Chapter

12

The Indigenous Sentinels Network

Community-Based Monitoring to Enhance Food Security

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INTRODUCTION

The Pribilof Islands are a five-island archipelago in the eastern Bering Sea, Alaska, and provide vital breeding and feeding habitat for more than half of the world's population of *laaqudan* (Unangam Tunuu [Aleut], northern fur seal, *Callorhinus ursinus*) and foraging and resting areas for the federally endangered western population of *qawan* (Unangam Tunuu [Aleut], Steller sea lion, *Eumetopias jubatus*). The precontact users of the Pribilof Islands created one of the world's most specialized and successful maritime hunter-gatherer traditions, lasting from roughly 4000 BP to the time of Russian contact in 1741 CE (Veniaminov 1984). The Indigenous peoples of the area, known among themselves by regional synonyms, were called by their historical colonizers "Aleuts." Prehistoric culture across the Aleutian and Pribilof Islands was based almost entirely on the utilization of marine resources, including hunting local sea mammals, fishing and foraging in coastal and offshore waters, and hunting birds on land and at sea.

Today, there are two permanent Alaska Native communities in the Pribilof Islands: St. Paul (2021 population of 477, > 80% Alaska Native) and St. George (2021 population of 97, > 90% Alaska Native). The Indigenous peoples collectively sharing the time-honored bond of living together on St. George and St. Paul prefer to be called Unangax̂ (singular noun, adjective), Unangan (plural collective), or Unangas. These communities rely heavily on access to marine resources for sustenance; for physical, emotional, and spiritual health; and to maintain the continuity of their customary and traditional ways of life.

Even after the Russian occupation of the islands and enslavement of Unangan for the purpose of harvesting *laaqudan* pelts on the Pribilof Islands (Black 1983, Torrey 1983), the predominance of marine mammals in Unangax̂ subsistence diets, despite the availability of Russian foodstuffs, demonstrates the maintenance of cultural traditions during a time of intense colonialism. Since the late 20th century, St. Paul has observed rapid and dramatic changes in the distribution and abundance of both *laaqudan* and *qawan*. Historically, a majority (75%) of the worldwide population of *laaqudan* have bred on the Pribilof Islands (Gentry 1998). The Pribilof *laaqudan* herd has declined ~ 70% since the 1970s, with a majority of *laaqudan* breeding on St. Paul (Short et al. 2021). Since 1998, pup production on St. Paul has declined by 57.7% (Towell et al. 2018). *Laaqudan* birth and survival rate decline factors currently under investigation include climate change (Francis et al. 1998, Hare and Mantua 2000); competition with commercial fisheries (McHuron et al. 2020, Short et al. 2021); predation (Springer et al. 2003, Springer et al. 2008, Newman et al. 2008); and emigration (Muto et al. 2019, Short et al. 2021). Understanding the factors influencing *laaqudan* population dynamics in order to promote population recovery is a high priority for resource managers at the local and regional levels. At the local level, it is vital in the context of ensuring food security.

In recorded history, *qawan* were abundant in the Bering Sea and bred in large numbers on the Pribilof Islands (Trites and Larkin 1996). However, populations of *qawan* on the islands have declined to exceedingly low levels, and the sole remaining breeding rookery, located at Walrus Island, is currently in danger of extinction. In the 1870s, approximately 10,000–12,000 sea lions were distributed at breeding rookeries on the Pribilof Islands (Elliott 1880). By 1916, these rookeries had been largely extirpated due to hunting and culling (Loughlin et al. 1984). Since the mid-20th century, *qawan* pup production on Walrus Island has declined by over 98%, from 2,866 pups born in 1960 to 48 in 2015 (Fritz et al. 2015). Subsistence takes of *qawan* on St. Paul have also declined. The cause of the decline of *qawan* on the Pribilof Islands remains poorly understood, though the most severe threats to the recovery of the western Alaska stock of *qawan* are environmental variability, competition with fisheries, killer whale predation, and toxins in the marine environment (NMFS 2008).

The decline of keystone subsistence resources such as *laaqudan* and *qawan*, in conjunction with increasing environmental variability and the unpredictability of other subsistence resources, has created an urgent need for ongoing resource monitoring. The communities of St. Paul and St. George, technical and scientific advisors, agency partners, and local volunteers together have developed a regional community-based coastal and ocean monitoring program that has enabled community members to collect reliable local data to inform decisions that affect these key species. The first iteration of the monitoring program, called the Sentinel Database, started in 2004, using personal digital assistant devices. The database was taken online in 2008 and renamed BeringWatch. BeringWatch data collection was rooted in both Traditional Ecological Knowledge and Western science, recognizing the diversity of qualitative and quantitative data and that both are valuable in decision-making, especially in a rapidly changing environment. In 2018, in response to a growing need for practical, streamlined, Indigenous-driven monitoring programs across

Alaska and Canada, the BeringWatch program evolved into the Indigenous Sentinels Network (ISN). ISN has broadened its reach in several Bering Sea and Aleutian Islands communities, including Akutan, False Pass, King Cove, and Unalaska.

In this chapter, we explore how the data collection and dissemination of components of ISN have been successful from a food security perspective. We use marine mammal harvest and winter sea duck and gull monitoring on St. Paul Island, Alaska, as case studies to demonstrate how ISN addresses a collective need for long-term subsistence resource monitoring for communities, agency and academic partners, and resource managers, while providing consistency in data collection.

METHODS

The Indigenous Sentinels Network Framework

ISN fills a niche for communities seeking to implement a monitoring program for their key environmental resources without high start-up costs or significant monetary investments in software or other infrastructure. The focus of ISN is on real-time ecological monitoring by local community members who are traditional knowledge-holders. ISN is taxonomically broad in scope and provides a flexible and customizable framework that enables local "sentinels" to monitor ecological phenomena and anomalies through standardized and repeatable surveys. Each participating community develops and customizes the structure of its monitoring program by identifying focal species or phenomena of concern. ISN also assists other organizations to build the capability to monitor focal and novel (e.g., invasive) species and address community needs to maintain or improve long-term food security. ISN was designed with flexibility to include a customized, community-based program with web-based and mobile data collection tools, a handbook of standardized protocols, hands-on training materials, an embedded quality control system, and technical assistance. The database is password protected for secure long-term archiving, interpretation, and dissemination of information.

Marine Mammal Harvest Monitoring

The real-time marine mammal harvest monitoring methods (Zavadil et al. 2006) were established in 1999 under the BeringWatch program. The Ecosystem Conservation Office (ECO) collects harvest information on St. Paul during the federally regulated subadult male *laaqudan* harvest season, 23 June to 31 December. During each subsistence harvest, ECO staff monitor and record the number of *laaqudan* harvested, released, flipper-tagged, or entangled in marine debris and successfully disentangled. Data are recorded using a mobile app on a handheld device in the field and then uploaded to the BeringWatch/ISN database.

ECO uses similar standardized methods to collect *qawan* harvest data from hunters within 12–48 hours following a subsistence hunting trip. *Qawan* hunting is monitored daily throughout the year and supplemented with weekly marine mammal stranding surveys. Data collected include the sex and age class of successfully hunted *qawan*, the location of the take, the status of the animal (retrieved or struck and lost), and any other relevant information (e.g., biological samples). Consistent year-round shoreline monitoring also allows ECO to document changes in the frequency and causes of marine mammal strandings. Active participation by ECO staff during *laaqudan* subsistence harvests entails voluntary reporting of *qawan*; this reporting has remained very high (up to 100%) since 2001 (Lestenkof et al. 2018). All harvest monitoring data for *laaqudan* and *qawan* are shared with the federal co-managers of marine mammals on St. Paul, the National Oceanic and Atmospheric Administration (NOAA), and the tribal community of St. Paul through annually published subsistence harvest reports and oral reports at tribal meetings.

Winter *San* and *Slukan* (Sea Duck and Gull) Surveys

Prior to ECO beginning surveys of winter *san* (birds, including sea ducks) and *slukan* (gulls) in 2008, the only estimate of sea duck and gull populations on the Pribilof Islands were from one month in 1993 and one month in 1996 (Sowls 1997). Biological data are currently collected on seabird species occurring on the islands during the summer (breeding) months on both St. Paul and St. George by the US Fish and Wildlife Service (USFWS) Alaska Maritime National Wildlife Refuge (AMNWR). However, the islands are known overwintering sites for a number of sea duck species, including *kasimax̂* (common eider, *Somateria mollissima*), *saakum aliĝii* (king eider, *Somateria spectabilis*), *kaangadgiix̂/kaaxadgix̂* (harlequin duck, *Histrionicus histrionicus*), *aalngaaĝix̂* (long-tailed duck, *Clangula hyemalis*), white-winged scoter (*Melanitta deglandi*), red-breasted merganser (*Mergus serrator*; Sowls 1993, 1997), and multiple species of *slukan*/gulls (*Larus* spp.; Insley et al. 2017). Subsistence hunters on St. Paul are known to hunt birds year-round, with effort concentrated in the winter and spring months before *laaqudan* return to the islands in April and May annually (Tran et al. 2020). Thus, monitoring subsistence waterfowl and seabird population trends is important for the cultural continuity for future generations of subsistence activities for Pribilof Islands communities, which are currently at risk due to environmental and societal changes that impact access to traditional and customary ways of life (Young et al. 2014, Romano et al. 2019).

Sea duck and gull surveys were initiated in 2008 in collaboration with the AMNWR. Data collection focuses on the overwintering months from autumn (typically beginning around 1 October) to early spring (mid-April). Focal species include eiders (*Somateria* spp.), harlequin ducks, long-tailed ducks, white-winged scoters, Eurasian wigeons (*Mareca penelope*), and glaucous-winged gulls (*Larus glaucescens*). Here, we review nine years of data collection: 2008–2011 (previously published in Insley et al. 2017) and 2015–2021. Survey locations were initially chosen due to high concentrations of focal species and visibility, accessibility, and repeatability across surveys. The same sites were used across all survey years (Sowls 1997, Insley et al. 2017). Only one site was discontinued (i.e., the city landfill) during the survey period because access was difficult and the site had consistently low counts; thus it has been excluded from this analysis.

RESULTS

Qawan Subsistence Hunting Monitoring

The number of *qawan* harvested has remained consistent since 2001 with local hunters taking between 15 and 40 *qawan* per year (ECO, unpub. data). Subsistence hunters typically target small male *qawan* (pups, juveniles). Preference for small animals is also seen in subsistence harvesting of *laaqudan* and reindeer on St. Paul. *Qawan* age 3+ are rarely harvested because they are too large to retrieve and butcher along the shore, especially in inclement weather. Based on ECO data, from 2001 to 2020, 92% of the 366 *qawan* harvested were juvenile males, with very few adults or females killed (table 12.1).

TABLE 12.1. Age Class and Sex of Subsistence Harvested *Qawan* (Steller Sea Lions) Retrieved by Local Hunters on St. Paul Island, Alaska, 2001–2020 (percentage retrieved in parentheses)

	AGE CLASS				
SEX	ADULT	JUVENILE	PUP	UNKNOWN	TOTAL
Male	4 (1.1%)	338 (92.3%)	6 (1.6%)	0	348 (95.1%)
Female	1 (0.3%)	11 (3.0%)	0	1 (0.3%)	13 (3.6%)
Unknown	0	3 (0.8%)	0	2 (0.5%)	5 (1.4%)
Total	5 (1.4%)	352 (96.2%)	6 (1.6%)	3 (0.8%)	366 (100%)

Since 2001, annual retrieval rates have varied from 50% to 91% with an average of 68% across all years and no obvious trends over time. *Qawan* hunting is evaluated on an annual as well as a seasonal basis (table 12.2) due to differences in effort and retrieval success among areas and seasons. There is virtually no hunting in June to August because of the presence of *laaqudan* at *qawan* hunting locations and the desire of St. Paul subsistence hunters to improve retrieval rates to ensure nonwasteful use of *qawan*. Retrieval rates have been 70% or higher in 10 of the last 20 years. Hunting on St. Paul only occurs when the hunter is on land, but animals may be shot while the animal is swimming within 100 yards of the shoreline or after they have hauled out on land. Retrieval rates are higher when *qawan* are hunted on land (table 12.2).

Contributing factors to observed differences in hunting performance include the environmental conditions following a hunt, wind direction and strength and oceanic current dynamics, the sinking rate of an animal, the presence of scavengers, and accessibility to the animal when it washes ashore. Hunters typically see more *qawan* traveling along the shoreline in the water during the spring and fall. From late May to early July, *qawan* are primarily located onshore at rookeries for pupping and breeding. Q*awan* are not known to migrate, but individuals disperse throughout western Alaska outside of the breeding season.

TABLE 12.2. Subsistence Harvested Q*awan* (Steller Sea Lions) That Were Retrieved or Struck and Lost after Being Hunted while the Animal Was on Land, Swimming in the Water, or in an Unknown Location on St. Paul Island, Alaska, 2005–2020

YEAR	LAND		IN WATER		UNKNOWN	
	RETRIEVED	STRUCK/ LOST	RETRIEVED	STRUCK/ LOST	RETRIEVED	STRUCK/ LOST
2005	7	0	11	2	2	0
2006	5	2	14	4	0	1
2007	13	1	9	11	0	0
2008	5	0	15	2	0	0
2009	1	0	17	8	0	0
2010	5	0	10	5	0	1
2011	7	0	17	2	0	6
2012	5	0	11	7	0	1
2013	1	0	20	4	6	3
2014	8	0	13	12	0	2
2015	4	0	13	7	0	0
2016	7	0	10	14	0	0
2017	5	1	12	12	0	0
2018	9	0	13	6	0	0
2019	6	0	9	9	0	0
2020	11	0	13	9	0	0
Subtotals	99 (96%)	4 (4%)	207 (64%)	114 (36%)	8 (36%)	14 (64%)
Total Take	Land (23%)		In Water (72%)		Unknown (5%)	

Biosampling

ECO has collected biosamples (blood, muscle, liver, blubber) of *laaqudan* and *qawan* since 1998 to assess body condition, diets, and contaminant loads (i.e., mercury, lead, organohalogen contaminants) of marine mammals used for subsistence foods. Detailed harvest data and chain of custody information for samples are critical for collaborating partners such as the Alaska Marine Mammal Tissue Archival Project (AMMTAP), an interagency project involved in the collection, archiving, and analysis of tissues from marine mammals from Alaska for retrospective research on contaminant levels and animal health (Kucklick et al. 2013, Reiner et al. 2016). For example, archived liver and blubber biosamples collected from 1987 to 2007 from *laaqudan* provided to AMMTAP were analyzed for persistent organic pollutants and vitamins (Kucklick et al. 2013). Ultimately, a suite of persistent organic pollutants (POPs) exponentially increased each sampling year, with only concentrations of polybrominated diphenyl ethers appearing to plateau over time (Kucklick et al. 2013). These results highlight the need to continue biosampling *laaqudan* because of increasing concentrations of current-use POPs and declining *laaqudan* populations in the northern Pacific (Kucklick et al. 2013).

ADDITIONAL MARINE MAMMAL SURVEYS

Rapid environmental shifts in the Arctic have impacted the ecology and phenology of Arctic marine mammals, such as occupation timing and habitat use of ice-dependent seals and cetaceans (Moore and Huntington 2008). St. Paul Sentinels conduct regular surveys of *laaqudan* at standardized and repeatable vantage points (observation locations) to determine timing of the arrival of adult males, timing of the departure of adult females and pups, and numbers of overwintering *laaqudan*. These surveys are designed to evaluate the timing of occupation for each age and sex class of *laaqudan* to understand the potential impacts of climate change on migration patterns and habitat use, and ultimately to address food security questions. In addition, traditional knowledge from northern and western Alaskan communities has documented how marine mammal migratory routes and timing have been affected by physical changes in Arctic marine environments, such as warmer water temperatures and changes in sea ice dynamics (Huntington et al. 2017).

Winter *San* and *Slukan* (Sea Duck and Gull) Monitoring

Sea duck abundance has remained consistent over time, but diversity has declined. Species such as Barrow's goldeneye (*Bucephala islandica*), common eider, and white-winged scoter were commonly seen in early survey years but have become rare or absent since 2018. In contrast, *saakum aliĝii* (king eider) have increased dramatically in abundance (weekly average of 21.6 ± 6.5 individuals from 2008 to 2011; 100.8 ± 34.4 from 2018 to 2021). The increase may be explained by niche space made available by the declining abundance of other sea duck species. The declining trend in sea ducks over the survey period was substantiated by St. Paul Sentinels, who noted that scoters were once counted in the hundreds at one vantage point but have not been seen in the same area since 2016. Observations and recollections by community members on the island also note a marked decrease in local scoter populations since 2011.

The decline in sea duck diversity may be attributable to trends in sea ice retreat in the southeastern Bering Sea (e.g., Hunt et al. 2018). Data obtained from the National Snow and Ice Data Center indicate that winter Bering Sea ice extent decreased an average of ~ 2% annually from 2008 to 2020 (Fetterer et al. 2017). St. Paul Sentinels, who also collect observations of sea ice, last observed sea ice around the island in 2017. Historically, winter sea ice has shown interannual variability in extent and thickness, but typically sea ice is at or just north of the Pribilof Islands. Community observers note that after 2010–2011, warmer winter air and ocean temperatures have been accompanied by a lack of sea ice around the Pribilof Islands and a decrease in predictability in the timing of the ice. For example, some have observed earlier arrival and longer periods of sea ice and noted a noncyclical pattern of sea ice over time (Lestenkof et al. 2013, Romano et al. 2019).

Previous studies have shown a negative correlation between winter sea ice coverage and bufflehead and common goldeneye lipid reserves, while long-tailed ducks (*aalngaaĝix̂*) were not similarly impacted (Schummer et al. 2012). This negative correlation supports Sentinels' observations of reduced populations for bufflehead and common goldeneye, while long-tailed duck populations remained stable. Intermediate ice coverage is known to provide ideal conditions for spectacled and king eider because it provides a platform for roosting. Heavy ice impedes foraging for benthic prey (e.g., clams), and sparse ice increases thermoregulation costs due to higher wave action (Christie et al. 2018, Oppel et al. 2009). Common eiders had higher breeding success during early ice retreat years, and it is predicted that the warming of the Arctic due to climate change may increase common eider populations in the future (Lechikoninen et al. 2006, Mehlum 2012).

Consistent with early data published by Insley et al. (2017), overwintering *slukan* continue to increase in abundance on St. Paul. This may be due to fish offal concentrations near the village area and harbor at the southern end of the island, providing a steady food source that can support high numbers of nonbreeding *slukan*. *Slukan* are considered to pose a threat to other seabird species because they prey on eggs and chicks (Lowney et al. 2018). If populations of *slukan* continue to increase, they may significantly impact the diversity and abundance of other species; however, if *slukan* can continue to be supported with fish offal, they may not be a threat to other seabirds utilizing the island (Insley et al. 2017). Further investigation into the linkages between fish offal and *slukan* population are warranted.

DISCUSSION

Alaska is experiencing some of the most severe impacts of coastal change observed in the United States, having warmed an average of 1.5°C since the mid-20th century, more than twice as fast as the continental United States (USGCRP 2014) Alaska's coasts are also home to over 80% of the state's residents, including the large majority of the 228 federally recognized Alaska Native tribes. These coasts also support many of the world's most economically important fisheries (Worm et al. 2009) and were home to 5 of the top 10 US fishing ports in value and landings in 2017 and 2018 (NMFS 2020).

The rapid pace of climate change has increased scientific uncertainty regarding the future productivity and resilience of the Bering Sea and other Arctic ecosystems. The value of the ISN approach and the proven competence of Indigenous communities to collect these data have been demonstrated through various BeringWatch/ISN projects conducted in the 21st century by Alaskan tribal organizations, such as the Aleut Community of St. Paul Island ECO, the St. George Traditional Council Kayumixtax Eco-Office, the Agdaagux Tribe of King Cove, and the villages of False Pass, Akutan, and Unalaska.

One of the strengths of ISN is its ability to scale from local- to landscape-level observations, providing an existing framework to build coordinated community-based monitoring programs customized to fit each community's needs. For example, the technical infrastructure necessary to support a series of new observation protocols for use in the interior of Alaska to monitor subsistence species in freshwater streams and rivers was implemented in the ISN database and mobile apps in partnership with the Tanana Chiefs Conference during a 2018 community-based monitoring project. The project was implemented to fill data gaps and improve monitoring regarding the major species of Pacific salmon and whitefish, which are important to Yukon River communities as subsistence foods.

We have been successful with previous efforts at building new partnerships with regional tribes and Native organizations and are currently planning to expand data collection procedures and protocols to include coastal vulnerability assessments, coastal erosion detection systems, and assessing real-time changes in inventories of indicator species. We look forward to building on existing partnerships and creating new partnerships as we expand the ISN network to new tribal communities. It is a proven, effective, and tribally driven environmental program that can enhance tribal resilience efforts throughout the Arctic.

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LITERATURE CITED

Black, L. 1983. Some problems in the interpretation of Aleut prehistory. Arctic Anthropology 20:49–78.

Christie, K. S., T. E. Hollmen, P. Flint, and D. Douglas. 2018. Non-linear effect of sea ice: spectacled eider survival declines at both extremes of the ice spectrum. Ecology and Evolution 8(23):11808–18. https://doi.org/10.1002/ece3.4637.

Elliott, H. W. 1880. Report on the Seal Islands of Alaska. Elliott's field notes transmitted by him to F. A. Walker, superintendent, 10th Census, 31 March. https://www2.census.gov/library/publications/decennial/1880/vol-08-news-press/1880v8-14.pdf.

Fetterer, F., K. Knowles, W. N. Meier, M. Savoie, and A. K. Windnagel. 2017. Sea Ice Index, version 3 [2008–2021]. National Snow and Ice Data Center, Boulder, Colorado. doi:https://doi.org/10.7265/N5K072F8. Accessed 23 April 2021.

Francis, R. C., S. R. Hare, A. B. Hollowed, and W. S. Wooster. 1998. Effects of interdecadal climate variability on the oceanic ecosystems of the NE Pacific. Fisheries Oceanography 7(1):1–21. https://doi.org/10.1046/j.1365-2419.1998.00052.x.

Fritz, L., K. Sweeney, R. Towell, and T. Gelatt. 2015. Results of Steller sea lion surveys in Alaska, June–July 2015. Memorandum to D. DeMaster, J. Bengtson, J. Balsiger, J. Kurland, and L. Rotterman, 28 December. AFSC, Marine Mammal Laboratory, NOAA, Seattle, Washington.

Gentry, R. L. 1998. Behavior and ecology of the northern fur seal. Princeton University Press, Princeton, New Jersey.

Hare, S. R., and N. J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography 47(2–4):103–45. https://doi.org/10.1016/s0079-6611(00)00033-1.

Hunt, G. L., M. Renner, K. Kuletz, S. Salo, L. Eisner, P. Ressler, C. Ladd, and J. Santora. 2018. Timing of sea-ice retreat affects the distribution of seabirds and their prey in the southeastern Bering Sea. Marine Ecology Progress Series 593:209–30. https://doi.org/10.3354/meps12383.

Huntington H. P., L. T. Quakenbush, and M. Nelson. 2017. Evaluating the effects of climate change on Indigenous marine mammal hunting in northern and western Alaska using traditional knowledge. Frontiers in Marine Science 4(319):1–17. doi:10.3389/fmars.2017.00319.

Insley, S. J., P. I. Melovidov, D. J. Jones, B. W. Robson, P. A. Zavadil, and R. Paredes. 2017. Multi-year counts of sea ducks and gulls in the nearshore of the Pribilof Islands, Alaska. Northwestern Naturalist 98(3):215–27. https://doi.org/10.1898/nwn16-20.1.

Kucklick, J., J. Reiner, M. Schantz, J. Keller, J. Hoguet, C. Rimmer, T. Ragland, R. Pugh, A. Moors, J. Rhoderick, J. Ness, D. Peterson, and P. Becker. 2013. Persistent organic pollutants and vitamins in northern fur seals (*Callorhinus ursinus*) collected from St. Paul Island, Alaska, as part of the Alaska Marine Mammal Tissue Archival Project. NIST Report. http://dx.doi.org/10.6028/NIST.IR.7958.

Lechikoninen, A., M. Kilpi, and M. Öst. 2006. Winter climate affects subsequent breeding success of common eiders. Global Change Biology 12(7):1355–65. https://doi.org/10.1111/j.1365-2486.2006.01162.x.

Lestenkof, P. M., P. I. Melovidov, A. P. Lestenkof, and L. M. Divine. 2018. The subsistence harvest of Steller sea lions on St. Paul Island, Alaska, from 2005–2016. Available from Aleut Community of St. Paul Island, Tribal Government, Ecosystem Conservation Office, St. Paul Island, Alaska.

Lestenkof, P. M., P. A. Zavadil, S. M. Zacharof, and E. M. Melovidov. 2013. Subsistence harvest monitoring results from 1999 to 2010 and local and traditional knowledge interview results for St. Paul Island, Alaska.

https://2pj6gg2zevt02q7hkno9xf7f-wpengine.netdna-ssl.com/wp-content/uploads/2021/03/BSIERP-St-Paul-final-report_LTK-interviews-and-data.pdf.

Loughlin, T. R., D. J. Rugh, and C. H. Fiscus. 1984. Northern sea lion distribution and abundance, 1956–1980. Journal of Wildlife Management 48:729–40.

Lowney, M. S., S. F. Beckerman, S. C. Barras, and T. W. Seamans. 2018. Gulls. USDA Animal and Plant Health Inspection Service, Wildlife Damage Management Technical Series. https://www.aphis.usda.gov/wildlife_damage/reports/Wildlife%20Damage%20Management%20Technical%20Series/Gulls-WDM-Technical-Series.pdf.

McHuron, E. A., K. Luxa, N. A. Pelland, K. Holsman, R. Ream, T. Zeppelin, and J. T. Sterling. 2020. Practical application of a bioenergetic model to inform management of a declining fur seal population and their commercially important prey. Frontiers in Marine Science 7:1–17. https://doi.org/10.3389/fmars.2020.597973.

Mehlum, F. 2012. Effects of sea ice on breeding numbers and clutch size of a high Arctic population of the common eider, *Somateria mollissima*. Polar Science 6(1):143–53. https://doi.org/10.1016/j.polar.2012.03.004.

Moore, S. E., and H. Huntington. 2008. Arctic marine mammals and climate change: impacts and resilience. Ecological Applications 18:S157-65. doi:10.1890/06-0571.1

Muto, M. M., V. T. Helker, J. Delean, R. P. Angliss, P. L. Boveng, J. M. Breiwick, M. M. Brost, M. F. Cameron, P. J. Clapham, and S. P. Dahle. 2019. Alaska marine mammal stock assessments, 2019. NOAA Technical Memo NMFS-AFSC-404. National Technical Information Service, Springfield, Virginia. https://media.fisheries.noaa.gov/dam-migration/2019_sars_alaska_508.pdf.

National Marine Fisheries Service [NMFS]. 2008. Recovery plan for the Steller sea lion (*Eumetopias jubatus*). Revision. NMFS, Silver Spring, Maryland.

National Marine Fisheries Service [NMFS]. 2020. Fisheries of the United States, 2018. US Department of Commerce, NOAA Current Fishery Statistics No. 2018. https://www.fisheries.noaa.gov/national/commercial-fishing/fisheries-united-states-2018.

Newman, K., A. Springer, and C. Matkin. 2008. Killer whales at the Pribilof Islands: who are they and what are they doing. Journal of the Acoustical Society of America 124(4):2507. https://doi.org/10.1121/1.4782886.

Oppel, S., A. N. Powell, and D. L. Dickson. 2009. Using an algorithmic model to reveal individually variable movement decisions in a wintering sea duck. Journal of Animal Ecology 78(3):524–31. https://doi.org/10.1111/j.1365-2656.2008.01513.x.

Reiner, J. L., R. P. Becker, M. O. Gribble, J. M. Lynch, A. J. Moors, J. Ness, D. Peterson, R. S. Pugh, T. Ragland, C. Rimmer, J. Rhoderick, M. M. Schantz, J. Trevillian, and J. R. Kucklick. 2016. Organohalogen contaminants and vitamins in northern fur seals (*Callorhinus ursinus*) collected during subsistence hunts in Alaska. Archives of Environmental Contamination and Toxicology 70(1):96–105. https://doi.org/10.1007/s00244-015-0179-y.

Romano, M. D., L. M. Divine, and S. Merculief. 2019. The role of red-legged kittiwakes in the subsistence culture of the Pribilof Islands, Alaska. AMNWR 2019/08. US Fish and Wildlife Service Report, Homer, Alaska.

Schummer, M. L., A. Petrie, R. C. Bailey, and R. B. Badzinski. 2012. Factors affecting lipid reserves and foraging activity of buffleheads, common goldeneyes, and long-tailed ducks during winter at Lake Ontario. Condor 114(1):62–74. https://doi.org/10.1525/cond.2012.110050.

Short, J. W., H. J. Geiger, L. W. Fritz, and J. J. Warrenchuk. 2021. First-year survival of northern fur seals (*Callorhinus ursinus*) can be explained by pollock (*Gadus chalcogrammus*) catches in the eastern Bering Sea. Journal of Marine Science and Engineering 9:975. https://doi.org/10.3390/jmse9090975.

Sowls, A. L. 1993. Trip report: winter wildlife and oil contamination surveys, St. Paul Island, Alaska, 8–12 March 1993. AMNWR 93/15. US Fish and Wildlife Service Report, Homer, Alaska.

Sowls, A. L. 1997. Winter observations associated with the Citrus oil spill of February/March, 1996. AMNWR 97/23. US Fish and Wildlife Service Report, Homer, Alaska.

Springer, A. M., J. A. Estes, G. B. Van Vliet, T. M. Williams, D. F. Doak, E. M. Danner, K. A. Forney, and B. Pfister. 2003. Sequential megafaunal collapse in the north Pacific

Ocean: an ongoing legacy of industrial whaling? Proceedings of the National Academy of Sciences 100:12223–28.

Springer, A. M., J. A. Estes, G. B. Van Vliet, T. M. Williams, D. F. Doak, E. M. Danner, and B. Pfister. 2008. Mammal-eating killer whales, industrial whaling, and the sequential megafaunal collapse in the north Pacific Ocean: A reply to critics of Springer et al. 2003. Marine Mammal Science 24:414–42.

Torrey, B. 1983. Slaves of the harvest. Tanadgusix Corporation, St. Paul Island, Alaska.

Towell, R., R. R. Ream, J. Sterling, J. Bengtson, and M. Williams. 2018. Northern fur seal pup production and adult male counts on the Pribilof Islands, Alaska. Memorandum for the record, 8 November. AFSC, Marine Mammal Laboratory, NOAA, Seattle Washington.

Tran, J., L. M. Divine, and L. R. Heffner. 2020. "What are you going to do, protest the wind?" Community perceptions of emergent and worsening coastal erosion from the remote Bering Sea community of St. Paul, Alaska. Environmental Management 67(1):43–66. https://doi.org/10.1007/s00267-020-01382-6.

Trites, A. W., and P. A. Larkin. 1996. Changes in the abundance of Steller sea lions (*Eumetopias jubatus*) in Alaska from 1956 to 1992: how many were there? Aquatic Mammalogy 22:153–66.

US Global Change Research Program [USGCRP]. 2014. National climate assessment. https://nca2014.globalchange.gov/.

Veniaminov, I. 1984 [1840]. Notes on the islands of the Unalashka District. L. T. Black and R. H. Geoghegan, translators, Richard A. Pierce, editor. Limestone Press, Kingston, Ontario, Canada.

Worm, B., R. Hilborn, J. Baum, T. A. Branch, J. S. Collie, C. Costello, M. J. Fogarty, E. A. Fulton, J. A. Hutchings, S. Jennings, O. P. Jensen, H. K. Lotze, P. M. Mace, T. R. McClanahan, C. Minto, S. R. Palumbi, A. M. Parma, D. Ricard, A. A. Rosenberg, R. Watson, and D. Zeller. 2009. Rebuilding global fisheries. Science 31(325):578–85. doi:10.1126/science.1173146.

Young, R. C., A. S. Kitaysky, C. Carothers, and I. Dorresteijn. 2014. Seabirds as a subsistence and cultural resource in two remote Alaskan communities. Ecology and Society 19(4):40. http://dx.doi.org/10.5751/ES-07158-190440.

Zavadil, P. A., D. Jones, A. D. Lestenkof, P. G. Tetoff, and B. W. Robson. 2006. The subsistence harvest of Steller sea lions on St. Paul Island in 2005. Unpublished report available from the Aleut Community of St. Paul Island, Alaska.