.S. Fish and Wildlife Service, including polar bear, sea otter and walrus, are not included. Reports are made by expert members of the marine mammal community as well as members of the general public with varying degrees of knowledge regarding marine mammal biology and ecology. The extent to which reported st randed animals have been examined is variable, from no examination to the performance of a full necropsy and analysis of pathology. Known subsistence takes are not included nor are fishery observer reports unless the animal was observed outside of statistical reporting protocols (and thus would not be included by the observer program as part of their watch data set). Variability in historic numbers between annual reports may reflect the addition of new reports or changing criteria for reports that are included as strandings. Not all reports of injured marine mammals are considered strandings and entered in to Marine Mammal Health and Stranding Response Program's (MMHSRP) National Stranding Database. As of 2017, stranding reports no longer include entanglements or vessel strikes, unless the event resulted in mortality or a response was deemed necessary. Instead, reports of live entanglements or vessel strikes are collected regionally and assessed separately (pages 11 - 13). interaction, such as ship strikes, fishery interactions/entanglements and firearm injury, are also included with a high level of confirmation.

Savage, K. (2019). 2018 Alaska Region Marine Mammal Stranding Summary. National Marine Fisheries Service Alaska Region. Retrieved from <u>https://www.fisheries.noaa.gov/alaska/marine-life-distress/alaska-marine-mammal-stranding-network</u>

Strandings of cetaceans (whales) and pinnipeds (seals and sea lions) that occurred in Alaskan waters and were reported to the National Marine Fisheries Service, Alaska Region (NMFS) in 2018 are summarized here. Stranding events cover animals found dead (floating and beached), and also reports of live stranded, mass stranded, abandoned, sick, or injured animals. Strandings include all marine mammals under NMFS jurisdiction. Marine mammal species managed by the U.S. Fish and Wildlife Service (polar bear, sea otter, and walrus) are not included. Reports are made by expert members of the marine mammal community as well as members of the general public with varying degrees of knowledge regarding marine mammal biology and ecology. The extent to which reported stranded animals have been examined is variable, from no examination to the performance of a full necropsy and analysis of pathology. Known subsistence takes are not included nor are fishery observer reports unless the animal was observed outside of statistical reporting protocols (and thus would not be included by the observer program as part of their watch data set). Variability in historic numbers between annual reports may reflect the addition of new reports or changing criteria for reports that are included as strandings. Not all reports of injured marine mammals are considered strandings and entered into Marine Mammal Health and Stranding Response Program's (MMHSRP) National Stranding Database. As of 2017, stranding reports no longer include entanglements or vessel strikes, unless the event resulted in mortality or a response was deemed necessary. Instead, reports of live entanglements or vessel strikes are collected regionally and assessed separately (pages 11 - 13).

Sydeman, W. J., & Jarman, W. M. (1998). Trace Metals in Seabirds, Steller Sea Lion, and Forage Fish and Zooplankton from Central California. *Marine Pollution Bulletin, 36*(10), 828-832. <u>https://doi.org/10.1016/s0025-326x(98)00076-9</u>

We studied concentrations of the trace metals, aluminum (AI), chromium (Cr), iron (Fe), copper (Cu), zinc (Zn), arsenic (As), selenium (Se), silver (Ag), cadmium (Cd), and mercury (ng), in krill (Euphausia pacifica and Thysanoessa spinifera), two species of fish (short-bellied rockfish Sebastes jordani and northern anchovy Engraulis mol dar), four species of marine bird (Common Murre Uria aalge, Brandt's Cormorant Phalacrocorax penicillatus, Rhinoceros Anklet Cerorhinca monocerata, and Pigeon Guillemot Cepphus columba) and a pinniped, (Steller sea lion *Eumetopias jubatus*) from the Gulf of the Farallones, central California in 1993, Geometric mean levels of some trace elements in Stellar sea lions were

elevated (Cu, 91.0 mg/kg dry weight; Hg, 19.0 mg/kg; Se, 4.1 mg/kg). Levels of Ng in Pigeon Guillemot (3.5 mg/kg) were also elevated. Mercury increased whereas Pb decreased with increasing trophic level in the Gulf of the Farallones food web, Selenium levels were highest for krill and sea lions, and intermediate for fish and birds occupying mid trophic levels. Results indicate little to relatively high trace metal contamination of upper trophic level marine wildlife in the central California coastal marine ecosystem,

Tanaka, E., Kimura, T., Wada, S., Hatai, K., & Sonoda, S. (1994). Dermatophytosis in a Steller Sea Lion (Eumetopias-Jubatus). *Journal of Veterinary Medical Science*, *56*(3), 551-553. <u>https://doi.org/10.1292/jvms.56.551</u>

Serious dermatophytosis caused by Trichophyton mentagrophytes was found in a Steller sea lion (*Eumetopias jubatus*) at Yomiuri Land Marine Aquarium in Tokyo. The external clinical signs were extensive depilation and hyperkeratosis, as well as redness and depigmentation of the skin. Histopathological findings of the skin revealed PAS positive fungal hyphae with septa in the corneum layer of the epidermis. Further microscopic examination suggested that this lesion of the skin was typical chronic dermatophytosis. Based on morphological and growth characteristics, the isolate was identified as Trichophyton mentagrophytes. It was thought that the infection was due to some factors including species and individual specific and environmental factors and so on.

Trites, A. W., Miller, A. J., Maschner, H. D. G., Alexander, M. A., Bograd, S. J., Calder, J. A., . . . Winship, A. J. (2007). Bottom-up Forcing and the Decline of Steller Sea Lions (*Eumetopias Jubatus*) in Alaska: Assessing the Ocean Climate Hypothesis. *Fisheries Oceanography*, 16(1), 46-67. https://doi.org/10.1111/j.1365-2419.2006.00408.x

Declines of Steller sea lion (Eumetopias jubatus) populations in the Aleutian Islands and Gulf of Alaska could be a consequence of physical oceanographic changes associated with the 1976–77 climate regime shift. Changes in ocean climate are hypothesized to have affected the quantity, quality, and accessibility of prey, which in turn may have affected the rates of birth and death of sea lions. Recent studies of the spatial and temporal variations in the ocean climate system of the North Pacific support this hypothesis. Ocean climate changes appear to have created adaptive opportunities for various species that are preyed upon by Steller sea lions at mid-trophic levels. The east-west asymmetry of the oceanic response to climate forcing after 1976–77 is consistent with both the temporal aspect (populations decreased after the late 1970s) and the spatial aspect of the decline (western, but not eastern, sea lion populations decreased). These broad-scale climate variations appear to be modulated by regionally sensitive biogeographic structures along the Aleutian Islands and Gulf of Alaska, which include a transition point from coastal to open-ocean conditions at Samalga Pass westward along the Aleutian Islands. These transition points delineate distinct clusterings of different combinations of prey species, which are in turn correlated with differential population sizes and trajectories of Steller sea lions. Archaeological records spanning 4000 yr further indicate that sea lion populations have experienced major shifts in abundance in the past. Shifts in ocean climate are the most parsimonious underlying explanation for the broad suite of ecosystem changes that have been observed in the North Pacific Ocean in recent decades.

U.S. Attorney's Office District of Alaska. (2018). Two Alaska Men Sentenced for Harassing, Killing Steller Sea Lions and Obstructing the Investigation into Their Illegal Activities. [Press release]. Retrieved from <u>https://www.justice.gov/usao-ak/pr/two-alaska-men-sentenced-harassing-killing-steller-</u> sea-lions-and-obstructing

Press release on charges filed against two men for the killing and harassment of Steller sea lions.

Wang, J., Hulck, K., Hong, S. M., Atkinson, S., & Li, Q. X. (2011). Accumulation and Maternal Transfer of Polychlorinated Biphenyls in Steller Sea Lions (*Eumetopias Jubatus*) from Prince William Sound and the Bering Sea, Alaska. *Environmental Pollution*, 159(1), 71-77. https://doi.org/10.1016/j.envpol.2010.09.022

The western stock of the Steller sea lion (*Eumetopias jubatus*) in the northern Pacific Ocean has declined by approximately 80% over the past 30 years. This led to the listing of this sea lion population as an endangered species in 1997. Chemical pollution is a one of several contributing causes. In the present study, 145 individual PCBs were determined in tissues of male sea lions from Tatitlek (Prince William Sound) and St. Paul Island (Bering Sea), and placentae from the Aleutian Islands. PCBs 90/101, 118, and 153 were abundant in all the samples. The mean toxic equivalents (TEQ) were 2.6, 4.7 and 7.4 pg/g lw in the kidney, liver, and blubber samples, respectively. The mean TEQ in placentae was 8 pg/g lw. Total PCBs concentrations (2.6-7.9 mu g/g lw) in livers of some males were within a range known to cause physiological effects. Further suggesting the possibility of adverse effects on this stock.

Warlick. (n.d.). Characterization of Pinniped Stranding and Human Interaction Cases Along the Oregon and Washington Coasts, 1989 - 2015. Manuscript.

Pinnipeds are often considered sentinels of ocean health. Strandings can be used as a proxy to assess pinniped health and the impacts of anthropogenic activities in the local marine environment. We used stranding response network data to examine stranding patterns over time (interannual and interseasonal) and space (regionally). From 1989 to 2015, a total of 14,167 pinnipeds stranded along the coasts of Washington and Oregon, 11% of which were documented as human interaction cases. Gunshot wounds and fisheries interactions comprised the majority of human interaction cases overall (36% and 20%, respectively), though the prevalence of specific types of human interaction cases has changed over time and varies significantly across sex, age class, and species. The majority of stranded individuals were harbor seals (59%) and California sea lions (19%) of specific age classes, likely reflecting species' demographic characteristics, such as local abundance, the timing of weaning, and seasonal migratory patterns. Overall, the number of strandings and human interaction cases have significantly increased over time. Spatial patterns in stranding vary across species, but overall, the average number of cases is higher in Washington and human interactions are significantly higher in certain counties of both states. Despite the challenges and uncertainties inherent in using stranding data as an indicator of pinniped health and anthropogenic impacts, these data and analyses are useful tools for evaluating major threats to pinniped populations, hotspots of anthropogenic impacts, and the importance of continued support and development of regional stranding response networks.

Warlick, A. J., Duffield, D. A., Lambourn, D. M., Jeffries, S. J., Rice, J. M., Gaydos, J. K., . . . Norman, S. A. (2018). Spatio-Temporal Characterization of Pinniped Strandings and Human Interaction Cases

in the Pacific Northwest, 1991-2016. *Aquatic Mammals*, 44(3), 299-318. https://doi.org/10.1578/am.44.3.2018.299

Pinniped strandings can be used as a proxy to evaluate the impacts of anthropogenic activities on the local marine environment. Stranding data from Oregon and Washington from 1991 to 2016 were used to examine regional and temporal patterns in strandings and human interaction cases across age and sex for six species. Over the study period, 14,729 pinnipeds were reported stranded along the coast in the Pacific Northwest, 11% of which were documented as human interaction cases. Total strandings and the number of reported human interaction cases increased over time for most species. The composition of age and sex classes varied for each species, as did the proportion of strandings identified as human interaction cases. Gunshot wounds and fisheries entanglements were concentrated in clusters along the, coast and together constituted the, majority of human interaction cases. Stranding and human interaction of pinnipeds and human activities along the, coast. Despite the challenges and uncertainties inherent in using stranding data as an indicator of pinniped health and anthropogenic impacts, modeling spatio-temporal patterns is useful for stranding response practitioners and natural resource managers when evaluating the scope and magnitude of threats to pinniped populations.

Welsh, T., Burek-Huntington, K., Savage, K., Rosenthal, B., & Dubey, J. P. (2014). Sarcocystis Canis Associated Hepatitis in a Steller Sea Lion (*Eumetopias Jubatus*) from Alaska. *Journal of Wildlife Diseases, 50*(2), 405-408. <u>https://doi.org/10.7589/2013-03-079</u>

Sarcocystis canis infection was associated with hepatitis in a Steller sea lion (*Eumetopias jubatus*). Intrahepatocellular protozoal schizonts were among areas of necrosis and inflammation. The parasite was genetically identical to S. canis and is the first report in a Steller sea lion, indicating another intermediate host species for S. canis.

Williams, R., Ashe, E., & O'Hara, P. D. (2011). Marine Mammals and Debris in Coastal Waters of British Columbia, Canada. *Marine Pollution Bulletin*, 62(6), 1303-1316. <u>https://doi.org/10.1016/j.marpolbul.2011.02.029</u>

Entanglement in and ingestion of synthetic marine debris is increasingly recognized worldwide as an important stressor for marine wildlife, including marine mammals. Studying its impact on wildlife populations is complicated by the inherently cryptic nature of the problem. The coastal waters of British Columbia (BC), Canada provide important habitat for marine mammal species, many of which have unfavorable conservation status in the US and Canada. As a priority-setting exercise, we used data from systematic line-transect surveys and spatial modeling methods to map at-sea distribution of debris and 11 marine mammal species in BC waters, and to identify areas of overlap. We estimated abundance of 36,000 (CIs: 23,000-56,600) pieces of marine debris in the region. Areas of overlap were often far removed from urban centers, suggesting that the extent of marine mammal-debris interactions would be underestimated from opportunistic sightings and stranding records, and that high-overlap areas should be prioritized by stranding response networks.

Winship, A. J., & Trites, A. W. (2006). Risk of Extirpation of Steller Sea Lions in the Gulf of Alaska and Aleutian Islands: A Population Viability Analysis Based on Alternative Hypotheses for Why Sea Lions Declined in Western Alaska. *Marine Mammal Science*, 22(1), 124-155. https://doi.org/10.1111/j.1748-7692.2006.00009.x

We estimated the risk that the Steller sea lion will be extirpated in western Alaska using a population viability analysis (PVA) that combined simulations with statistically fitted models of historical population dynamics. Our analysis considered the roles that density-dependent and density-independent factors may have played in the past, and how they might influence future population dynamics. It also established functional relationships between population size, population growth rate and the risk of extinction under alternative hypotheses about population regulation and environmental variability. These functional relationships can be used to develop recovery criteria and guide research and management decisions. Life table parameters (e.g., birth and survival rates) operating during the population decline (1978–2002) were estimated by fitting simple age-structured models to time-series of pup and non-pup counts from 33 rookeries (subpopulations). The PVA was carried out by projecting all 33 subpopulations into the future using these estimated site-specific life tables (with associated uncertainties) and different assumptions about carrying capacities and the presence or absence of density-dependent population regulation. Results suggest that the overall predicted risk of extirpation of Steller sea lions as a species in western Alaska was low in the next 100 yr under all scenarios explored. However, most subpopulations of Steller sea lions had high probabilities of going extinct within the next 100 yr if trends observed during the 1990s were to continue. Two clusters of contiguous subpopulations occurring in the Unimak Pass area in the western Gulf of Alaska/eastern Aleutian Islands and the Seguam–Adak region in the central Aleutian Islands had relatively lower risks of extinction. Risks of extinction for a number of subpopulations in the Gulf of Alaska were reduced if the increases observed since the late 1990s continue into the future. The risks of subpopulations going extinct were small when density-dependent compensation in birth and survival rates was assumed, even when random stochasticity in these vital rates was introduced.

Wise, J. P., Goertz, C. E. C., Wise, S. S., Morin, A. T., Dunn, J. L., Gulland, F. M. D., . . . Thompson, W. D. (2006). *Chromium Cytotoxicity in Steller Sea Lion Lung, Skin, and Testes Cells*. In *Sea Lions of the World*. A.W. Trites, S.K. Atkinson, D.P. DeMaster, L.W. Fritz, T.S. Gelatt, L.D. Rea, and K.M. Wynne (Eds.) Sea Grant Alaska. <u>https://doi.org/10.4027/slw.2006.05</u>

The western population of Steller sea lions is endangered, and several hypotheses have been proposed to explain its decline. We are investigating the hypothesis that metals might be a factor in this decline. We found that chromium induced a concentration-dependent cytotoxicity in an organ-specific manner in Steller sea lion cells. Testicular cells were the most sensitive, and skin cells the most resistant. Lung cells were of intermediate sensitivity. Chromium uptake, measured by ICP-AES, increased. with concentration in a cell-specific manner. When exposed to the same concentrations of sodium chromate, testicular cells accumulated greater intracellular concentrations of chromium ions than skin or lung cells did. This difference in chromium ion uptake may account for part of the differences in cytotoxicity among cell types. Tissue samples obtained opportunistically from pups were analyzed using inductively coupled plasma mass spectrometry (ICP-MS). Most pups had undetectable levels of chromium; however, in those where chromium was detected, its concentration was similar to that causing 50% cytotoxicity in culture. This finding suggests chromium may be a significant risk factor for Steller sea lions. These data were determined from a small number of samples from pre-weaned pups, and thus may not reflect adult exposure levels. However, given that chromium is known to accumulate and persist in human tissues, it is likely that adult exposures will prove to be much higher than pup levels.

Further research is aimed at identifying chromium levels in adult tissues, determining genotoxic levels and investigating effects of other metals on Steller sea lion cells.

Wise, S. S., Shaffley, F., LaCerte, C., Goertz, C. E. C., Dunn, J. L., Gulland, F. M. D., . . . Wise, J. P. (2009). Particulate and Soluble Hexavalent Chromium Are Cytotoxic and Genotoxic to Steller Sea Lion Lung Cells. Aquatic Toxicology, 91(4), 329-335. <u>https://doi.org/10.1016/j.aquatox.2008.12.004</u>

Hexavalent chromium is an environmental contaminant. Within the environment, marine waters are a common site for hexavalent chromium deposition. We have recently reported significantly high levels of chromium in skin tissue from North Atlantic right whales, These findings demonstrate that marine species are being exposed to chromium. It is possible that such exposures may be playing a role in population declines evident among certain marine mammals, such as the Steller sea lion. We developed a Steller sea lion lung cell line from Steller sea lion lung tissue. Hexavalent chromium was cytotoxic to these primary lung fibroblasts as 1, 2.5, 5, 10 and 25 mu M sodium chromate induced 104, 99, 92, 58 and 11% relative survival, respectively. It was also genotoxic as 0, 1, 2.5, 5 and 10 mu M sodium chromate damaged chromosomes in 6,11,21,36, and 39% of metaphases and damaged 6,12,27,49 and 57 total aberrations in 100 metaphases, respectively. We also considered the toxicity of particulate hexavalent chromium, as it is the more potent carcinogen in humans. We found that 0.1, 0.5, 1, 5 and 10 mu g/cm(2) particulate chromate induced 95, 88, 91, 70, and 52% relative cell survival, respectively. These concentrations were genotoxic and damaged chromosomes in 9, 13, 18, and 23% of metaphases and induced 9, 15, 20 and 30 total aberrations per 100 metaphases, respectively. These data indicate that if sufficiently exposed, chromium may adversely affect the struggling Steller sea lion population. It would be prudent to investigate the effects chromium has in other Steller sea lion organs in order to derive a better understanding of how chromium in the marine environment may be affecting the declining Steller sea lion population.

Wolfe, R. J., & Mishler, C. (1993). The Subsistence Harvest of Harbor Seal and Sea Lion by Alaska Natives in 1992. Alaska Department of Fish and Game Division of Subsistence. Technical Paper No. 229. Retrieved from <u>https://www.arlis.org/docs/vol1/31110534.pdf</u>

This report describes the subsistence takes of harbor seal (Phoca vitulina) and Steller sea lion (*Eumetopias jubatus*) by Alaska Natives in 1992 including size, seasons, geographic distribution, and age and sex of the harvest. Information is summarized at the state, region, and community levels. The research was conducted by the Division of Subsistence, Alaska Department of Fish and Game under contract with the National Marine Fisheries Service.

Wolfe, R. J., & Mishler, C. (1997). The Subsistence Harvest of Harbor Seal and Sea Lion by Alaska Natives in 1996. Alaska Department of Fish and Game Division of Subsistence. Technical Paper No. 241. Retrieved from <u>http://www.adfg.alaska.gov/techpap/tp241.pdf</u>

This report describes the subsistence take of harbor seal (Phoca vitulina) and Steller sea lion (*Eumetopias jubatus*) by Alaska natives in 1996, including quantity seasons, geographic distribution, and age and sex of the harvest.

Wright, S. (2016). 2016 Copper River Delta Carcass Surveys, Annual Report. National Marine Fisheries Service Alaska Region. Retrieved from <u>https://repository.library.noaa.gov/view/noaa/17307</u>

NMFS Protected Resources Division conducted six survey flights of the shifting sand shoals of the Copper River Delta (Delta) from May 10 to August 9, 2016. The purpose of the flights was to search for marine mammal carcasses, and, if carcasses were observed, coordinate with the USCG to fly to the carcasses via helicopter to determine cause of death and conduct necropsies. PRD biologists flew with the USCG following four of the six surveys to collect samples and conduct necropsies from observed marine mammals. At least three Steller sea lion (*Eumetopias jubatus*), one whale, and five harbor seal (Phoca vitulina) carcasses were observed on the survey flights. Six of the eight pinniped carcasses showed evidence that they may have been intentionally killed by humans. In addition, we were able to examine and sample five whale carcasses east of the survey area while we were in Cordova to conduct scheduled surveys of the Delta.

Ylitalo, G. M., Stein, J. E., Hom, T., Johnson, L. L., Tilbury, K. L., Hall, A. J., . . . Gulland, F. M. (2005). The Role of Organochlorines in Cancer-Associated Mortality in California Sea Lions (*Zalophus Californianus*). *Marine Pollution Bulletin, 50*(1), 30-39. https://doi.org/10.1016/j.marpolbul.2004.08.005

Wild California sea lions (Zalophus californianus) have an unusually high prevalence of neoplasms (18% of stranded dead adults) and high levels of contaminants. The contribution of organochlorine (OC) tissue burdens to the probability of sea lions dying from carcinoma was explored using a logistic regression model. Levels of PCBs and DDTs were determined in blubber of sea lions diagnosed with metastatic carcinoma and animals that had died from non-carcinoma-related incidents (e.g., gunshot, domoic acid poisoning). Animals with carcinoma had higher mean concentrations (based on wet weight) of PCBs and DDTs (more than 85% and 30% higher, respectively) in blubber than did sea lions without carcinoma; the highest concentrations of OCs in the sea lions affected with carcinoma were measured in the males. Blubber thickness was significantly different between the two groups of sea lions, but after controlling for this difference, there was still a significant effect of PCBs, but not DDTs, on the probability of sea lions dying with carcinoma. Age, sex, mass and length did not affect the probability of dying from carcinoma.

Zabka, T. S., Buckles, E. L., Gulland, F. M. D., Haulena, M., Naydan, D. K., & Lowenstine, L. J. (2004).
Pleomorphic Rhabdomyosarcoma with Pulmonary Metastasis in a Stranded Steller (Northern)
Sea Lion (*Eumetopias Jubatus*). *Journal of Comparative Pathology*, 130(2-3), 195-198.
https://doi.org/10.1016/j.jcpa.2003.08.001

A Steller (northern) sea lion (SSL), stranded in northern California in July 2000 had an anaplastic, pleomorphic rhabdomyosarcoma in the latissimus dorsi muscle, with pulmonary metastasis. Diagnosis was, based on light and electron microscopy and immunohistochemistry. Death was attributed to multiple parasitic and bacterial lesions. The SSL is of special concern because, for unknown reasons, the global population has declined by 50% over the last decade. Published post-mortem data, however, are scarce. This case report highlights several disease conditions that affect this species and is the first report of a malignant neoplasm in a free-ranging SSL.

 Zaleski, A., Atkinson, S., Burkanov, V., & Quinn, T., 2nd. (2014). The Effect of Organohalogen Contaminants on Western Steller Sea Lion Survival and Movement in the Russian Far East. Science of the Total Environment. 490, 561-569. <u>https://doi.org/10.1016/j.scitotenv.2014.04.113</u>

The western stock of Steller sea lions (Eumetopias jubatus) have experienced dramatic declines since the 1960s, particularly in the western Alaskan and Asian portions, which have continued to decline or stabilized at low levels. Multiple causes for this decline have been proposed and may include anthropogenic contamination from organohalogen contaminants (OCs). These include polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT), which have not been ruled out as a potential cause for the lack of recovery. The objective of this study was to determine the effects of OCs on survival and movement probabilities estimated in program MARK using resighting data collected from 2003 to 2009. PCBs and DDTs were measured in whole blood from 136 (74 males and 62 females) individually marked, free-ranging pups from four Russian Far East rookeries. The mean concentration of summation operatorPCB and summation operatorDDT was 4.25+/-5.12 and 3.22+/-4.28 ng g(-1) ww (n=136), respectively, and the average summation operatorPCB and summation operatorDDT concentration for those above the aggregate mean (n=44) was 9.25+/-6.55 and 7.65+/-5.21 ng g(-1) ww, and those below the aggregate mean (n=92) the concentration was 1.86+/-0.89 and 1.11+/-0.65 ng g(-1) ww, respectively. The lowest estimated probabilities of survival occurred in the first year, ranging from 38% to 74%, but increased for ages 1-9, ranging from 82% to 94%. The greatest movement occurred from Medny Island west toward the Kamchatka Peninsula (33%) and to Bering Island (18%), and low movement estimates for other natal rookeries was largely due to minimal resighting effort. The estimated probabilities of resighting varied by location (48%-87%), but had greater precision than survival or movement parameters. Survival and movement were most affected by age and location rather than OCs.

Zenteno-Savin, T., Castellini, M. A., Rea, L. D., & Fadely, B. S. (1997). Plasma Haptoglobin Levels in Threatened Alaskan Pinniped Populations. *Journal of Wildlife Diseases, 33*(1), 64-71. <u>https://doi.org/10.7589/0090-3558-33.1.64</u>

We evaluated the plasma concentration of the acute phase protein haptoglobin (Hp) from Steller sea lions (*Eumetopias jubatus*) and harbor seals (Phoca vitulina) in regions of Alaska (USA) where the populations of these pinnipeds were declining and compared the values with concentrations of Hp from the same species in areas where the populations were stable. Samples were collected from 1992 through 1994 at sites in Southeast Alaska, Prince William Sound, the Gulf of Alaska, and the Aleutian Islands. Significantly higher levels of Hp were found in the samples from the areas of decline compared to those from stable populations. Based on these findings, we propose that one may be able to distinguish these compromised pinniped populations using Hp as a biomedical indicator.