APPENDIX A

Assessment of ecological and cultural values within the National Petroleum Reserve – Alaska

Assessment of ecological and cultural values within the National Petroleum Reserve – Alaska

Table of Contents

1: Introduction

This document was written to provide technical information regarding the ecological importance of the National Petroleum Reserve – Alaska (NPR-A). Several scientists from various organizations and with diverse areas of expertise came together to produce this report. Each author is responsible for their own section and not the document as a whole.

Author contributions are as follows (in alphabetical order):

- **R. Travis Belote**, Ph.D., Senior Science Director, The Wilderness Society, travis_belote@tws.org – Sections 5a and 5c
- **Meda DeWitt**, M.A., Senior Manager of Alaska, The Wilderness Society, Meda_DeWitt@tws.org – Section 4
- **Timothy J. Fullman**, Ph.D., Senior Ecologist, The Wilderness Society, tim_fullman@tws.org – Sections 3a, 5b, 5d, and overall document handling
- **Kayla Heidenreich**, Consultant, heidenreichmk@gmail.com – Section 4
- **Christi Heun**, Senior Alaska Representative, Defenders of Wildlife, CHeun@defenders.org – Sections 3e and 3f
- **Jason C. Leppi**, Ph.D., Lead Fisheries Biologist, The Wilderness Society, Jason_Leppi@tws.org – Sections 2 and 3b
- **Peter S. McKinley**, Ph.D., Senior Conservation Biologist, The Wilderness Society, peter_mckinley@tws.org – Section 3c
- **Mariah H. Meek**, Ph.D., Director of Research, The Wilderness Society, mmeek@tws.org – Section 1 and overall document handling
- **Laura A. Nunes**, Ph.D., Senior GIS Analyst, Center for Conservation Innovation, Defenders of Wildlife, LNunes@defenders.org – Sections 3e and 3f
- **Martha Reynolds**, Ph.D., Alaska Geobotany Center, University of Alaska Fairbanks, mkraynolds@alaska.edu – Section 3g
- **Lisa M. Rotterman**, Ph.D., Consultant, lisa.rotterman@gmail.com – Section 3h
- **Nick Underwood**, Cartographer, nunderwood6@gmail.com – Mapping and GIS support
- **Nils Warnock**, PhD, Director of Conservation Science at Audubon Canyon Ranch, nils.warnock@egret.org – Section 3d

Funding for this technical report was provided by the NorthLight Foundation, Campion Foundation, and Wilburforce Foundation. The funders had no role in preparation of the technical report, determining the content of the document, data collection and analysis, nor did they review the materials prior to completion.

In this technical report, we first summarize the NPR-A background, including the history of its formation and current land management, as well as a description of the physical and biological features contained within the NPR-A. We then provide technical information about several groups of sensitive species that rely on the NPR-A: caribou, Arctic fishes, shorebirds and loons, tundra vegetation, wolverines, moose, and polar bears. Next, we provide information about the importance and history of Indigenous science and lifeways within the NPR-A. We finish with information about the landscape value of the NPR-A when considering ecosystem intactness, wildness, soil carbon storage, and terrestrial ecosystem representation. This report by no means includes an exhaustive covering of the values found in the NPR-A to both humans and non-humans, yet provides technical information based on our many years of expertise and experience working in this critical area of the Arctic.

2: NPR-A Background

NPR-A history and current land management

Originally known as the Naval Petroleum Reserve Number 4, the NPR-A was originally set aside by President Warren G. Harding as a potential source of fuel for the Navy. In 1977, the jurisdiction of the Reserve was transferred from the Navy to the Department of Interior under public law following the Naval Petroleum Reserves Production Act. Under these new governing provisions, the Secretary of Interior was now required to consider additional NPR-A values and resources, such as Native livelihood and dependence, wilderness values, cultural resources, and important fish and wildlife habitat while at the same time managing for oil and gas production (National Petroleum Reserve in Alaska Task Force 1979).

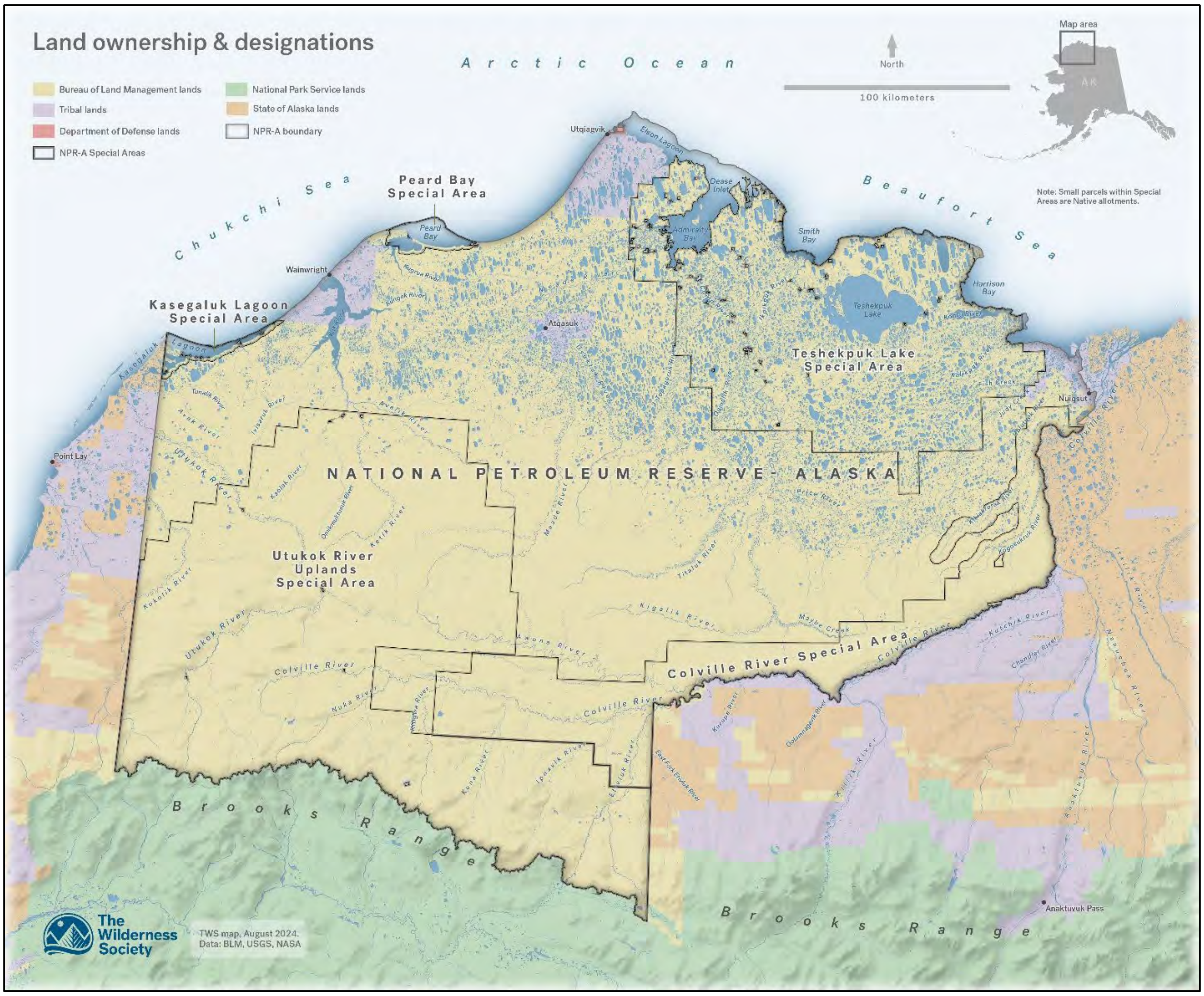

Figure 2.1. Land ownership within and surrounding the NPR-A. Tribal, State of Alaska, and Bureau of Land Management lands represent the dominant land ownership. Please see Appendix B for a higher resolution version of this figure.

The NPR-A is a 90,000 km^2 (23 million acres) semi-continuous area of federal land on the North Slope of Alaska (broadly defined as the region between the crest of the Brooks Range mountains and the Arctic Ocean) that is managed by the U.S. Bureau of Land Management (BLM) for oil and gas development and the protection of physical, biological, and cultural values (Figure 2.1, BLM 2022). The BLM manages resource extraction through its oil and gas leasing program and protects natural resources through regulations and the designation of Special Areas within the Reserve. Approximately 52% of the NPR-A is available for oil and gas leasing and the remaining area is closed to leasing to protect and conserve physical, biological, and cultural resources (Figure 2.2). To date, the majority of oil and gas development has occurred in the north-east section of the NPR-A near the community of Nuiqsut, but minor oil fields are being developed in other locations near Umiat and Utqiaġvik (Figure 2.3).

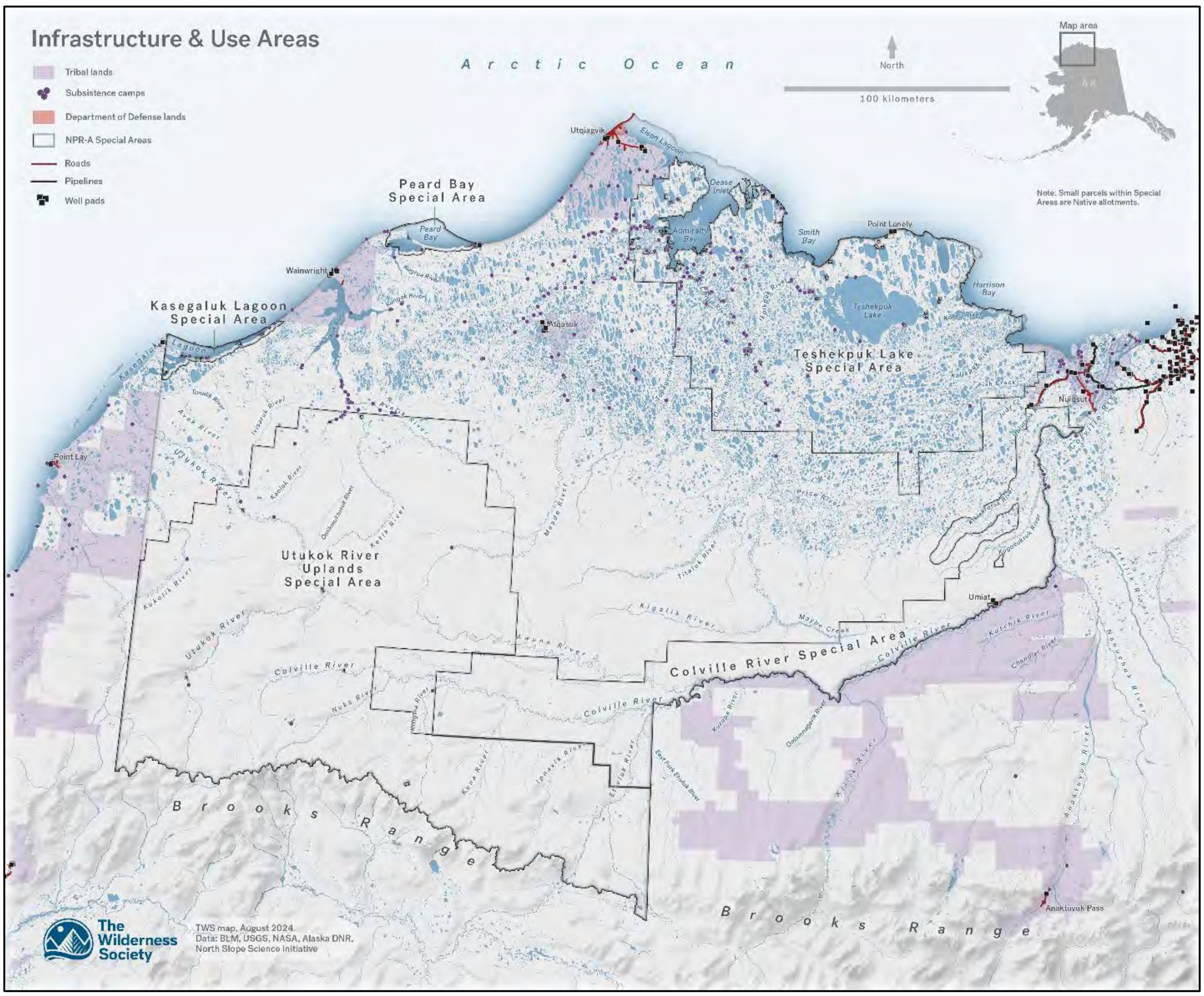

Figure 2.2. Map of Arctic Iñupiat communities and outposts, tribal lands, Native allotments, and subsistence camps and cabins within and surrounding the NPR-A. Please see Appendix B for a higher resolution version of this figure.

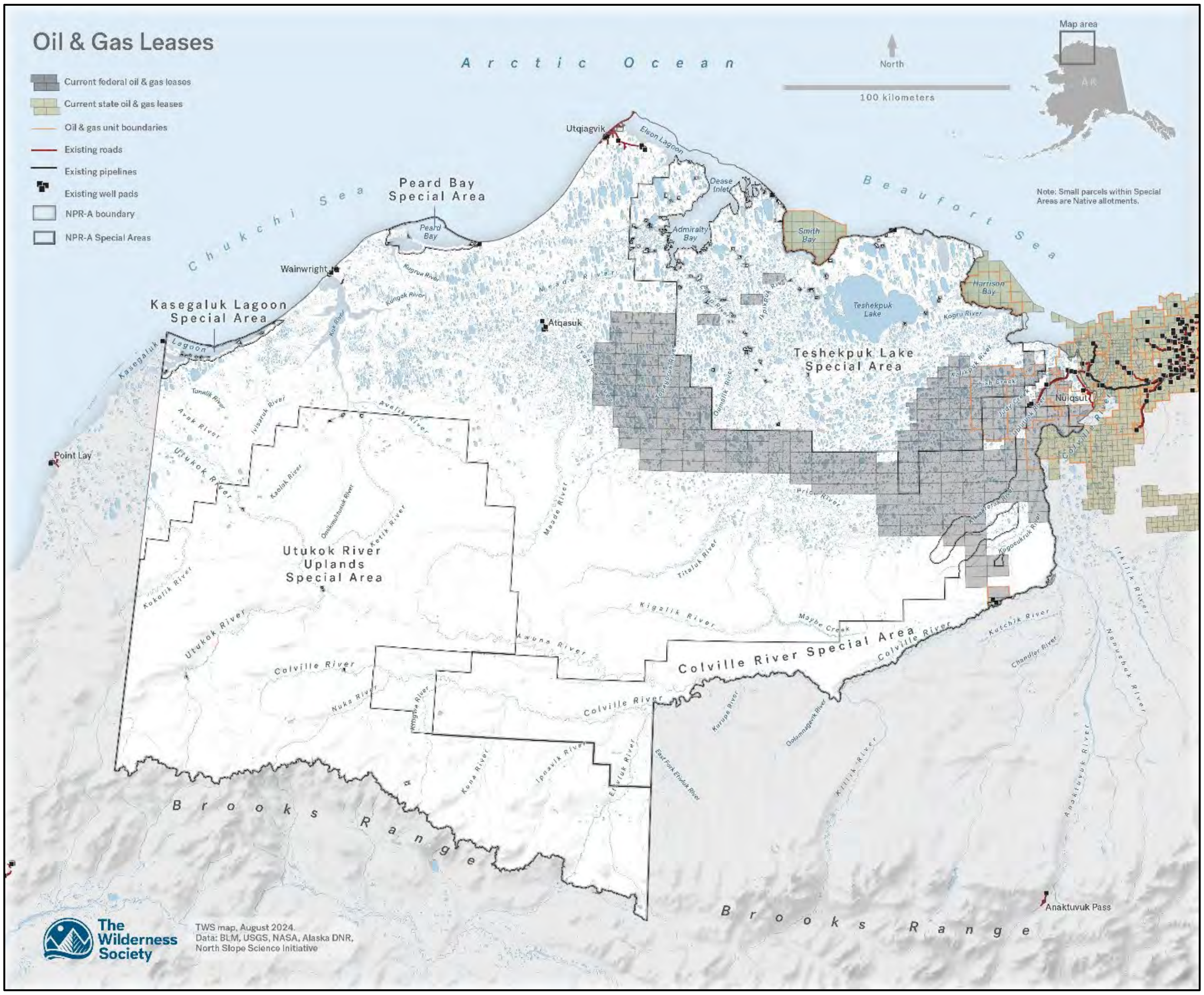

Figure 2.3. Existing development and current federal oil and gas leases within the NPR-A and state leases on surrounding lands and waters. Please see Appendix B for a higher resolution version of this figure.

NPR-A physical and biological features

The NPR-A encompasses an area that spans from the northern slopes of the Brooks Range mountains to the Arctic Ocean, including three physiographic regions: the Brooks Range, the Arctic foothills, and the Arctic coastal plain. The area is considered an Arctic tundra biome and is characterized by continuous and deep permafrost (Kanevskiy et al. 2013), extreme climate (both cold and hot), low-growing plants, and large seasonal variations in day length (Shulski and Wendler 2007).

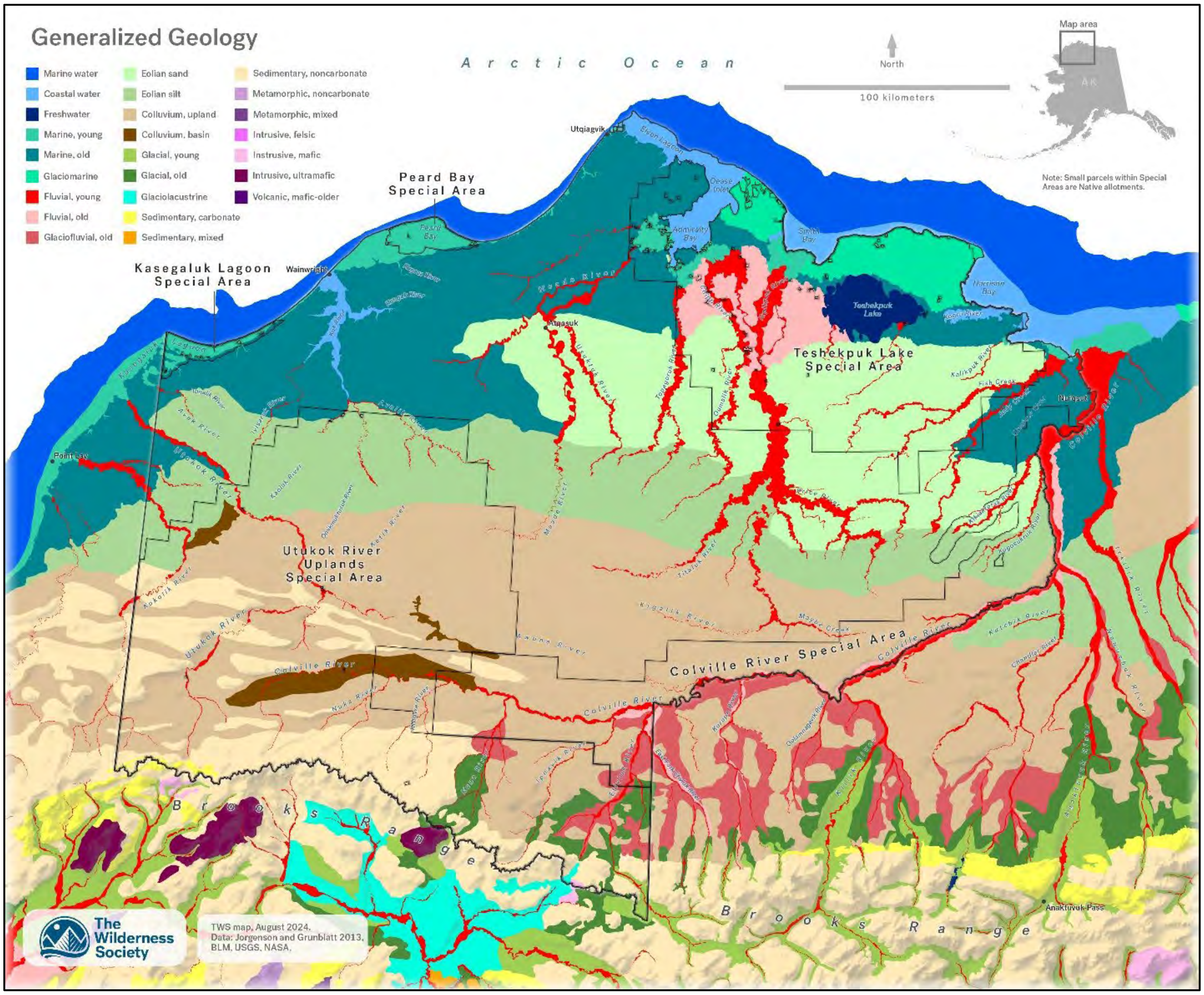

Figure 2.4. Generalized geology within the NPR-A and surrounding lands and waters. Data source: Jorgenson and Grunblatt (2013). Please see Appendix B for a higher resolution version of this figure.

The region is consistently below freezing for eight months a year and therefore the landscape is shaped dramatically by snow and ice. The Brook Range region receives the most precipitation on the Arctic North Slope (Shulski and Wendler 2007). This region contains the partially glaciated Brooks Range mountains, which have large glacially carved valleys, and a variety of sedimentary noncarbonate lithologies with minor areas of intrusive mafic and ultramafic lithologies (Jorgenson and Grunblatt 2013; Figures 2.4 and 2.5).

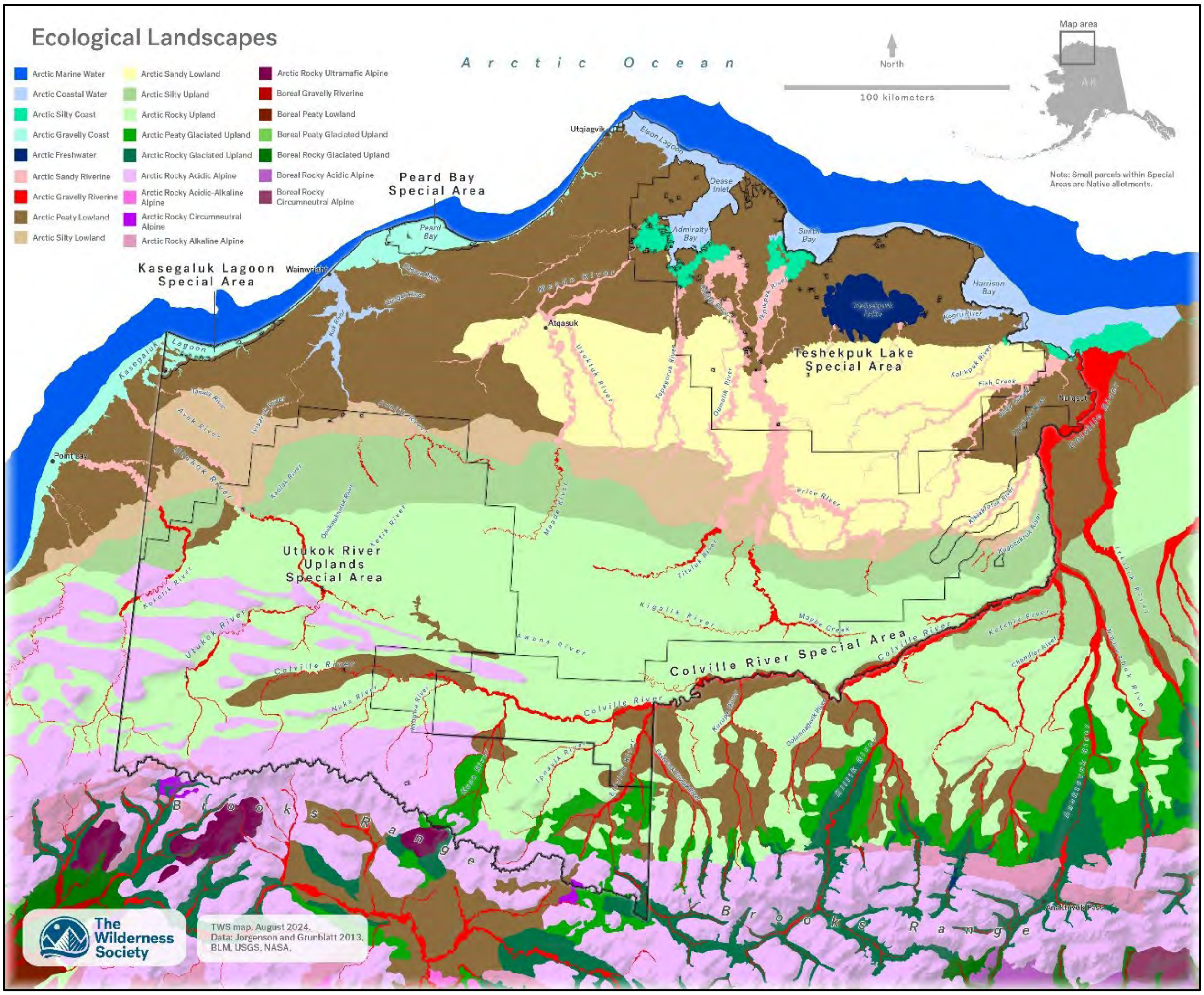

Figure 2.5. Ecological landscapes within the NPR-A and surrounding lands and waters. Data source: Jorgenson and Grunblatt (2013). Please see Appendix B for a higher resolution version of this figure.

The Arctic foothill region is a transition area that includes the rolling hills and ridges between the high mountains and the flat Arctic coastal plain. The geology generally consists of upland colluvium (Figure 2.4) and the vegetation is dominated by tussock tundra and tussock shrub tundra (Figure 2.6). The Arctic coastal plain region is a relatively flat area that contains large deposits of silt, sand, and marine silt on top of continuous permafrost. These features create a landscape where water can move freely across the surface, shaping the landscape, but is unable to infiltrate to due continuous permafrost in most areas. Consequently, the Arctic coastal plain is dominated by permafrost features, wetlands, thousands of shallow lakes and ponds, sinuous rivers with sand and silt substrate, and small beaded streams (Figure 2.7). The vegetation in the coastal plain shifts dramatically to plant communities associated with wetlands, such as sedges and dwarf willows (Figure 2.6).

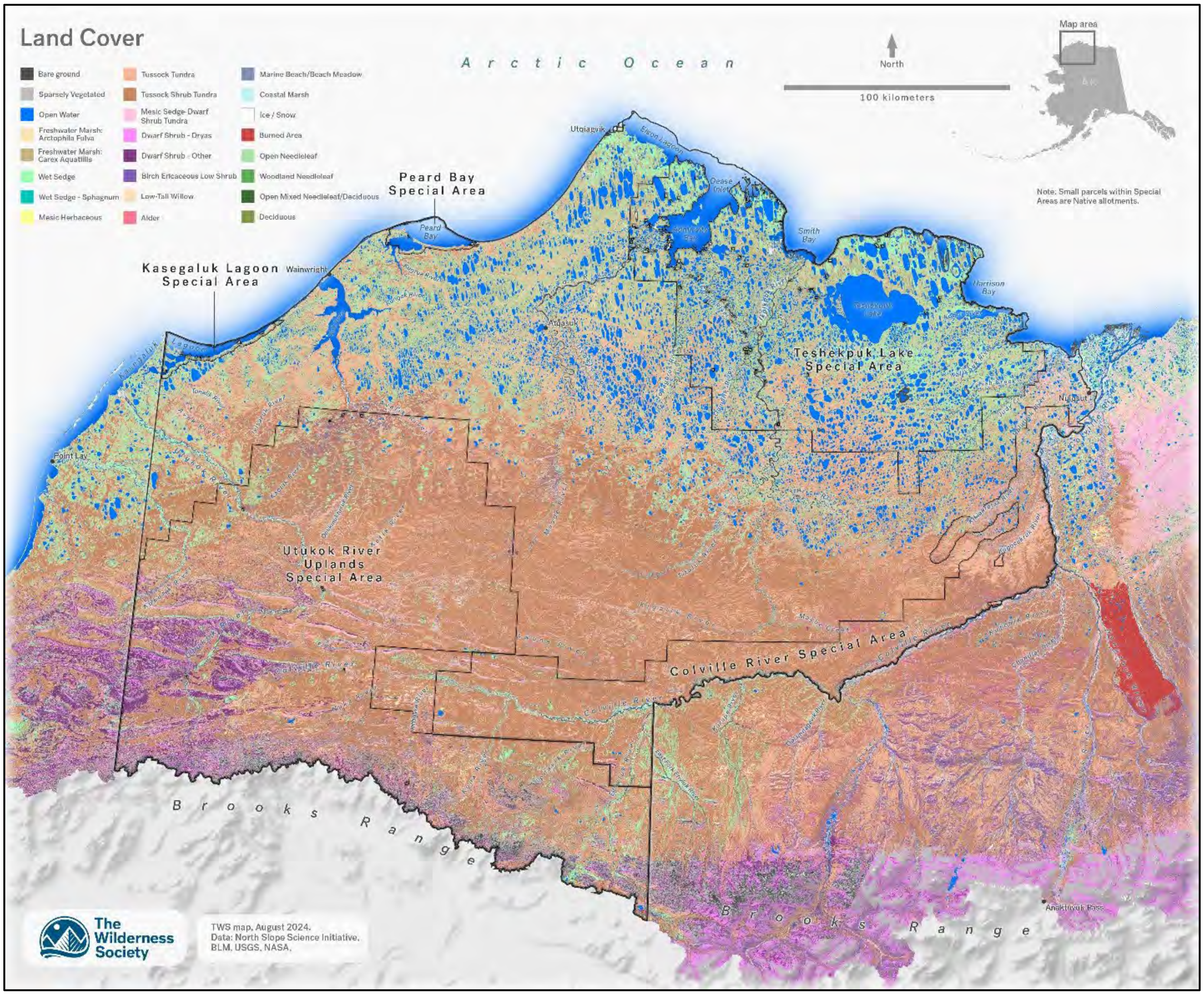

Figure 2.6. Land cover types within the NPR-A and nearby areas. Modified from Ducks Unlimited (2013) and Boggs et al. (2014). See Section 5d for details. Please see Appendix B for a higher resolution version of this figure.

Rivers, streams, and lakes vary across the NPR-A due to geology and topography. In the Brooks Range region, rivers and streams are unique and can be characterized as large-braided rivers with gravel to cobble-dominated substrates (Figure 2.7). Numerous large rivers and thousands of small tributaries flow from the Brooks Range into large rivers such as the Colville River and Utukok River (Figure 2.7). Lakes are common in the region, but not nearly as abundant as in the coastal plain region. The Arctic foothill region contains the headwaters of several large rivers, which flow out of rocky upland colluvium into eolian silt and sand geology (Figure 2.5). This drastic change in geology along with relatively flat topography creates river networks that are characterized by moderate to low gradient, sinuous channel networks with sand and silt substrate. Numerous small channel networks and streams feed into major rivers, such as the Meade River, that flow to the Beaufort Sea and Chukchi Sea. Shallow and deep lakes are more abundant and often connected by small stream channels to larger rivers (Figure 2.7). The Arctic coastal plain region contains thousands of shallow lakes (Grosse et al. 2013) among permafrost ponds, wetland complexes, small beaded streams, and a suite of rivers. Shallow permafrost and limited relief facilitate an environment conducive to creating thermokarst lakes. Beaded streams (narrow streams formed through freeze-thaw cycles) connect many lakes in the region (Arp et al. 2014) and seasonal floods facilitate temporary aquatic connectivity across the region (Heim et al. 2019).

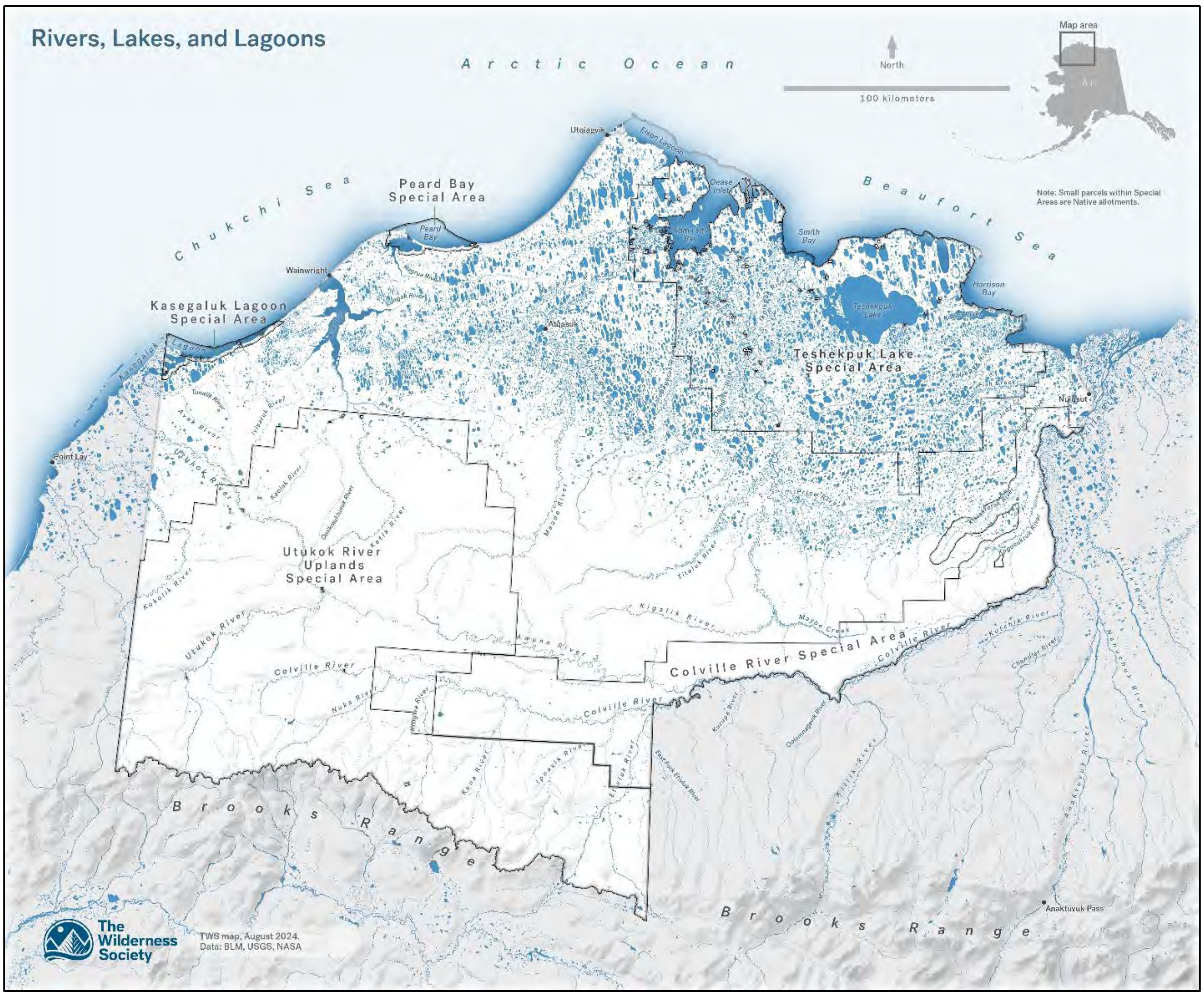

Figure 2.7. Major Arctic rivers, lakes, and lagoons within the NPR-A and nearby areas. Please note that thousands of streams have been left off the map to improve visualization. Please see Appendix B for a higher resolution version of this figure.

Background literature cited

Arp, C. D., M. S. Whitman, B. M. Jones, G. Grosse, B. V. Gaglioti, and K. C. Heim. 2014. Beaded streams of Arctic permafrost landscapes. Biogeosciences discussions 11(7):11391–11441. Available from: https://bg.copernicus.org/preprints/11/11391/2014/bgd-11-11391-2014.pdf.

BLM. 2022. National Petroleum Reserve in Alaska: Integrated Activity Plan Record of Decision. Bureau of Land Management, U.S. Department of the Interior. Available from: https://eplanning.blm.gov/public_projects/117408/200284263/20058238/250064420/2022_NPRA_IAP_ROD_508.pdf.

Boggs K, Boucher TV, Kuo TT, Fehringer D, Guyer S. 2014. Vegetation map and classification: Northern, Western and Interior Alaska, 2014 update. Alaska Natural Heritage Program, University of Alaska Anchorage, Anchorage, Alaska, USA. Available from: https://accscatalog.uaa.alaska.edu/node/41/revisions/85/view.

Ducks Unlimited, Inc. 2013. North Slope Science Initiative landcover mapping summary report. Rancho Cordova, CA. Available from: https://catalog.northslopescience.org/gl/dataset/2450.

Grosse, G., B. Jones, and C. Arp. 2013. Thermokarst lakes, drainage, and drained basins 8:325–353. Available from: https://www.sciencedirect.com/science/article/abs/pii/B9780123747396002165?via%3Dihub.

Heim, K. C., T. E. McMahon, L. Calle, M. S. Wipfli, and J. A. Falke. 2019. A general model of temporary aquatic habitat use: Water phenology as a life history filter. Fish and fisheries (faf.12386). Available from: https://onlinelibrary.wiley.com/doi/10.1111/faf.12386.

Inupiat Community of the Arctic Slope. 1979. The Inupiat View. U.S. Department of the Interior, Volume 1b. Available from: https://www.blm.gov/sites/blm.gov/files/Planning_Alaska_The_Inupiat_View_NPRA_105C_Volume1b.pdf.

Jorgenson, M. T., and J. Grunblatt. 2013. Landscape-Level Ecological Mapping of Northern Alaska and Field Site Photography Report. Arctic Landscape Conservation Cooperative. Available from: https://catalog.northslopescience.org/dataset/8e2d5a71-7808-4ea2-b60b-c2b615fceaa8/resource/7aead4d6-4fe9-4914-bc38-a1e072ff6030/download/n-alaska-landscape-mapping-and-field-site-photography-2013.pdf.

Kanevskiy, M., Y. Shur, M. T. Jorgenson, C.-L. Ping, G. J. Michaelson, D. Fortier, E. Stephani, M. Dillon, and V. Tumskoy. 2013. Ground ice in the upper permafrost of the Beaufort Sea coast of Alaska. Cold Regions Science and Technology 85:56–70. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0165232X12001644?via%3Dihub.

Kunz, M., M. R. Bever, and C. Adkins. 2004. The Mesa site: Paleoindians above the Arctic circle. U.S. Bureau of Land Management, BLM-Alaska Open File Report 86. Available from: https://catalog.northslopescience.org/dataset/e4b9c1b5-6e67-4e62-9b5f-ceb33f317266/resource/08afa32c-5b83-4e3e-b6dd-3f1aa2750a8a/download/library_alaska_openfilereport86.pdf.

National Petroleum Reserve in Alaska Task Force. 1979a. 105(c) Final Study: summaries of values and resource analysis and land use options (excluding petroleum values and uses). U.S. Department of Interior, Volume 1. Available from: https://babel.hathitrust.org/cgi/pt?id=uc1.31210024735969&seq=5.

National Petroleum Reserve in Alaska Task Force. 1979b. 105(c) Final Study: volume 1 Summaries of values and resource analysis and land use options (excluding petroleum values and uses). U.S. Department of Interior. Available from: https://books.google.com/books?id=oc_uAAAAMAAJ&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false..

Shulski, M., and G. Wendler. 2007. The Climate of Alaska. University of Alaska Press.

3: Sensitive Species and Habitats in the NPR-A

3a: Caribou

Highlights:

- Caribou are the most abundant large terrestrial herbivore in the circumpolar Arctic but have seen sharp global declines across the majority of their range, raising concerns about their future.
- The NPR-A is used by caribou throughout the year, including for critical calving, post-calving, insect relief, migratory, and winter habitat.
- Decades of study have revealed persistent effects of human activity and development on caribou that lead to avoidance of infrastructure with no clear evidence of habituation.
- Climate change will likely compound the pressures on caribou and reinforce the importance of some Alaskan habitat.
- The NPR-A Special Areas provide critically important caribou habitat warranting protection, but caribou also use areas outside of Special Area boundaries, pointing to a need for increased protection in other areas as well.

Figure 3a.1. A caribou migrating through the Arctic National Wildlife Refuge, Alaska. Photo by Tim Fullman.

Caribou ecology overview

Caribou (*Rangifer tarandus* or *tuttu* in Iñupiaq; Figure 3a.1) are the most abundant large terrestrial herbivore in the circumpolar Arctic (Bråthen et al. 2007). Caribou populations stretch across North America, Europe, and Asia, though they are called reindeer outside of North America (Festa-Bianchet et al. 2011; Mallory and Boyce 2018). Movement is central to life for caribou, especially for the barren-ground caribou (*R. t. granti*) that live on the North Slope of Alaska. Barren-ground caribou are renowned for their long-distance migrations, covering hundreds to thousands of kilometers each year in some of the longest overland movements in the world (Fancy et al. 1989; Joly et al. 2019). These migrations allow caribou to take advantage of resources that change over space and time, such as moving to areas with greater winter food availability and shelter and then returning to calving grounds with lower densities of predators (Person et al. 2007; Dau 2011). However, migration is costly, with one study showing that pregnant females may lose about 4 kg of body fat during spring migration (Fancy 1986). During their annual movements, caribou contribute to larger ecosystem processes as they alter vegetation and nutrient patterns through grazing and trampling (Stark et al. 2015; Heggenes et al. 2018) and are preyed upon by a variety of species including brown bears (*Ursus arctos*; Reynolds and Garner 1987; Mowat and Heard 2006), wolves (*Canis lupus*; Dale et al. 1994; Ballard et al. 1997), wolverines (*Gulo gulo*; Magoun et al. 2018), and other predators. In addition to their ecological value, caribou also contribute to the cultural well-being and food security of many Indigenous groups across the circumpolar Arctic (Bjørklund 1990; Berkes et al. 1994; Braem 2012; Borish et al. 2022). Subsistence hunting provides important sources of nutrition, cultural and spiritual connections, and supports customary and traditional ways of life (Lambden et al. 2007; Smith et al. 2009; Fall 2018; Borish et al. 2022).

Global population trends

Although widely distributed, many caribou and wild reindeer populations have faced strong declines, likely influenced in part by global changes in climate and anthropogenic landscape change (Vors and Boyce 2009; Russell et al. 2015; Mallory and Boyce 2018). The Arctic Report Card released by the National Oceanic and Atmospheric Association (NOAA) reported global declines of more than 50% of migratory caribou and reindeer over the past two decades, with some herds declining more than 90% (Russell et al. 2018). While caribou herds naturally fluctuate in size (Ferguson et al. 1998.; Zalatan et al. 2006), the NOAA report notes that several herds show no sign of recovery after drastic declines, and some are at record low levels since reliable recording began (Russell et al. 2018). Indeed, a 2022 report indicated that "at the global scale, the historical trend continues with declining abundance and contracting distribution for most *Rangifer* populations in the seven Circum-Arctic countries with wild *Rangifer*" (Gunn and Russell 2022).

Canada especially has seen drastic declines in its caribou herds, leading it to recognize barren-ground caribou as nationally "Threatened" (COSEWIC 2016). Two eastern migratory Canadian herds are now listed as “Endangered” (COSEWIC 2017). In the late 1990s, the George River Herd, found in the Newfoundland & Labrador and Quebec Provinces of eastern Canada, was at a population high of over 750,000 animals (Canadian Press 2020). Since that time, it decreased sharply, down to an estimated 7,200 caribou in 2022 (FFA 2022). This 99% decline in population has shown no clear evidence of recovery and has led to a complete hunting ban for the herd since 2013 (FFA 2022). Similarly, the Bathurst Herd in the Northwest Territories and Nunavut has shown an approximately 99% decline from a population high of about 470,000 caribou in the mid-1980s down to about 6,240 animals in 2021 (ECC n.d.). Harvest for this herd has been banned, or severely restricted, since 2015.

Russia contains herds of both wild reindeer and semi-domesticated reindeer that are tended by reindeer herders (Syroechkovski 2000). The largest wild herd has long been the Taimyr-Evenk population, which experienced a strong population increase in the late 1980s and 1990s up to a high count of 1 million individuals in 2000 (Savchenko et al. 2020). Since that time, the herd has experienced a sharp decrease down to approximately 400,000 – 420,000 reindeer in 2017 (Kolpashchikov et al. 2019). Just two years later, staff at Taimyr Nature Reserves reported over a 1/3 decline, down to 250,000 – 280,000 animals (Savchenko et al. 2020). Expectations about the future of the herd are mixed, with some researchers predicting natural recovery (Savchenko et al. 2020) while others have raised concerns about population extirpation within a decade (Kolpashchikov et al. 2019).

US population trends

In the past, caribou occupied the northern reaches of the contiguous United States, however as of 2019 this is no longer the case, with the last known wild individuals removed to Canada (Moskovitz 2019). Alaska is now the only place in the United States with wild caribou herds. While Alaska long stood apart as an outlier to global trends of decline in caribou and reindeer populations, recently there have been greater signs of concern. There are 31 caribou herds delineated by the Alaska Department of Fish & Game (Harper and McCarthy 2015). However, seven herds comprise the vast majority of caribou in the state. These include the four northern barren-ground caribou herds – the Western Arctic Herd (WAH), Teshekpuk Caribou Herd (TCH), Central Arctic Herd (CAH), and Porcupine Caribou Herd (PCH) – along with the Fortymile, Nelchina, and Mulchatna herds that occur further south in the state.

Several of these large Alaskan caribou herds have shown strong declines in recent years. This is true of all three southern herds. The Fortymile Herd occupies eastern Interior Alaska and crosses the border into Canada. The herd increased through the 1990s and early 2000s, reaching a peak in 2018 at 82,000 caribou (ADFG 2023a). The 2022 count, however, showed a marked decrease of over 50%, down to 38,000 animals (ADFG 2023a). The allowable harvest level was decreased annually in 2021-2023 but some level of harvest has been maintained (ADFG 2023a,b). The Mulchatna Herd primarily occupies the Yukon-Kuskokwim Delta in western Alaska. The herd reached a peak size of around 200,000 animals in 1997 and then decreased through the early 2000s down to 12,000 caribou in 2019, a 94% decrease (ADFG 2023c). In light of these declines, which take the herd below the estimated amount necessary for subsistence, hunting has been closed for the past several years (MCHIMG 2022). The Nelchina Herd also spans the border with Canada, mainly occupying southcentral Alaska. The herd remained relatively stable from the 1990s through 2021, ranging between roughly 35,000 – 55,000 animals (Robbins and Hatcher 2015; ADFG 2023d). In 2022, however, the herd size dropped to about 21,000 caribou and then down to about 8,800 caribou in 2023 (ADFG 2023d). These sharp decreases in herd size led to a reduction in harvest in 2022 and to complete closure of hunting in 2023 (ADFG 2023d).

The North Slope caribou herds are among the largest in the state. The WAH in northwestern Alaska was formerly the largest herd, with a population high of 490,000 individuals in 2003 (Dau 2015; Figure 3a.2). Over the last two decades, however, the herd has shown a sustained decline with the 2023 population count reporting about 152,000 animals (Hansen 2023). This 69% decline in the herd size has led to plans for reduced harvest limits (Naiden 2024). The TCH is smaller than the WAH, with a peak recorded size of over 68,000 caribou in 2008 (Parrett 2021). After declining by over 50% by 2013 (down to about 32,600 animals; Parrett 2021), the herd increased in size, with a 2022 count of approximately 62,000 caribou (Karpovich, pers. comm.). To the east on the North Slope of Alaska, the CAH has shown similar overall patterns to the TCH, peaking at about 68,500 caribou in 2010 before declining to just over 22,630 in 2016 (Lenart 2021). Since that time the herd has seemed to increase slightly, with a 2019 count of 30,000 animals (ADFG 2020). The final North Slope caribou herd, the PCH, spans the border between Alaska and Canada. The PCH has grown from a herd size of 123,000 caribou in 2001 to almost 218,500 in 2017 (Caikoski 2020). No count has been successfully conducted since 2017. Multiple counts have been attempted, but conditions have not been suitable to provide a robust count, leaving uncertainty as to current herd numbers. While the PCH currently is a notable exception to the declining trend seen in many caribou populations, the lack of a recent count and prevailing observations noted above about declines in many other herds in Alaska and around the globe should lead to caution about the future of the herd.

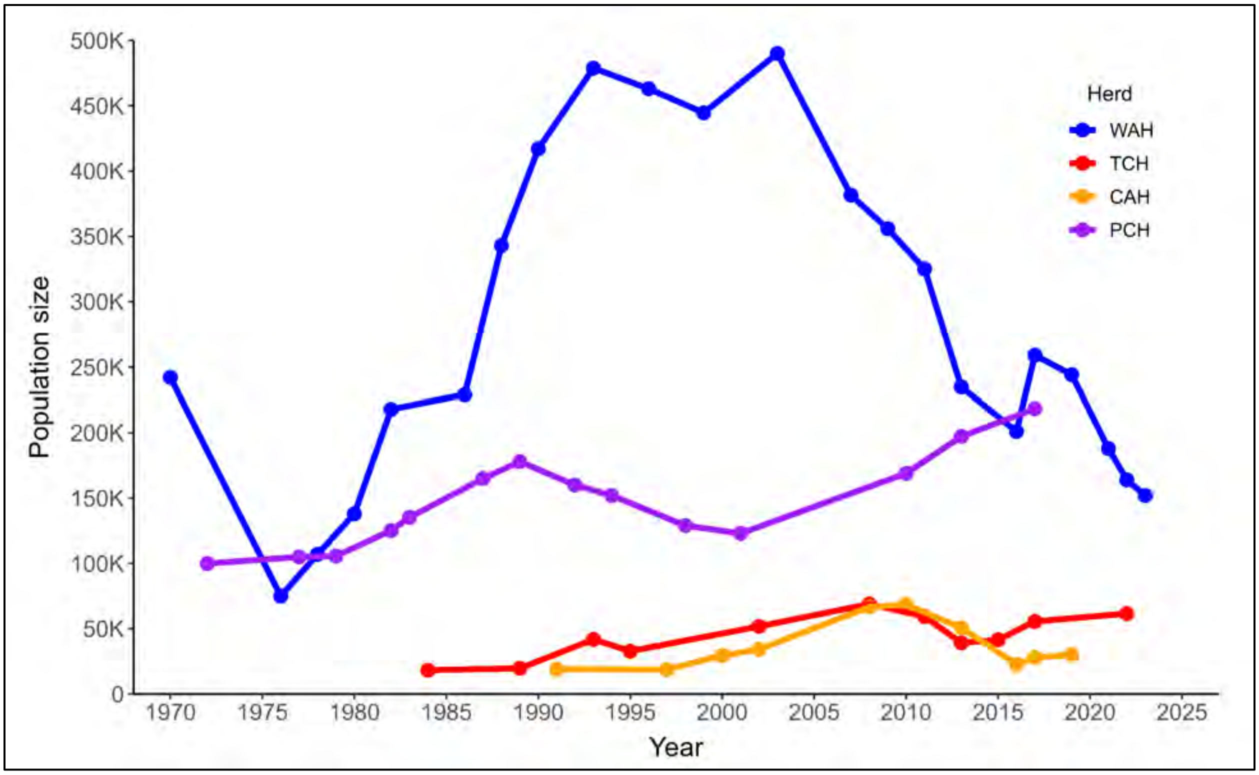

Figure 3a.2. Population size over time for the four North Slope caribou herds in Alaska. WAH = Western Arctic Herd, TCH = Teshekpuk Caribou Herd, CAH = Central Arctic Herd, PCH = Porcupine Caribou Herd. Population estimates are displayed wherever available. For the PCH only minimum counts are available between 1972-2001 so those are reported. Data sources: Dau 2015; ADFG 2020; Caikoski 2020; Lenart 2021; Parrett 2021; Hansen 2023; Karpovich, pers. comm.

Decreases in caribou populations are concerning not just because of the heightened risk of extinction faced by small populations generally (Pimm et al. 1988; Brito and Fernandez 2000; Purvis et al. 2000; Fagan and Holmes 2006), but also because of the other additional effects of small herd size. As herd size decreases, caribou may contract their range use (e.g., Taillon et al. 2012; Virgl et al. 2017). This is of special concern in light of research in other species that indicates that species with small geographic range size face increased risk of extinction (Purvis et al. 2000). While the degree to which this applies to caribou is unclear, it has been observed in Alaska that altered range use by caribou impacts subsistence hunting opportunities. Combined with a greater likelihood of implementing hunting restrictions when caribou populations are low (such as in the cases described above), these patterns may challenge harvest opportunities as caribou herds decline in size. The implications of this not only influence food security for communities, they also have cultural implications that influence emotions, identity, psychological wellbeing, social connections, and cultural continuity for people with deep relationships with caribou (e.g., Cunsolo et al. 2020; Borish et al. 2021,2022). Finally, recent research suggests that a caribou herd's population size can influence the effect of development on that herd’s future population dynamics, raising concerns about strengthened anthropogenic impacts at smaller population sizes (Russell and Gunn 2019).

Seasonal behavior, habitat use, and development impacts

Calving

Caribou show a high degree of fidelity to their calving grounds, returning to the same general areas year after year (Lent 1964; Skoog 1968; Gunn and Miller 1986; Cameron et al. 2020; Joly et al. 2021b). This behavior is used to distinguish caribou herds in Alaska and elsewhere (Skoog 1968; Gunn and Miller 1986; Festa-Bianchet et al. 2011). Barren ground caribou exhibit gregarious calving behavior, with pregnant females coming together in larger numbers to have their calves in a relatively short span of time (Lent 1964). This is thought to be a predator defense mechanism (Bergerud 1996). Survival of offspring is thought to be a crucial factor influencing population dynamics of ungulates (Gaillard et al. 2000) and protection of calving areas has been emphasized as a key component of caribou management and conservation both by scientists (e.g., Festa-Bianchet et al. 2011; Taillon et al. 2012) and Indigenous-led advisory groups (e.g., WACHWG 2019).

Habitat use and distribution during calving appears to be strongly influenced by vegetation and snow. A study of resource selection during the calving season for the TCH found that parturient females (those that had calves) tended to select strongly for sedge-grass meadow and water sedges, which led to strong concentration of calving use in the area around Teshekpuk Lake and to the southeast (Figure 1.8; Wilson et al. 2012). Caribou may also select sites with greening vegetation (Griffith et al. 2002; Cameron et al. 2020; Severson et al. 2021). As part of this, caribou seem to be able to judge the relative condition of various parts of their calving range. A study of the WAH found that caribou calving sites tended to be characterized by high-quality forage conditions that were above-average compared to the surrounding sites (Cameron et al. 2020). Similarly, a study of PCH calving found that though the overall landscape used for calving might be snow covered with little green vegetation, at finer scales caribou selected for greening vegetation in areas where snow had already melted (Severson et al. 2021). Such dynamics can lead to year-to-year variability in specific areas used for calving, even when overall caribou show generally high calving fidelity (Griffith et al. 2002; Cameron et al. 2020; Severson et al. 2021). This is also reinforced by timing of snowmelt, which can affect caribou calving distribution (Carroll et al. 2005). Because of this, calving areas used less frequently may still be of great importance to the ability of a caribou herd to survive and thrive. It is crucially important for caribou to access nutritious forage during the calving and post-calving periods to support newborn calves and restore body condition lost during migration, winter, and pregnancy (see further details and citations in the post-calving section below).

Areas that provide nutritious vegetation vary spatially over time, with caribou appearing to shift specific calving locations in response (Griffith et al. 2002; Cameron et al. 2020). In the Arctic National Wildlife Refuge the US Fish and Wildlife Service noted that due to annual variability the PCH "needs a large region from which the best conditions for calving can be selected in a given year" (USFWS 2015 p.4-101). Similarly, in a 2002 report on the PCH, the United States Geological Survey (USGS) concluded that "unrestricted access to annual calving grounds and concentrated calving areas maximized performance of lactating Porcupine caribou herd females and their calves" (Griffith et al. 2002 p.32). It is likely similar patterns may be valid for caribou in the National Petroleum Reserve – Alaska (NPR-A). This reinforces the importance of understanding both current and historical patterns of caribou calving, as well as how those may change in the future, and of considering broader protections for suitable calving habitat, even if that habitat is not currently used by calving caribou. As USFWS described, "certain areas within a caribou herd's range may not be used by caribou for a long period. But as herd movement patterns shift (possibly due to climatic changes), these infrequently used areas may become important" (Garner and Reynolds 1986 p.241).

In addition to environmental factors like snow cover and vegetation, caribou calving patterns may be strongly affected by human activity and development. Industrial-scale oil production within the NPR-A only began in 2015, leading to few studies examining the effects of NPR-A development on calving caribou. Nonetheless, studies of the CAH in relation to development of the Prudhoe Bay and Kuparuk development areas to the east of the NPR-A provide a cautionary tale about effects of energy development on caribou. Studies of the CAH following expansion of the Kuparuk Development Area found evidence of local avoidance of development areas, with use of areas near development declining after infrastructure was established (Dau and Cameron 1986; Cameron et al. 1992) and being lower than expected within 4 km of roads (Cameron et al. 2005). Over time, these local changes in habitat use were also accompanied by a larger shift in calving distribution away from developed areas (Joly et al. 2006). The CAH historically used two calving grounds, one in the west between the Colville and Kuparuk rivers and one in the east between the Sagavanirktok and Canning rivers (Lenart 2015). As development expanded west from Prudhoe Bay, caribou using the western calving grounds where new development occurred shifted south (Wolfe 2000; Noel et al. 2004; Cameron et al. 2005; Joly et al. 2006; Lenart 2015), while those in the east outside of main development areas did not shift (Wolfe 2000; Russell and McNeil 2005). A review by USGS concluded there was no clear biological explanation for the shift in concentrated calving in the west, implicating petroleum development as its likely cause (Griffith et al. 2002). The observation that only the development-exposed portion of the herd showed this shift in calving location casts doubt upon alternative explanations, such as the timing of snowmelt. In addition to these observations, research has shown that development can impede movement for females about to give birth and those with very young calves (Wolfe et al. 2000; Griffith et al. 2002). These caribou tend to avoid, or are less likely to cross, roads and pipelines during the calving season (Wolfe et al. 2000; Griffith et al. 2002).

Scientific studies have reinforced the importance of caribou calving habitat. What is less clear, however, is how to identify the boundaries of areas to protect to minimize impacts to calving caribou. Studies of calving habitat have often relied upon tools such as resource selection functions to identify which resources caribou select during the calving season (e.g., Wilson et al. 2012; Cameron et al. 2020; Severson et al. 2021). Such analyses typically result in visualizations of relative probability of use by caribou during calving (e.g., Figure 4 in Wilson et al. 2012; Figure 5 in Cameron et al. 2020; Figure 4 in Severson et al. 2021). Approaches vary for identifying "high quality" or "suitable" habitat from these continuous probability layers. Severson et al. (2021) used data-driven thresholds of maximized classification success to delineate suitable habitat, while other studies simply took the top 25% of relative probability of use values to represent "high quality" calving habitat (Wilson et al. 2013; Fullman et al. 2021b). Other studies identify calving areas directly from caribou locations, often using kernel density estimates and utilization distributions to represent contours of calving areas, with either amount of overlap across years or density contours used to define higher use calving areas (e.g., Person et al. 2007; Caikoski 2020; Cameron et al. 2020; Lenart 2021; Parrett 2021). With these various approaches to delineating calving habitat, it is uncertain how to precisely identify which areas would lead to a greater than minimal impact on caribou calving, and thus population dynamics. Whatever approach is used should be based on the best available scientific information and additional research should be conducted to continue to identify important calving areas and the impacts to those areas.

Post-calving and insect relief

While the post-calving period has traditionally received less attention than the calving period in the scientific literature and in Environmental Impact Analyses, it is also very important for caribou. The International Porcupine Caribou Board ranked both calving and post-calving habitat as of equally high importance for the PCH in northeastern Alaska (IPCB 1993). The post-calving period is crucial to providing nourishment for growing calves and replenishing depleted body reserves. Caribou rely on stored body fat and energy reserves accumulated through the summer to get them through the long, difficult winter (Barboza and Parker 2008; Parker et al. 2009; Taillon et al. 2013). They then use these reserves to fuel their spring migration. This can be costly, with one study showing that pregnant females in the PCH may lose about 4 kg of body fat during spring migration (Fancy 1986). Female caribou with new calves continue to rely on their body reserves to fuel lactation (Taillon et al. 2013). They then have to replenish their depleted body stores during the brief summer growing season. Failure to do so can have strong consequences, as summer weight gain influences calf survival rate, the probability of conceiving in the subsequent fall, and the likelihood of successfully carrying that calf to birth the next spring (Cameron et al. 1993; Crête and Huot 1993; Cameron et al. 2005; Veiberg et al. 2017). In converse, access to greater digestible nitrogen in caribou forage during the early summer post-calving and insect relief periods increases the probability of a caribou having a calf the next year (Johnson et al. 2022). Unimpeded access to sufficient quality forage is important during this period to enable caribou to regain body condition and support calf development.

Insect activity, primarily that of mosquitoes and oestrid flies, has a strong influence on caribou space use in July and August, leading caribou to seek areas of relief from insects, such as the windy coastline, gravel bars and elevated areas (Pollard et al. 1996; Wilson et al. 2012; Joly et al. 2020) and to aggregate together in large groups (Russell et al. 1993). Harassment due to insects decreases the amount of time caribou spend feeding (Russell et al. 1993) and can have a negative effect on caribou populations, leading to lower rates of calves being born in years following high insect activity and reduced survival (NRC 2003; Johnson et al. 2022). It can also threaten the ability of caribou to replenish depleted body stores, as prolonged exposure to insects can shift lactating female caribou from positive to negative energy balance (Fancy 1986). This makes it very important that caribou be able to access insect relief habitat and move between insect relief areas and quality forage habitat as conditions change. As a Canadian report stated, “unhindered movement is the key to how caribou adapt to annual variations in forage availability and insect harassment” (Russell and Gunn 2019 p. 91).

Insect harassment also influences the way caribou interact with human activity and infrastructure. Avoidance of infrastructure by mothers and calves is reduced during periods of moderate to high insect activity, though females with calves still show some avoidance of infrastructure during this period (Pollard et al. 1996; Johnson et al. 2020; Prichard et al. 2020). Similarly, caribou continue to avoid roads with greater traffic levels even during insect harassment seasons, but the level of avoidance decreases as insect harassment increases in severity (Severson et al. 2023). Observations of lower reproduction rates following years of high insect activity for caribou occupying relatively developed areas compared to those occupying less developed areas led the National Research Council to conclude that by altering caribou movements development “probably exacerbates the adverse effects of insect harassment” (NRC 2003 p.115). Research has also shown that when in large groups during insect harassment CAH caribou “were relatively unsuccessful in crossing road/pipeline corridors” (Cameron et al. 2005 p.1). These observations are concerning as warming conditions in the Arctic are leading to earlier growth and increased survival of mosquitoes (Culler et al. 2015), which may increase potential for harassment in the future.

Migration

Migration benefits species worldwide by providing access to spatiotemporally varying resources and reduction of predators and parasites (Dingle and Drake 2007; Southwood and Avens 2010; Avgar et al. 2014; Brönmark et al. 2014). At the same time, species making these migratory movements contribute to ecological processes such as nutrient transport between different ecosystems and temporary alteration of local trophic interactions (Brodersen et al. 2011; Bauer and Hoye 2014; Brönmark et al. 2014). For caribou, migration is crucial to access high-quality forage, escape insects and parasites, and avoid predators. Fulfilling these needs requires caribou to conduct both the short-distance migrations observed within the Alaskan coastal plain throughout the year, as well as the longer migrations some individuals take to and from wintering grounds to the southwest and southeast of the NPR-A (Person et al. 2007; Fullman et al. 2021a).

Previous study of other herds has noted remarkable synchrony in timing of spring migration by pregnant females across North America (Gurarie et al. 2019). Unlike for ungulates in temperate areas of the contiguous United States and elsewhere, which “surf” or “jump” the green wave of maturing vegetation to follow along with nutritious new plant growth (e.g., Bischof et al. 2012; Merkle et al. 2016; Aikens et al. 2017), caribou tend to be relatively unaffected by timing of vegetation green-up, often migrating in spring while the ground is still largely snow covered and completing migration with snow still on the ground (Gurarie et al. 2019). In contrast, non-pregnant females and male caribou often lag behind pregnant females in their migratory movements, providing access to higher quantities and qualities of forage (Heard et al. 1996). For pregnant caribou, snow level, temperature, and other weather conditions can affect timing of such migrations in any given year (Le Corre et al. 2017; Gurarie et al. 2019). Such factors are important, as linkages between arrival timing and timing of calving have been noted (Gurarie et al. 2019) and earlier birth date leads to a lower risk of mortality (Vuillaume et al. 2023).

Research has shown that caribou migration can be delayed or otherwise altered by the presence of roads or other development (Carroll 2005; Panzacchi et al. 2013; Wilson et al. 2016; Fullman et al. 2021c). While various measures have been employed to mitigate disturbance due to physical barriers created by oil development, success of these measures has not yet been determined (Lenart 2015). It is, however, notable that caribou continue to avoid infrastructure during the calving, post-calving, and mosquito relief seasons despite decades of exposure and use of mitigation measures (Johnson et al. 2020). If human activities and development delay migration, this could have implications for calves later in their life, such as higher mortality risk (Vuillaume et al. 2023).

Winter

Winter is a critical time for caribou. Foraging opportunities are limited during the winter and caribou rely on body stores of fat and protein for survival and gestation (Barboza and Parker 2008; Parker et al. 2009; Taillon et al. 2013). Studies in other ungulate species of displacement and altered habitat use due to energy development have noted that fitness costs are likely greater during winter, when individuals already exhibit a negative energy balance (Northrup et al. 2015). Further energetic costs at such a time may lead to loss of body mass and depletion of vital energy reserves (Bradshaw et al. 1998).

Previous development to the east of the NPR-A has taken place in an area that is mostly abandoned by caribou in the winter. Because of this, there has been little study of winter responses by caribou to industrial development and activity in Alaska. This presents an area of need for future research. Nonetheless, studies from Canada reveal that disturbances, such as loud noises, can lead to flight responses in caribou (Bradshaw et al. 1997; Bradshaw et al. 1998), causing them to expend additional energy, and that caribou may avoid human infrastructure and disturbance in the winter (Dyer et al. 2002; Johnson and Russell 2014; Plante et al. 2018). Behavioral responses may also occur in proximity to temporary infrastructure, such as ice roads used to access industrial areas (Smith and Johnson 2023; Smith et al. 2023). The impacts of winter disturbance on caribou may be greater in years of severe winter conditions such as high snow depth (Bradshaw et al. 1998), when energetic costs of movement increase (Fancy and White 1987), foraging opportunities are reduced (Fancy 1986; Hobbs 1989; Bradshaw et al. 1998) and more body protein and fat are lost, increasing the likelihood of death or reproductive failure (Parker et al. 2009). If animals survive, the effects of such harsh weather conditions may persist into later years, even if future winters are milder (Hobbs 1989). In light of this, some researchers have suggested that greater restrictions on oil and gas exploration may be needed in years with harsh winter conditions (Bradshaw et al. 1998).

While caribou exhibit their lowest annual movement rates during the winter (Person et al. 2007; Prichard et al. 2014), this does not necessarily imply a lack of awareness or response to their environment. Studies of European reindeer found vigilance is highest in winter, compared to other seasons (Reimers et al. 2000). Similarly, a study in Canada found that caribou avoided human settlements more strongly in winter than summer, resulting in a smaller winter range due to development (Plante et al. 2018). Any extra expenditure of energy that caribou undertake as a result of interaction with human activity or development is of concern, as reproductive success in caribou is strongly correlated with nutritional stress (Cameron et al. 2005). Late winter body mass of female caribou has been linked to calf production and survival (Cameron et al. 2005; Albon et al. 2017; Veiberg et al. 2017), potentially influencing population growth rates.

Human impacts on caribou

Road impacts

There has been extensive research on negative impacts to the CAH of roads associated with the Trans-Alaska Pipeline and the Prudhoe Bay and Kuparuk oilfields (e.g., Cameron et al. 1979; Cameron and Whitten 1979; Cameron and Whitten 1980; Whitten and Cameron 1983; Smith and Cameron 1985; Dau and Cameron 1986; Cameron et al. 1992; Smith et al. 1994; Cameron et al. 1995; Nellemann and Cameron 1996; Nellemann and Cameron 1998.; Cameron et al. 2005; Johnson et al. 2020; Severson et al. 2023). Much of this research on effects to caribou and their habitats was addressed in an extensive synthesis of cumulative impacts of oil and gas activities by the National Academy of Sciences (NRC 2003). As is noted above, the level of displacement caribou exhibit away from roads appears to vary by season. Movement studies for the CAH indicated displacement distances of around 1 km during mosquito harassment season, 2 km during post calving, and around 5 km from roads during the calving season (Johnson et al. 2020; Prichard et al. 2020). A study of Canadian caribou herds found displacement distances varied widely, between 0-15 km depending on season and hunting conditions (Plante et al. 2018). Displacement during migration for two different caribou herds in Canada was estimated at between 16-17 km before the animals crossed and 3 km after crossing (Boulanger et al. 2024). This pre-crossing area of effect is similar to that used for analysis in Alaska (15 km; Wilson et al. 2016), though one study found relative probability of selection by caribou remained diminished during migration at longer distances from roads (Fullman et al. 2021c).

Dust and contaminants

Dust generation during creation of gravel roads and travel upon those roads can lead to deposition of dust and toxic heavy metals on roadside vegetation fed on by caribou (Hasselbach et al. 2005; Neitlich et al. 2022). Dust covering vegetation may extend between 100 - 1000 m or more on either side of roads (Walker and Everett 1987; Myers-Smith et al. 2006; Chen et al. 2017; Ackerman and Finlay 2019; Neitlich et al. 2022). This has the effect of altering soil pH, plant community composition, permafrost thaw depth, plant nutritional quality, and soil moisture and temperature (Myers-Smith et al. 2006; Chen et al. 2017; Ackerman and Finlay 2019; Neitlich et al. 2022). Important forage species, like lichens, may also show reductions in areas of dust deposition near roads (Chen et al. 2017; Neitlich et al. 2022). In some cases, airborne heavy metals may spread much farther than 1 km from roads (Hasselbach et al. 2005).

Decreased albedo due to dust on snow can cause earlier snowmelt and green-up near roads (Walker and Everett 1987). While this may provide an early food source, attracting caribou to areas near roads, such benefits may be countered by increased risks of vehicular collisions and by negative effects from any toxic metals present in the dust. Toxicity is especially of concern for caribou about to have calves or with newborn calves. Young organisms, especially those that are still feeding on milk, experience greater absorption and lower excretion of toxic metals, making early age a critical period for metal toxicity (Jugo 1977; Kostial et al. 1978).

The potential for chemical effects is not just limited to the vicinity of roads. Contaminants in snow have been previously documented at Prudhoe Bay, likely through airborne transmission (Snyder-Conn et al. 1997). Such contaminants are of special concern in these developed areas given that indirect effects of Prudhoe Bay infrastructure combined with rapid climate change have increased rates of thermokarsting, creating more channels as permafrost melts (Raynolds et al. 2014), which may exacerbate spread of contaminants after deposition. Studies of drilling waste reserve pits also documented spread of drilling waste components across tundra wetlands and ponds away from the actual drilling sites (West and Synder-Conn 1987; Woodward et al. 1988), including at nearshore drilling sites (Snyder-Conn et al. 1990).

There remains uncertainty about the likelihood of such toxic metal deposition and about the expected impacts for caribou.

Mining

Caribou have been shown to respond negatively to mining, exhibiting displacement from the area around mines (Boulanger et al. 2012; Plante et al. 2018; Boulanger et al. 2021) and alteration of movement behavior in response to mining roads and traffic (Wilson et al. 2016; Boulanger et al. 2024). The zone of influence, or area around development in which caribou avoid or are affected by infrastructure, appears to vary from year to year based on changes in caribou demographics and environmental conditions (Boulanger et al. 2021). Nonetheless, estimated zones of influence have often been extensive around mining sites, spanning about 6 – 23 km (Boulanger et al. 2012; Plante et al. 2018; Boulanger et al. 2021).

To date, most of the published studies of mining impacts on caribou have been conducted in Canada (Boulanger et al. 2012; Plante et al. 2018; Boulanger et al. 2021; Boulanger et al. 2024). A key source of uncertainty is understanding how these studies will translate to caribou in the NPR-A. While the previous studies have typically involved large open-pit or underground pit mines, caribou on the North Slope of Alaska are more likely to interact with smaller gravel mines (apart from the Red Dog Mine to the west of the NPR-A). Reactions of caribou to gravel mining, including the extent of displacement, remain an understudied area and future work is needed to address this uncertainty.

Lack of habituation

Habituation is a process by which animals exhibit reduced responses to some sort of stimulus over time (Bejder et al. 2009). There is a clear lack of evidence for habituation of caribou to human development and activity in Alaska or elsewhere (Vistnes and Nellemann 2008). Johnson et al. (2020) investigated movement responses of the CAH to infrastructure in the Prudhoe Bay and Kuparuk development areas and found that caribou exhibited avoidance responses to infrastructure during all time periods studied. These findings demonstrate that previously reported patterns of caribou displacement from roads in the CAH have not dissipated over 40 years of exposure, as would be expected if habituation were occurring, but instead continue to be demonstrated. The paper concludes that “habituation to industrial development in caribou in the Arctic is likely to be weak or absent” (Johnson et al. 2020 p.401). These findings align with other studies of caribou, such as a paper from Canada that found avoidance of long-established infrastructure, “suggesting that long-term habituation is unlikely” (Plante et al. 2018 p.138) and a study that found variation in caribou disturbance responses near a diamond mine in Canada over time but no clear evidence of habituation (Boulanger et al. 2012). Similarly, a study in Norway found no evidence of habituation by reindeer to ski resorts, trails, and recreational cabins over a 20-year study (Nellemann et al. 2010). Schaefer (2003) described almost a century of decline in Canadian woodland caribou that appeared to coincide with human forestry practices and showed no evidence of habituation. Other studies of ungulates also have failed to find strong evidence of habituation to industrial development and activity. Researchers found that mule deer (*Odocoileus hemionus*) in the contiguous United States did not habituate to energy development despite 15 years of exposure and intensive mitigation efforts (Sawyer et al. 2017).

Some studies of the CAH have claimed to show evidence of habituation (Haskell et al. 2006; Haskell and Ballard 2008), however this has not been clearly demonstrated. Haskell et al. (2006) based their claim of habituation largely on use of areas closer to infrastructure during the period when insect harassment is a dominant driver of caribou space use. Calving caribou only moved closer to infrastructure during the calving period in one of the three years evaluated (Haskell et al. 2006). Similarly, Haskell and Ballard (2008) found no evidence of habituation across years. They observed greater percentages of calves and numbers of caribou per kilometer surveyed in years with earlier snowmelt and inferred this as evidence that caribou habituated to infrastructure during each year but also point out that "the available data were few, so our results may benefit from further verification or falsification" (Haskell and Ballard 2008 p.628). Another study examined winter distribution responses of the PCH to various human infrastructure and disturbance in Canada and found a decreasing response of caribou to human infrastructure over time (Johnson and Russell 2014). However, concurrent decreases in oil and gas activities made it unclear whether this was due to habituation or to regeneration of natural habitats and processes after the cessation of human activities. One possible exception to the lack of evidence for habituation was noted for reindeer on the island of Svalbard where a decreasing pattern of escape distance was noted for collared reindeer intentionally approached repeatedly by researchers (Hansen and Aanes 2015). However, this was observed in a population without natural predators and with a lack of hunting, which makes the application to other populations less clear. Also, a subsequent study found that repeated stresses (in this case capture events) did not result in habituation but rather in increased behavioral response to human disturbance and possibly decreased calf survival rates (Trondrud et al. 2022).

Taken together, these studies do not present clear evidence of habituation in caribou. It is thus inappropriate to assume that detrimental effects of development and human activity on caribou will decrease over time. Instead, the best available scientific information indicates continuing adverse effects of development on caribou over decades of exposure, leading to expectations that any future development will have long-lasting and undiminishing effects on caribou.

Climate change

Climate change is expected to have a wide array of potential impacts on caribou. Climate change is disproportionately affecting the Arctic, with warming occurring more strongly than the global average (IPCC 2013). Caribou population dynamics have been shown to be influenced by broad-scale climate patterns (Joly et al. 2011; Mallory et al.

2018), though in many cases local factors may exert population pressures as strong as, or stronger, than climate (Mahoney et al. 2016; Uboni et al. 2016). Climate change has the potential to both negatively and positively influence caribou populations, however there are far more anticipated negative effects than positive ones.

The negative impact of harsh winter weather conditions on caribou and reindeer has long been recognized (e.g., Collinder 1949, cited in Skoog 1968 p.658). Skoog (1968) noted that extensive ice cover may reduce food availability, leading to mass starvation. More recent observations have noted that warming winter conditions in the Arctic have led to an increase in rain-on-snow events (Hansen et al. 2011; Hansen et al. 2014; Forbes et al. 2016). Such events lead to thick ice cover when temperatures subsequently decrease, blocking access to food for caribou and other species (Hansen et al. 2011; Hansen et al. 2013). The potential of such icing events to decrease body condition of overwintering caribou is of great concern, as late winter body mass of female caribou is strongly linked to calf production and survival, influencing population growth rates (Hansen et al. 2011; Albon et al. 2017; Veiberg et al. 2017). These icing events are expected to continue to increase as the Arctic keeps warming and sea ice retreats (Hansen et al. 2014; Forbes et al. 2016). Warmer conditions may also lead to longer ice-free periods on rivers and lakes, which can increase energetic expenditures as caribou must travel farther or face barriers to migration (Leblond et al. 2016).

Shifts in climate also are influencing the timing of snowmelt and plant green-up and growing season length across the globe. In northern Alaska, earlier plant greening and longer growing seasons have been observed (Gustine et al. 2017). While this could increase food availability, warming may also reduce forage quality for caribou, as has been seen in other systems (Barboza et al. 2018). Thus far, however, forage quality does not seem to have declined during the calving period (Gustine et al. 2017). Warming conditions also have been associated with expansion of shrubs in the Arctic (Tape et al. 2016; Fauchald et al. 2017). Some researchers have suggested that decreased edibility of shrubs for caribou may explain why patterns of Arctic greening sometimes are accompanied by population declines in caribou (Fauchald et al. 2017).

Climate change is leading to the northward expansion of some ungulate populations (e.g., Dickie et al. 2024). This has been linked to caribou declines caused by altered predator-prey dynamics, as predator numbers increase in response to alternative prey but then also consume caribou (McLoughlin et al. 2003; Hervieux et al. 2013; Hebblewhite 2017; Serrouya et al. 2017; ECCC 2020). Moose in Alaska are one species that appears to be moving northward in response to climate-facilitated shrub expansion (Tape et al. 2016), with continued increases in moose habitat predicted (Joly et al. 2012; Zhou et al 2020). If predator densities increase in response to increases in moose this could have a detrimental effect on caribou, as has been seen in Canada. Studies from Canada have also noted that human modification of habitat, such as creation of linear features such as seismic lines, can play a facilitating influence on predators, serving as travel corridors and increasing contact with and predation of caribou (Latham et al. 2011; Whittington et al. 2011; McKenzie et al. 2012; Hervieux et al. 2013; Dickie et al. 2017; Dabros et al. 2018; DeMars and Boutin 2018). Such findings have primarily occurred in woodland systems and may have limited applicability to the tundra of the NPR-A but may be relevant to caribou in other parts of their annual range, such as wintering areas south of the Brooks Range. There may thus be additive impacts of climate change and human development on caribou.

Warmer summer conditions can also pose other challenges for caribou. Warmer temperatures in summer have been correlated with higher adult female mortality rates in a Canadian caribou herd (Russell et al. 2018). Furthermore, scientists are increasingly noting increased abundance, altered timing, and range expansion of parasites and pathogens (Altizer et al. 2013; Culler et al. 2015; Kafle et al. 2018; Russell et al. 2018). Such patterns can sometimes lead to sudden and large-scale die offs of herbivores, such as was seen in 2016 in Russia when over 2000 reindeer were killed by anthrax that was apparently exposed by melting permafrost (Golovnev 2017). In 2015, an outbreak of *Pasteurella* similarly killed off over 200,000 saiga antelope (*Saiga tatarica tatarica*), which calve in large aggregations somewhat similarly to caribou, reducing the global population by over 60% (Kock et al. 2018). There are concerns that such trends could become increasingly common as the Arctic continues to warm.

Habitat use also may change in the future due to climate change. Research on the PCH in northeastern Alaska and the Canadian Yukon found that the distribution of adult female caribou during the calving and post-calving periods can be predicted by environmental factors like timing of snow melt and greening of vegetation (Severson et al. 2021). Projecting these selection patterns into the future based on climate change scenarios predicted increased use of the Alaskan Coastal Plain during the calving and post-calving periods (Severson et al. 2021). While this work has not been applied to northwestern Alaska, it is possible that climate-induced shifts to habitat and phenology (environmental timing) could influence caribou in the NPR-A. This is an area of uncertainty that warrants future research.

Potentially contradictory effects of Arctic warming make cumulative effects of climate change on caribou difficult to determine (Mallory and Boyce 2018). The variability in potential responses of caribou to changing climate in the Arctic calls for increased studies to understand how caribou are likely to respond to warming conditions and for monitoring to determine whether predicted patterns are met. An analysis from Canada evaluated net effects that consider both positive and negative influences under different climate scenarios (Tews et al. 2007). Similar studies are needed for the Alaskan Arctic to help provide increased understanding of climate effects along with cumulative analyses of potential stresses from climate change and resource development.

Caribou in the NPR-A

The National Petroleum Reserve – Alaska (NPR-A) is used throughout the year by three of the four caribou herds that calve on the North Slope of Alaska: the TCH, WAH, and CAH (Figure 3a.3).

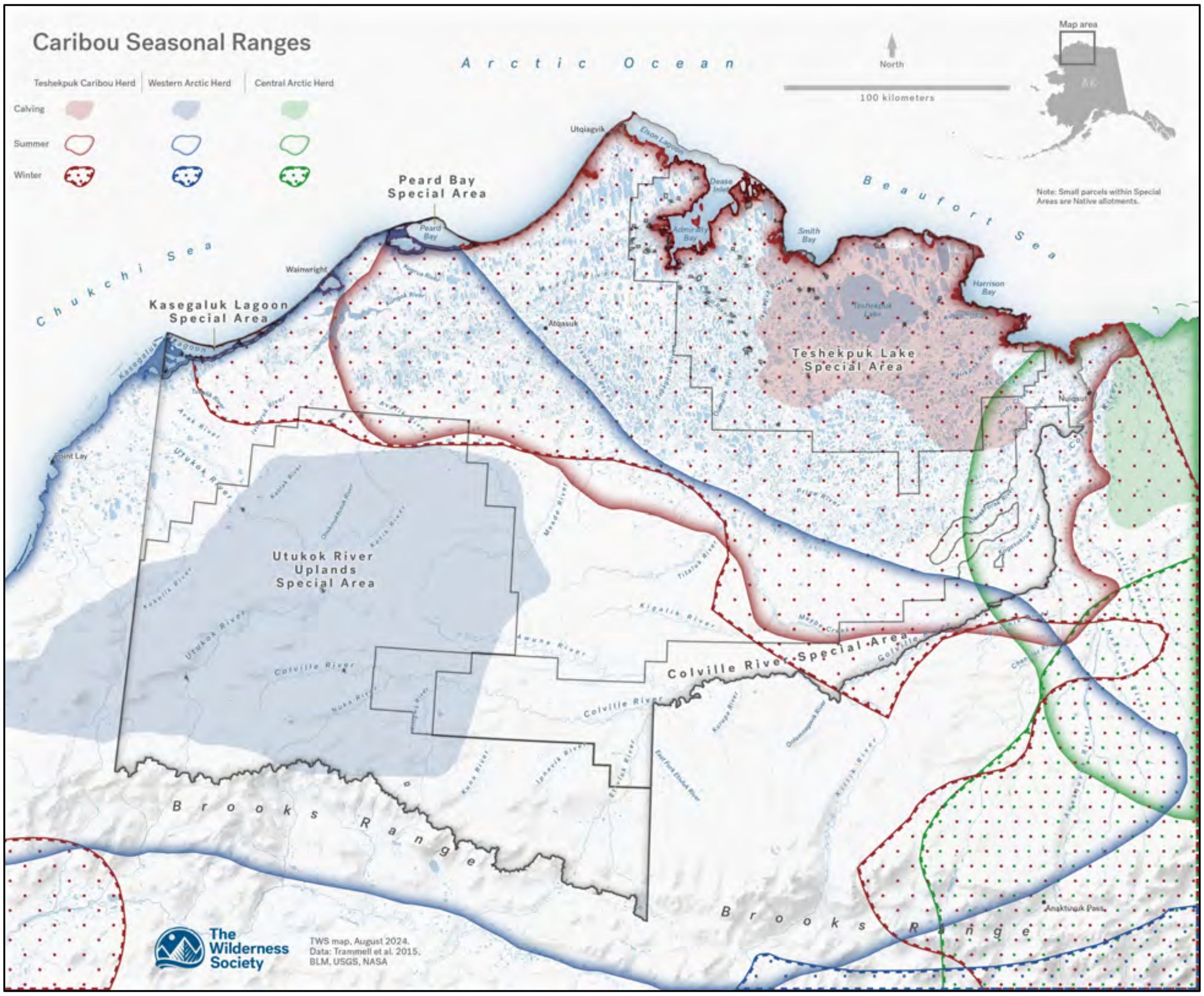

Figure 3a.3. Seasonal ranges of the three caribou herds that use lands within the National Petroleum Reserve – Alaska. Seasonal range data from Trammell et al. (2015). Note that seasonal range boundaries should be considered general approximations as there is annual variability in the specific areas used by caribou. For example, any given year of Western Arctic Herd calving distribution (see Figure 3a.5) differs from the more generalized calving range shown here. Please see Appendix B for a higher resolution version of this figure.

The most extensive use of the NPR-A is by the TCH. Caribou of the TCH make use of most of the NPR-A for seasonal habitats and varied movements (Person et al. 2007; Fullman et al. 2021a). The TCH calves primarily in the northeastern NPR-A around Teshekpuk Lake (Figure 3a.3; Carroll et al. 2005; Person et al. 2007; Wilson et al. 2012), with some calving also occurring in the northwestern NPR-A (Wilson et al. 2012; Prichard et al. 2019). Much of this calving area overlaps the Teshekpuk Lake Special Area, including both areas with restricted leasing and infrastructure and those available for leasing and development (Figure 3a.4). The calving area also overlaps existing oil and gas leases and existing and permitted development. Some calving extends beyond the boundary of the Teshekpuk Lake Special Area to the southeast, extending far enough to overlap the northeast part of the Colville River Special Area (Figure 3a.4).

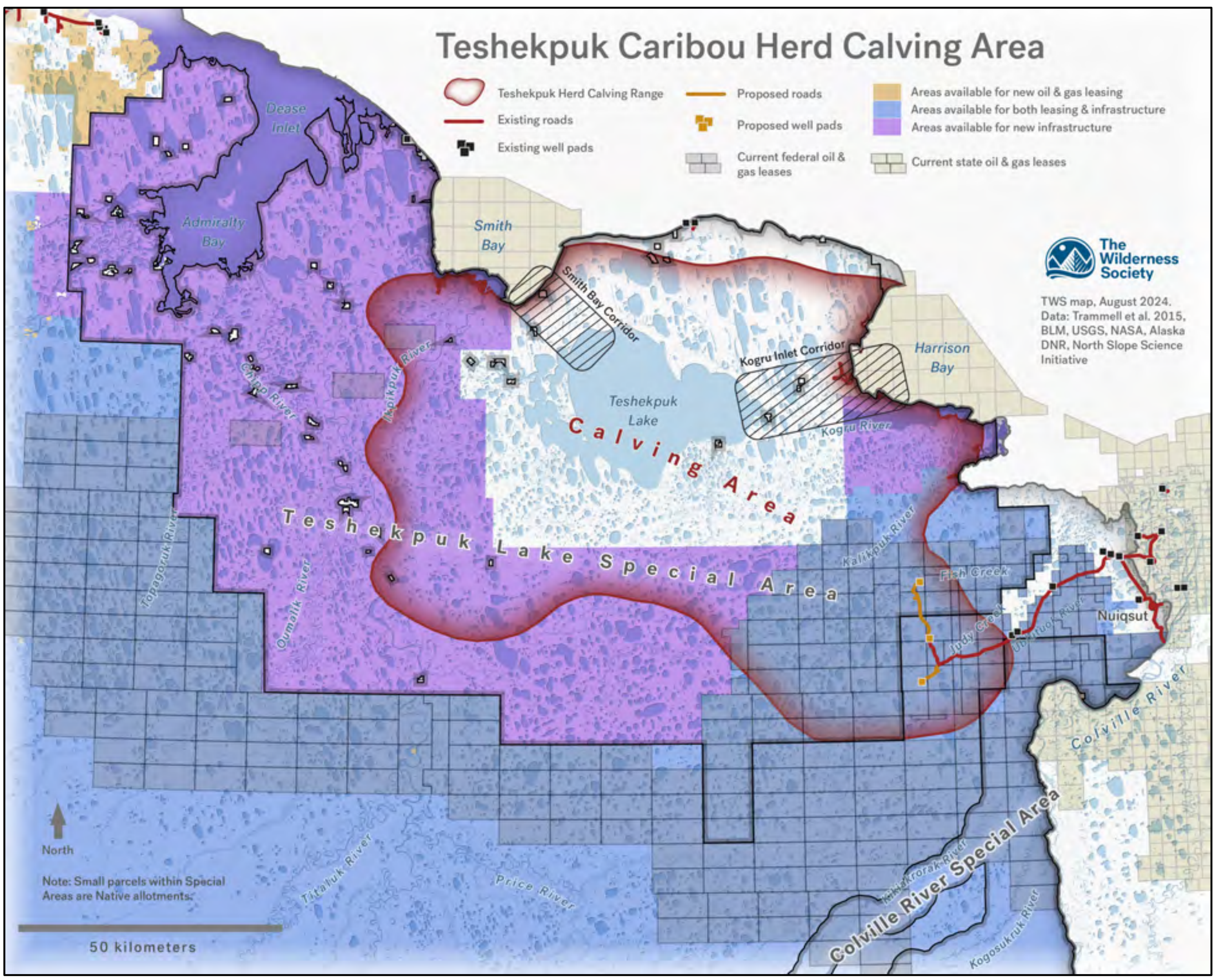

Figure 3a.4. Teshekpuk Caribou Herd primary calving area in relation to existing Special Areas, infrastructure, and oil and gas leases. The Smith Bay and Kogru Inlet movement corridors on either side of Teshekpuk Lake provide narrow regions of connectivity for caribou moving between seasonal areas south and north of the lake. Range data from Trammell et al. (2015) reflect general approximations as specific areas used vary annually. Please see Appendix B for a higher resolution version of this figure.

After calving, the TCH spreads out across the northern NPR-A seeking foraging and insect relief habitat (Person et al. 2007; Wilson et al. 2012). Use of areas north and west of Teshekpuk Lake increases during the post-calving and insect relief seasons (Person et al. 2007; Wilson et al. 2012). Caribou passing back and forth between areas north of Teshekpuk Lake typically have to cross within two relatively narrow corridors of land lying between either side of the lake and the ocean (Person et al. 2007; Figure 3a.4). One study noted that “to reach the coast, 86% of the collared caribou moved through the Kogru Inlet and Smith Bay corridors within two weeks of calving” (Person et al. 2007 p.247). The coastline in this area is subject to high rates of erosion (Jones et al. 2008), which seem to be increasing over time (Mars and Houseknecht 2007). If such trends continue it could hinder access to these important foraging and insect relief sites. In late summer, the TCH spreads out across the northern NPR-A, with extensive use of areas southwest of Teshekpuk Lake and some use of areas to the west (Figure 3a.3; Person et al. 2007; Wilson et al. 2012).

In the fall, many of the TCH animals migrate to their winter ranges. The TCH is unique among North Slope herds in that a majority of TCH animals remain on the coastal plain throughout the winter (Person et al. 2007; Fullman et al. 2021a). The herd tends to use four primary overwintering areas, with some animals that stay in the NPR-A remaining resident around Teshekpuk Lake, others making relatively short distance migrations within the coastal plain of the NPR-A, and those that leave migrating hundreds of kilometers southeast and southwest to overwintering areas among and beyond the Brooks Range mountains (Fullman et al. 2021a). There is a high degree of year-to-year variability in how the TCH allocates its distribution among these four winter areas, but between 2004-2015 roughly one-quarter of the herd remained in the northeastern NPR-A throughout the winter, over 40% overwintered in the northwestern part of the NPR-A, about one-quarter migrated to the southeast out of the NPR-A towards Anaktuvuk Pass, and less than 10% migrated southwest of the NPR-A towards the western Brooks Range and areas further south (Fullman et al. 2021a). Repeated use of all four wintering areas with variable use across years by the herd as a whole and by individuals that switch wintering locations from year to year (Fullman et al. 2021a) suggest that the TCH derives some benefit from maintaining access to multiple wintering areas.

Caribou that migrate out of the NPR-A to the southwest tend to remain fairly close to the coastline in the northwestern part of the NPR-A and as they continue out of the NPR-A down to the winter range (Figure 4 in Person et al. 2007; Figure 7 in Parrett 2021). Those animals heading southeast toward Anaktuvuk Pass mostly travel through the NPR-A and cross the Colville River before continuing through State, Federal, and Tribal lands toward their winter range (Figure 3a.3). Open water and rugged terrain, such as that found along the Colville River, can serve as barriers to caribou movement (Leblond et al. 2016; Fullman et al. 2017), limiting the number of potential crossing sites for caribou. Maintaining the ability of caribou to cross barriers such as the Colville River is critical for continuation of historical migration paths. The implications of any disruption in migration also have strong consequences for Alaska Native people in communities lying near migration paths, who rely upon movements of caribou for harvest opportunities. Some communities, such as Anaktuvuk Pass, are highly dependent on caribou, which form a large portion of their annual subsistence harvest (Bacon et al. 2011; Martin 2015).

In the spring, caribou reverse direction and head back toward Teshekpuk Lake for another season of calving. They again travel hundreds of kilometers over mountains and across rivers and tundra to return to the calving grounds and summer range. Movements during this period tend to be more linear and directed than during fall migration (Fullman et al. 2021a), possibly due to the need of pregnant female caribou to arrive at their calving grounds before it is time to give birth.

Western Arctic Herd

The WAH also calves in the NPR-A, consistently utilizing the foothills of the Utukok Uplands in the southwestern portion of the Reserve, but with year-to-year variability in the specific area used for calving (Figure 3a.5; Cameron et al. 2020; Joly and Cameron 2023). Much of the core WAH calving ground is contained within the Utukok River Uplands Special Area, though calving does happen on all sides of the Special Area (Figure 3a.5). Over time, the entire calving area is likely important for caribou, as has been noted for other herds in Alaska (Garner and Reynolds 1986; Griffith et al. 2002; USFWS 2015).

The northernmost portion of the Utukok River Uplands Special Area is open to oil and gas leasing and infrastructure, overlapping areas of repeatedly used calving grounds (Figure 3a.5). A simulation study examining the impacts of plausible future development under different land management alternatives found that extending leasing and infrastructure protections to include the full northern portion of the Utukok River Uplands Special Area boundary significantly reduced projected losses of high-quality calving habitat for the WAH (Fullman et al. 2021b). This underscores the sensitivity of calving caribou to development, noted above.

The WAH primarily uses the southern portion of the NPR-A throughout the summer, along with areas further to the west and along the coast (Figure 3a.3; Joly et al. 2021b; Joly and Cameron 2023). Caribou of the WAH move back and forth between the NPR-A and insect relief areas further west in midsummer and then spread out more broadly to use lands both within the NPR-A and further south for late summer foraging (Joly and Cameron 2023). In the fall, most individuals migrate south of the Brooks Range, though some animals winter north of the Brooks Range, including within the NPR-A (Joly and Cameron 2023).

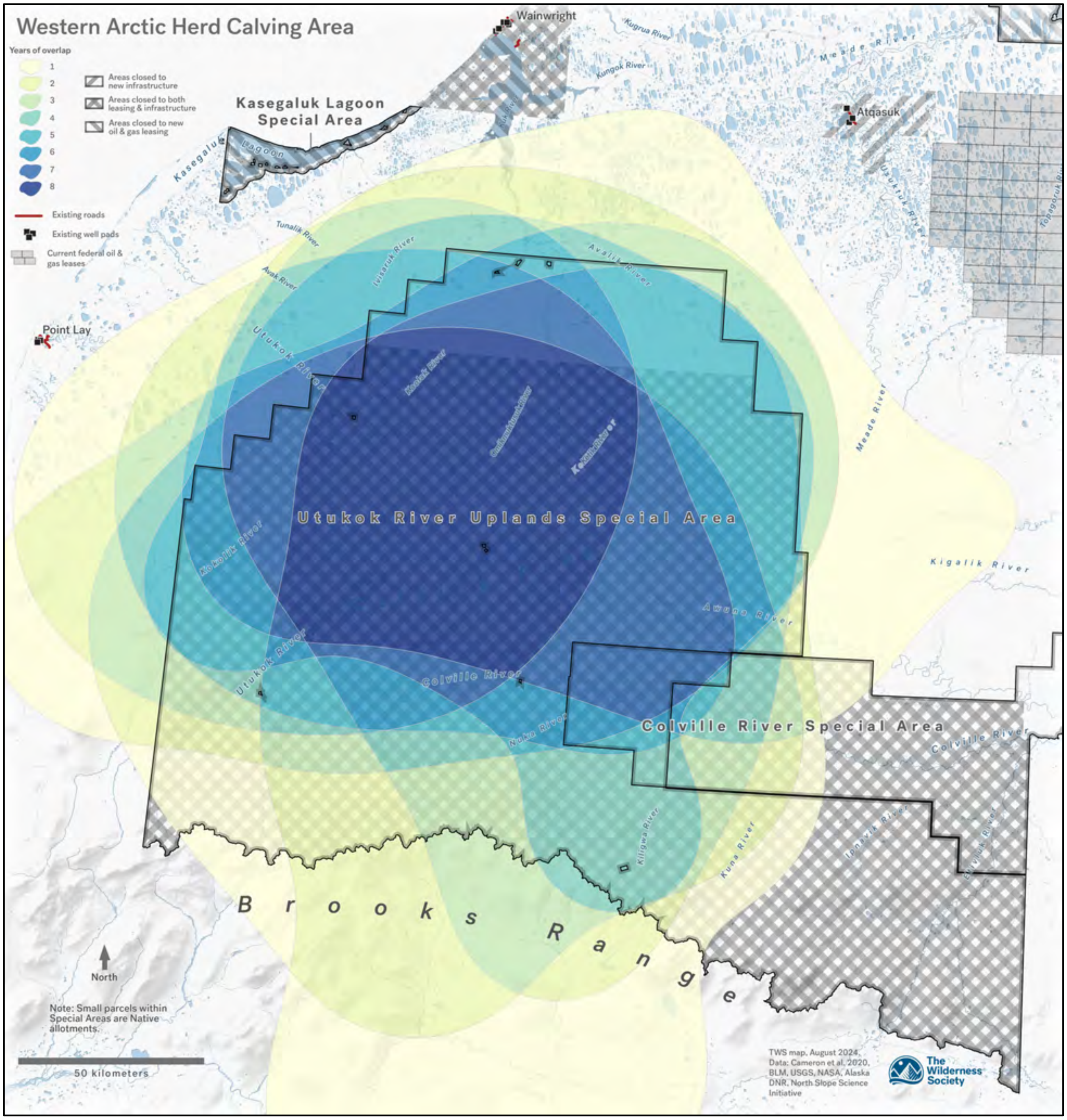

Figure 3a.5. The main Western Arctic Herd calving area lies within the Utukok River Uplands Special Area, though calving also occurs outside the Special Area in some years. The northernmost portion of the Special Area is open to oil and gas leasing and infrastructure, overlapping lands repeatedly used for Western Arctic Herd calving. Calving overlap data are from Cameron et al. (2020) and reflect the number of years of overlap of annual calving areas defined using 95% contours of kernel density estimates for caribou calving locations identified using GPS data. Please see Appendix B for a higher resolution version of this figure.

Central Arctic Herd

The CAH primarily occupies state lands to the east of the NPR-A but does occasionally use the NPR-A (Figure 3a.3; Nicholson et al. 2016; Lenart 2021). Indeed, the recent Ambler Road Final Supplemental Environmental Impact Statement depicts the range of the CAH extending even further west into the NPR-A than shown in Figure 3a.3 (Map 3-20 in BLM 2024a). Use of the NPR-A by the CAH is most common during the summer seasons, especially during insect relief and late summer, but has been noted in other seasons as well (Lenart 2021). When the CAH uses lands in the NPR-A, overlap tends to occur with the Colville River Special Area and to a lesser degree with the Teshekpuk Lake Special Area (Lenart 2021).

Review of Lease Stipulations and Required Operating Procedures from the 2022 IAP ROD

The NPR-A rule affirms that, when issuing a use authorization, it must conform to the Integrated Activity Plan (IAP) for the NPR-A (BLM 2024b §2361.10(b)(1)), or any subsequent overriding amendment. We thus here review the stipulations and Required Operating Procedures (ROPs) in the 2022 IAP ROD (BLM 2022) with regards to their level of protection for caribou and alignment with the best available scientific information.

Multiple lease stipulations identify areas in which no surface occupancy (NSO) setbacks are established or leasing is prohibited to protect important resources, including caribou insect relief habitat (K-1, K-2, K-4, K-5, K-6, K-8, K-10, K-13, K-14, and K-15; BLM 2022 p.A-6 to A-21). As is noted above, insect harassment can have a strong impact on caribou body condition, with implications for survival and calving success, making such protections valuable. This is especially notable given that caribou continue to avoid infrastructure more than expected by chance during the mosquito harassment season (Johnson et al. 2020) and show negative reactions to traffic volume during periods of insect harassment (Severson et al. 2023). The efficacy of these lease stipulations is compromised, however, by the exceptions found in each stipulation that state that sand and gravel mining could be authorized on a case-by-case basis. While the particular impacts of gravel mining on caribou have not been sufficiently studied, as noted above, negative reactions to other mining operations for caribou raise concerns about the detrimental effects such use of caribou habitat could have. Furthermore, for several of the stipulations exceptions are possible for roads and pipelines deemed essential (e.g., BLM 2022 p.A-6). Such infrastructure may hinder caribou movements and access to insect relief habitat. In general, exceptions to the stipulations and ROPs are an issue that compromise the ability of the requirements to provide maximum protections for caribou. Eliminating exceptions to stipulations and ROPs would increase certainty of protections for caribou.

Lease Stipulations K-9 and K-14 are intended to protect caribou in the Teshekpuk Lake Caribou Habitat Area and Utukok River Uplands Special Area, respectively. The scientific evidence describing the importance of calving, post-calving, insect relief, and foraging habitat is clearly outlined above, as are the potential negative impacts from development on caribou use of these habitats. These stipulations thus make an important step toward protections for caribou; however, there are deficiencies in their requirements and standards that do not align with the best available scientific information.

Traffic speed limits in the stipulations constrain vehicles to 15 miles per hour when caribou are within 0.8 km (0.5 miles) of the road (BLM 2022 p.A-16, A-19). However, caribou can travel very quickly, covering such a distance in a matter of minutes (Jim Dau, Alaska Department of Fish & Game caribou biologist, retired, pers. comm.). More robust protections for caribou would thus include extending this boundary and using multiple monitoring methods to manage vehicle activities. These monitoring methods could include: 1) daily review of location data from collared caribou to examine general movement patterns long before caribou contact roads, 2) daily or alternate day aerial reconnaissance flights in buffer areas around roads using the least disruptive means possible (e.g., unmanned aerial systems or other comparable technology where feasible) to provide detailed location information, including of non-collared individuals, and 3) road-based surveys to detect caribou proximity to roads. While science has not yet clearly indicated the appropriate distance from roads at which traffic patterns should be modified, road responses of caribou to the Delong Mountain Transportation System evaluated at a broader spatial scale of 15 km from roads found altered movement behavior and slow crossing for a portion of individuals (Wilson et al. 2016). This was on a road system where traffic was stopped when caribou were on or adjacent to the road, suggesting that some caribou may show altered movement behavior even with the proposed requirements and at greater distances than protected by the provisions of this stipulation. Similarly, a study around mining roads in Canada found pre-crossing displacement spanned 16-17 km for caribou (Boulanger et al. 2024). These studies caution that distances far beyond 0.8 km may be required to avoid impacts to caribou and that traffic alteration should be started early and increasingly restricted as caribou near roads.

The scientific literature also indicates that caribou are influenced not just by the speed of traffic, but by the volume of traffic. Recent work shows that adult female caribou select areas with lower traffic volumes throughout the summer, with the greatest selection probabilities when traffic was < 5 vehicles per hour (Severson et al. 2023). Similarly, maternal caribou avoid roads during calving even with traffic levels < 8 vehicles per day and despite convoying to increase gaps between traffic (Prichard et al. 2022). No limits on traffic volume are included in Lease Stipulations K-9 or K-14. Restricting traffic speed and volume whenever caribou are in proximity to roads, along with incorporating the monitoring described above, would better align with the best available scientific information.

Both stipulations include a statement that traffic may be stopped “throughout a defined area for up to four weeks to prevent displacement of calving caribou” (BLM 2022 p.A-16, A-20). However, specific details of what might lead to such a closure are not provided. Furthermore, no justification is given for why a four-week maximum is listed for closure. To the best of our knowledge, the scientific literature does not indicate that such a time limit would lead to reduced impacts. Rather, stopping traffic whenever necessary to prevent displacement of caribou seems more in line with the best available science, both removing the seemingly arbitrary 4-week deadline and broadening the focus from just calving caribou to reflect the importance of the post-calving, insect relief, winter, and other periods, as noted above.

The stipulations also include provisions to go beyond simply stopping traffic and state that “sections of road will be evacuated whenever an attempted crossing by a large number of caribou appears to be imminent” (BLM 2022 p.A-16, A-20). There is uncertainty, however, in what will qualify as “a large number” as no guidelines are specified in the stipulations. Child (1973) found that crossing success of groups of caribou was “significantly correlated with the size of the group” (p.14). That study found crossing success was rare for groups of caribou overall, with 75% of crossing attempts by groups unsuccessful. For groups with more than 10 animals, only 3 groups successfully crossed and all of these were at ramps, not at pipeline underpasses (Child 1973). Furthermore, no group with more than 50 individuals showed successful crossing at any crossing structure (Child 1973). Smith and Cameron (1985) also concluded that large groups of caribou do not readily cross pipelines. They reference groups of greater than 100 caribou as seeming to indicate “large” groups, though it is not clear how this value was identified. It is also notable that these studies focused on pipelines rather than roads. Further research on group size and crossing success of goads may help inform restrictions such as those in stipulations K-9 and K-14.

Even with inclusion of the improvements above, these mitigation measures are unlikely to be ultimately effective in avoiding impacts to caribou, as attested to by the studies cited above recording altered caribou response to infrastructure and human activity despite various mitigation measures in place. The high sensitivity of caribou to human disturbance and sustained shifts in CAH calving distribution away from development areas in spite of mitigation measures (e.g., Wolfe 2000; Cameron et al. 2002; Russell and Gunn 2019) indicate that the requirements specified in these stipulations are unlikely to remove disturbance and displacement entirely.

In addition to the proposed measures above, Stipulations K-9 and K-14 require a study of TCH or WAH movement before authorization of permanent facility construction (BLM 2022 p.A-15, A-19). This includes consideration of at least four years of current data on caribou movement. While the importance of using the best available scientific data to understand recent patterns of caribou movement is clear, the scientific record also emphasizes the need to consider broader historical patterns of caribou movement and habitat use. Caribou may vary their use of habitats widely over time. While they show strong fidelity to certain seasonal ranges (e.g., calving and summer range; Cameron et al. 1986; Cameron et al. 2020; Joly et al. 2021b), other seasons show lower fidelity, with periodic use, abandonment, and later reuse (Griffith et al. 2002; Baltensperger and Joly 2019; Joly and Cameron 2023). It is thus important that recent data be complemented with a broader historical perspective of the value of lands for caribou and other wildlife species. This is reinforced by research that shows decreases and increases in herd range area can accompany reduction and growth of caribou populations, respectively (Taillon et al. 2012; Virgl et al. 2017), making very recent patterns of movement and habitat use only partially reflective of what caribou may display at a different point in their population cycle. In light of this and the long duration of caribou reactions to permanent infrastructure (e.g., Johnson et al. 2020), there is likely merit in expanding the amount of data required to inform permitting decisions. This variability also means that the area needed to prevent more than minimal impacts may vary from year to year. This is why scientific experts have repeatedly emphasized the need to protect large intact areas to minimize impacts upon caribou over time (e.g., Griffith et al. 2002; USFWS 2015).

Lease Stipulation K-13 is established to protect the Pik Dunes. Leasing is prohibited and only “approximately perpendicular pipeline crossings and ice pads” are permitted, along with sand and gravel mining on a case-by-case basis (BLM 2022 p.A-18). The Pik Dunes are a unique geological feature consisting mainly of sand dunes lying approximately 30 km southeast of Teshekpuk Lake. The area is extensively used by caribou throughout the year, and especially serves as important insect relief habitat (BLM 2022 p.A-18) as caribou seek to escape biting insects on the windy, barren slopes of the dunes. The Pik Dunes lie within the Teshekpuk Lake Special Area and are unavailable for leasing (BLM 2022 Map 2). Nonetheless the allowance of exceptions for pipelines, ice pads, and mining undermine protections for this area. Given the relatively small size of the Pik Dunes, the geological uniqueness of the habitat within the NPR-A, and the documented sensitivity of caribou to disturbance (e.g., Cameron et al. 2005; Johnson et al. 2020), mining, development, or other disturbance within the Pik Dunes could have detrimental effects on the TCH and other caribou passing through the area.

ROP E-5 seeks to minimize the footprint of development by sharing and collocating oil and gas facilities (BLM 2022 p.A-32). Given the documented responses of caribou to the infrastructure footprint noted above, these measures are likely to yield beneficial results for reducing disturbance of caribou. As is also noted above, however, sufficiently large areas without infrastructure and with minimal human activity still are likely to be required to fully minimize development impacts on caribou.

ROP E-19 specifies that geospatial data be provided to BLM of all new infrastructure construction (BLM 2022 p.A-37). This is very important to enable robust scientific investigation of the impacts of future development on wildlife and other significant resource values, which will help BLM better meet its obligations in the NPR-A. Lack of such data availability can hinder scientific assessments. It is thus unfortunate that there is not a similar requirement that as-built shapefiles of ice roads, snow trails and ice pads be provided after infrastructure is completed. Caribou also show adverse reactions to temporary infrastructure (Smith and Johnson 2023; Smith et al. 2023), making it important to understand where such infrastructure and activities occur to facilitate future studies that can examine the true impact of winter exploration, construction and other activities. Impacts of such temporary infrastructure on caribou and other species remain a major gap in knowledge. This is especially crucial in the northeastern NPR-A where a sizeable portion of the TCH spends the winter in areas overlapping existing oil and gas leases (Figures 3.1-3.2). Maximum protection would better be attained by including a requirement for such data to be included under ROP E-19. Such language would be strengthened further by clarifying that ancillary data be provided that includes when exploration activities and temporary infrastructure were concluded/removed, activity levels of traffic density and speed, and documentation of any other potential disturbances (e.g., timing and location of seismic testing events). This information will enable a wide array of important analyses. Furthermore, specification that all data provided under ROP E-19 will be made available to researchers and management agencies upon request would enhance the opportunity to conduct meaningful scientific study. There have been issues in the past with infrastructure locations being considered proprietary information and their spatial data not being shared. This hinders the ability of scientists to conduct analyses that can help reveal what impacts, if any, human activities have on public lands and the species and habitats within them.

Concerns about the impact of aircraft on wildlife and subsistence hunting have long been voiced by Alaska Native hunters (Georgette and Loon 1988; Halas 2015) and continue to be an issue today (e.g., Stinchcomb et al. 2019; Stinchcomb et al. 2020). Wolfe et al. (2000) provided a review of aircraft effects on caribou, but little research has been done since, leaving this an area requiring further study. Restrictions on aircraft activity to support wildlife are addressed in Lease Stipulations K-6 and K-14 as well as ROP F-1 (BLM 2022 p.A-14, A-20, A-38, A-39). Lease Stipulation K-9 also mentions “air traffic restrictions” but no specific restrictions are described (BLM 2022 p.A-16). Taken together, these requirements set a minimum flight altitude of 610 m (2000 ft) over the Teshekpuk Lake Caribou Habitat Area and Utukok River Uplands Special Area between May 20 – August 20 each year. This timeframe comprises the primary calving, post-calving, and insect relief seasons and should help reduce aircraft impacts on caribou during this time, if enforced. It should be noted, however, that weather conditions may often lead to flight ceilings that are lower than those established in the regulations such that weather safety exceptions may increase the impact of aircraft on caribou despite the guidance of the lease stipulations and ROP. Similarly, between December 1 – May 1 each year minimum flight altitudes are set to 305 m (1000 ft) over annually derived caribou winter ranges. The IAP ROD indicates that winter areas will be identified each year in consultation with the Alaska Department of Fish and Game (BLM 2022 p.A-20, A-38). Greater specificity as to what standards will be used to identify these winter areas would strengthen the stated protections for caribou.

Given the annual variability in calving and summer distribution of the TCH, as well as observations of calving outside of this area, protections would be strengthened by clarifying that altitude restrictions over the Teshekpuk Lake Caribou Habitat Area be considered the minimum extent. Maximum protections for caribou could then include additional altitude restriction zones over annual calving areas identified by Indigenous Knowledge or in consultation with the Alaska Department of Fish and Game. This would increase responsiveness to changing conditions and annual variation, enhancing the likelihood of maximum protections for caribou.

Lease Stipulation K-14 also includes limitations on aircraft exceeding certain sizes, restrictions on takeoff/landing volume per airstrip, and the potential to suspend all aircraft activity if unacceptable disturbance occurs (BLM 2022 p.A-20). The language surrounding these protections is tentative, however, indicating that there “may” be restrictions on aircraft size, volume limitation, and “perhaps” suspension of activity (BLM 2022 p.A-20). Such tentative language without clarity on what conditions would trigger such restrictions makes it uncertain whether protections for caribou would actually be implemented. Furthermore, these requirements are not applied to the TCH or the Teshekpuk Lake Caribou Habitat Area in Lease Stipulation K-9. Doing so would increase protections for that herd.

Other factors influencing maximum protection measures

Achieving the standard of maximum protection for caribou within Special Areas will largely entail avoidance of leasing and infrastructure. Studies in Prudhoe Bay and Kuparuk have demonstrated continued avoidance responses to infrastructure by caribou after about 40 years of exposure to development and multiple measures intended to mitigate impacts (Johnson et al. 2020; Prichard et al. 2020). The continued behavioral reactions to infrastructure and traffic (e.g., Prichard et al. 2022; Severson et al. 2023) suggest that such measures are insufficient and thus only maintaining large areas sufficiently far from roads and other development to avoid the “zone of influence” across which impacts persist around development (e.g., Boulanger et al. 2012; Boulanger et al. 2021), will offer maximum protection. Indeed, a recent summary by an international group of renowned caribou experts concluded with the recommendation that large areas of undeveloped critical habitat be protected to conserve caribou (Joly et al. 2021a). They warn that, “where barriers exist, or will exist, migrations will be altered or lost. This will have disproportional impacts on (often Indigenous) residents of remote Arctic regions, including on their subsistence harvests, culture, economics, and well-being” (Joly et al. 2021a p.162).

One of the challenges for achieving maximum protection of caribou habitat in the NPR-A is dealing with uncertainty. The new BLM rule on Management and Protection of the NPR-A explicitly requires BLM to document uncertainty and ensure decisions reflect this uncertainty (BLM 2024b §2361.10(b)(3)). However, additional specificity is needed for how uncertainty will be determined and what will be done about it. The published scientific literature includes methods to account for the uncertainty in future development locations while revealing a range of possible impacts on species of interest (Wilson et al. 2013; Fullman et al. 2021b; Russell et al. 2021). For example, Wilson et al. (2013) utilized a Monte Carlo simulation approach to explicitly address uncertainty in where future oil and gas development would occur while quantifying the range of expected impacts to TCH calving habitat and bird nests under the various alternatives considered during the 2012 NPR-A Integrated Activity Plan (IAP) Environmental Impact Statement (EIS) process. This information clearly demonstrated lower impacts to caribou and passerine birds under one alternative than under the other three (Wilson et al. 2013). Preliminary findings from the model were used to help analyze impacts among alternatives in the 2013 IAP process (BLM 2012 Volume 2 p.194, Volume 3 p.274-275). Fullman et al. (2021b) updated the Wilson et al. (2013) model and added calving habitat for the WAH and an expanded array of birds. They analyzed alternatives in the 2020 IAP Draft EIS and made their code freely available to facilitate future use (https://github.com/tfullman/dia). Such approaches demonstrate the feasibility of estimating impacts to significant resource values while accounting for uncertainty in future conditions, including in locations of future discoveries or development proposals.

Climate change also induces considerable uncertainty. Here too, however, there are previously published approaches that provide examples of ways to account for uncertainty in impacts on significant resource values. A Canadian study used a spatially explicit simulation model to examine net effects of positive and negative climate-induced factors on a caribou herd (Tews et al. 2007). Similarly, recent work evaluated Arctic Refuge Coastal Plain development effects on the Porcupine Caribou Herd under various estimates of climate variability (Russell and Gunn. 2019; Russell et al. 2021). These studies found that climate change strongly influenced population consequences of development for caribou and resulting impacts on subsistence users. Other research has also predicted future caribou habitat suitability under climate change (e.g., Severson et al. 2021) and could be combined with approaches such as those used in Wilson et al. (2013) and Fullman et al. (2021b) to look at possible future interactions of caribou habitat under climate change and infrastructure expansion. The modeling studies described above are just some of the many available in the scientific literature that present options for explicit consideration and quantification of uncertainty. Meeting the standards of the best-available scientific approaches to evaluating impact while accounting for uncertainty involves conducting scientific analyses that quantify impact across various aspects of potential development effects. This includes, but is not limited to, quantifying and mapping caribou habitat selection and the relative value of habitat across different seasons (e.g., Wilson et al. 2012; Severson et al. 2021), using energetics models (e.g., Russell et al. 2004) to estimate energy consequences of displacement away from prime forage areas, identifying the range of uncertainty in habitat loss under different alternatives (e.g., Wilson et al. 2013; Fullman et al. 2021b), calculating population-level consequences of displacement (e.g., Griffith et al. 2002; Russell et al. 2021), and considering cumulative effects of climate change on caribou (e.g., Tews et al. 2007). While uncertainty will never be able to be fully eliminated, use of cutting-edge scientific tools such as these will enable BLM to better consider and quantify uncertainty in management, conservation, and permitting decisions. Recent applications to BLM permitting decisions in Alaska (Russell and Gunn 2019; Russell et al. 2021) show that such approaches are feasible and can be built upon to better reflect the suite of uncertainty surrounding various decisions.

Much of the attention around conservation of caribou habitat has been placed on the calving period. The scientific literature is clear on the critical nature of such habitat and on the sensitivity of female caribou with calves to infrastructure and disturbance during the calving period. However, as is documented above, calving is not the only important season for caribou. Caribou use of the NPR-A occurs throughout the year and robust maximum protection measures will span the entire annual cycle in which caribou are present. This includes crucial calving and post-calving periods, movements between insect relief habitat and foraging habitat during the summer, migratory movements between summer and winter range and back again, and overwintering habitat. The latter is especially important for the TCH, which remains in the northern NPR-A throughout the winter. There has been a paucity of studies specifically examining caribou response to winter activity and development in Alaska, leading to uncertainty in caribou response. Ongoing study of winter habitat use and response to infrastructure and development activities by the TCH and any WAH or CAH individuals that overwinter within the NPR-A is needed to inform relevant maximum protection measures. These analyses should consider permanent infrastructure, temporary infrastructure such as ice roads, and other activities like seismic exploration that may affect caribou winter behavior and habitat use. Reports of traffic influences on caribou also indicate that activity levels of traffic density and other potential disturbances (e.g., timing and location of seismic testing events) should be reported to improve understanding of these specific effects in winter. As is discussed above, costs of winter disturbance for caribou may be higher in years of greater snowfall and may persist into later years, even if future winters are milder. Increased rain-on-snow events and other harsh winter conditions have been noted recently (e.g., Joly and Cameron 2023) and are expected to increase under climate change, reinforcing the importance of winter studies that include both anthropogenic and climate components. These expectations also suggest that it may be wise to account for uncertainty in future conditions with flexible stipulations that enable the BLM Authorized Officer, in consultation with state, federal, regional and other wildlife biologists, to restrict, or even close entirely, winter seismic exploration and development activity in caribou winter habitat during years of heavy winter snowfall or in response to rain-on-snow events.

Previous EIS documents have tended to focus primarily on quantifying the expected footprint of development, rather than the functional loss of habitat associated with caribou avoidance of development (e.g., BLM 2018; BLM 2023). While the footprint of development leads to direct habitat loss, multiple scientific reports have documented additional functional habitat loss as caribou displace away from development and human activity (e.g., Cameron et al. 2005; Boulanger et al. 2012; Plante et al. 2018; Johnson et al. 2020; Boulanger et al. 2021). It is more difficult to represent the expected effects of such functional habitat loss, but this does not remove the importance of doing so as a means of better reflecting expected effects of future development. Similarly, identifying maximum protection measures is complicated by a lack of clarity on how observed displacement, delay, or other adverse reactions will translate into population-level metrics that could reveal whether impacts of a proposed activity extend beyond “minimum impact.” With both this question and that of functional habitat loss, simulation modeling approaches, such as those described above, offer an intriguing possible way that population effects and functional habitat loss could be incorporated into future decisions. This will require population modeling that links changes in movement, nutrition, and stressors, to population-level effects (e.g., Russell et al. 2021) and may require additional scientific studies to better parameterize model inputs. Nonetheless, it presents a science-based avenue for accounting for uncertainty and identifying minimum impacts. As has been noted, this should be done across seasons, as different activities and impacts may be present during various time periods, as well as cumulatively for multiple developments and other potential stressors. Until such time as these studies are completed, the known impacts, global observations of Rangifer decline, and uncertainties described above encourage a conservative approach to determining and implementing maximum protection measures that seeks to emphasize reduction of potential impacts to caribou.

The new NPR-A management rule indicates that lands within Special Areas (other than the Teshekpuk Lake and Utukok River Uplands Special Areas, which can only be changed by congressional statute) may only be removed “when all of the significant resource values that support the designation are no longer present” (BLM 2024b §2361.30(c)). As is noted above, caribou may vary their use of habitats widely over time. Thus one, or even several, years with a lack of use by caribou does not indicate justification for removing lands from Special Areas. Rather, decades without observed use, combined with scientific modeling studies that show conditions have changed such that future use is unlikely, should be required before a significant resource value is considered “no longer present.”

The NPR-A management rule includes an exception to allow infrastructure within Special Areas, including within areas indicated as closed to leasing or unavailable to new infrastructure, provided certain circumstances are met (BLM 2024b §2361.40(e)). While traffic level increases caribou response to roads, as described above, displacement and other disturbance responses are likely for non-industry roads as well, raising concerns about the effects of these possible exceptions. One location of particular concern is the crucial caribou and bird nesting and molting area surrounding Teshekpuk Lake and the migratory corridors on either side of the lake (e.g., Figure 3a.4). Allowing roads or any other type of new infrastructure in this sensitive area is inconsistent with providing maximum protection for caribou within Special Areas.

Special Area protections for caribou

Teshekpuk Lake Special Area

The value of the Teshekpuk Lake Special Area to the TCH cannot be overstated. The area provides critical habitat for the herd throughout the year, especially during sensitive calving, post-calving, and insect relief periods. The Special Area has differing levels of restrictions on leasing and infrastructure, ranging from complete prohibitions to no restrictions (Figure 3a.4). As is noted above, even those areas indicated as being closed to leasing and infrastructure have vulnerabilities to development under the new NPR-A management rule. There is also substantial oil and gas leasing within the Special Area, including overlapping calving and other sensitive habitat (Figure 3a.4). Avoiding development and disturbance of caribou where possible within this Special Area will reduce impacts on the TCH.

Currently there is a gap between the Teshekpuk Lake Special Area and Colville River Special Area that is heavily used by the TCH year-round, along with some use by the CAH and yet which has no restrictions on leasing or infrastructure (Figure 3a.3). Caribou use of and movement through these lands is an important part of their annual cycle and any development or other activities that disturb caribou use of these areas could have detrimental impacts upon the herds.

Colville River Special Area

The Colville River Special Area is used throughout the year by the TCH, encompassing summer range, winter range, and important migratory connectivity areas for animals moving between the summer range and winter areas in the Brooks Range near Anaktuvuk Pass (Figure 3a.3; Person et al. 2007; Fullman et al. 2021a). The CAH uses parts of the Special Area as well (Figure 3a.3; Map 3-20 in BLM 2024a). It also is used for subsistence harvest of caribou, fish, and other species by the people of Nuiqsut. Furthermore, the western parts of the Colville River Special Area overlap seasonal ranges of the WAH, include calving, summer, and migratory areas (Figure 3a.3; Joly and Cameron 2023). Despite this multitude of uses by caribou, important caribou habitat is not listed among the significant resource values for the Colville River Special Area (BLM 2024b §2361.20(a)). It is also notable that the vast majority of the Colville River Special Area is open to leasing and new infrastructure. Development in this area could threaten caribou habitat and connectivity.

Utukok River Uplands Special Area

The Utukok River Uplands Special Area protects the majority of the WAH calving grounds, as well as other important caribou summer and migratory habitat (Figure 3a.3). Much of this Special Area is unavailable for oil and gas leasing and new non-subsistence surface infrastructure, with the exception of the northernmost portion (Figure 3a.5). This northern portion overlaps with the upper limits of the core WAH calving distribution. As is noted above, previous scientific study found that leaving this area available for leasing and development increases risks of calving habitat loss for the WAH (Fullman et al. 2021b). Actions that prevent leasing and development in this area are predicted to reduce impacts upon the declining WAH, in keeping with providing maximum protection of significant resource values within Special Areas (BLM 2024b §2361.30(b)(5)).

Peard Bay and Kasegaluk Lagoon Special Areas

The Peard Bay Special Area abuts a calving area for the TCH. First predicted as calving habitat based on observed patterns of resource use (Wilson et al. 2012), use of the northwestern NPR-A for calving by the TCH was later confirmed with aerial surveys (Prichard et al. 2019). While not as intensively used as the calving area around Teshekpuk Lake, this calving area nonetheless may be important for some caribou of the TCH, as well as serving as overwintering habitat (Person et al. 2007; Fullman et al. 2021a). If the southern boundary of the Peard Bay Special Area is extended, it might encompass this caribou calving area. As is noted above, those TCH individuals that migrate to the western Brooks Range to overwinter tend to travel along the coastline. Such travel areas currently do not have minimal restrictions on leasing or infrastructure but this could change if the southern boundaries of the Peard Bay and Kaseagaluk Lagoon Special Areas are extended. This is the least used of the four TCH winter areas (Fullman et al. 2021a) but nonetheless could protect an important movement pathway for some caribou.

Caribou literature cited

Ackerman DE, Finlay JC. 2019. Road dust biases NDVI and alters edaphic properties in Alaskan arctic tundra. Scientific Reports 9, 214. Available from: https://www.nature.com/articles/s41598-018-36804-3.

ADFG. 2020. Central Arctic Caribou Herd News. Division of Wildlife Conservation, Alaska Department of Fish and Game, Fairbanks, AK, USA. Available from: https://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/central_arctic_herd/cah_newsletter_summer_2020.pdf (accessed 2024-04-25).

ADFG. 2023a. Fortymile Caribou Herd News. Division of Wildlife Conservation, Alaska Department of Fish and Game, Fairbanks, AK, USA. Available from: https://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/fortymile_caribou_herd_news_2023.pdf (accessed 2024-04-25).

ADFG. 2023b. New Fortymile Caribou Hunt Quota. Division of Wildlife Conservation, Alaska Department of Fish and Game, Fairbanks, AK, USA. Advisory Announcement released 2023-07-21. Available from: https://www.adfg.alaska.gov/static/applications/publicnotification/2023/orders/AR-1-23.pdf (accessed 2024-04-25).

ADFG. 2023c. Mulchatna Caribou Intensive Management Frequently Asked Questions (FAQs): December 2023. Alaska Department of Fish and Game. Available from: https://www.adfg.alaska.gov/static/applications/web/nocache/research/programs/intensivemanagement/pdfs/mulchatna_faq.pdf0B542B2A7AA31F410B7536A373508471/mulchatna_faq.pdf (accessed 2024-04-25).

ADFG. 2023d. Nelchina Caribou News. Alaska Department of Fish and Game. Palmer, AK, USA. Available from: https://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/nelchina_caribou_news/nelchina_caribou_news_2023.pdf (accessed 2024-04-25).

Aikens EO, Kauffman MJ, Merkle JA, Dwinnell SPH, Fralick GL, Monteith KL. 2017. The greenscape shapes surfing of resource waves in a large migratory herbivore. Ecology Letters 20(6), 741-750. Available from: https://onlinelibrary.wiley.com/doi/10.1111/ele.12772.

Albon SD, Irvine RJ, Halvorsen O, Langvatn R, Loe LE, Ropstad E, Veiberg V, Van der Wal R, Bjørkvoll EM, Duff EI, Hansen BB, Lee AM, Tveraa T, Stein A. 2017. Contrasting effects of summer and winter warming on body mass explain population dynamics in a food-limited Arctic herbivore. Global Change Biology 23, 1374-1389. Available from: https://onlinelibrary.wiley.com/doi/epdf/10.1111/gcb.13435.

Altizer S, Ostfeld RS, Johnson PTJ, Kutz S, Harvell CD. 2013. Climate change and infectious diseases: from evidence to a predictive framework. Science 341, 514-519. Available from: https://www.science.org/doi/10.1126/science.1239401.

Avgar T, Street G, Fryxell JM. 2014. On the adaptive benefits of mammal migration. Canadian Journal of Zoology 92, 481–490. Available from: https://cdnsciencepub.com/doi/10.1139/cjz-2013-0076.

Bacon JJ, Hepa TR, Brower Jr HK, Pedersen M, Olemaun TP, George JC, Corrigan BG. 2011. Estimates of subsistence harvest for villages on the North Slope of Alaska, 1994–2003. Department of Wildlife Management, North Slope Borough, Barrow, Alaska, USA. Available from: https://www.north-slope.org/wp-content/uploads/2022/04/MASTER-SHDP-94-03-REPORT-FINAL-and-Errata-info-Sept-2012.pdf (accessed 2024-05-20).

Ballard WB, Ayres LA, Krausman PR, Reed DJ, Fancy SG. 1997. Ecology of wolves in relation to a migratory caribou herd in northwest Alaska. Wildlife Monographs 135, 3–47. Available from: https://www.jstor.org/stable/3830776.

Baltensperger AP, Joly K. 2019. Using seasonal landscape models to predict space use and migratory patterns of an arctic ungulate. Movement Ecology 7, 18. Available from: https://movementecologyjournal.biomedcentral.com/articles/10.1186/s40462-019-0162-8.

Barboza PS, Parker KL. 2008. Allocating protein to reproduction in Arctic reindeer and caribou. Physiological and Biochemical Zoology 81(6), 835-855. Available from: https://www.journals.uchicago.edu/doi/epdf/10.1086/590414.

Barboza PS, Van Someren LL, Gustine DD, Bret-Harte MS. 2018. The nitrogen window for arctic herbivores: plant phenology and protein gain of migratory caribou (*Rangifer tarandus*). Ecosphere 9(1), e02073. Available from: https://esajournals.onlinelibrary.wiley.com/doi/epdf/10.1002/ecs2.2073.

Bauer S, Hoye BJ. 2014. Migratory animals couple biodiversity and ecosystem functioning worldwide. Science 344, 1242552. Available from: https://www.science.org/doi/10.1126/science.1242552.

Bejder L, Samuels A, Whitehead H, Finn H, Allen S. 2009. Impact assessment research: use and misuse of habituation, sensitization and tolerance in describing wildlife responses to anthropogenic stimuli. Marine Ecology Progress Series 395, 177-185. Available from: https://www.int-res.com/abstracts/meps/v395/p177-185/.

Bergerud AT. 1996. Evolving perspectives on caribou population dynamics, have we got it right yet? Rangifer 9, 95-116. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/1225/1164.

Berkes F, George PJ, Preston RJ, Hughes A, Turner J, Cummins BD. 1994. Wildlife harvesting and sustainable regional native economy in the Hudson and James Bay Lowland, Ontario. Arctic 47, 350–360. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/64363/48298.

Bischof R, Loe LE, Meisingset EL, Zimmermann B, Van Moorter B, Mysterud A. 2012. A migratory northern ungulate in the pursuit of spring: jumping or surfing the green wave? The American Naturalist 180(4), 407-424. Available from: https://www.journals.uchicago.edu/doi/10.1086/667590.

Bjørklund I. 1990. Sámi reindeer pastoralism as an indigenous resource management system in northern Norway: a contribution to the common property debate. Development and Change 21, 75–86. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1467-7660.1990.tb00368.x.

BLM. 2012. National Petroleum Reserve – Alaska Final Integrated Activity Plan/Environmental Impact Statement. Bureau of Land Management, US Department of the Interior. Anchorage, AK, USA. Available from: https://eplanning.blm.gov/public_projects/nepa/5251/41003/43153/Vol1_NPR-A_Final_IAP_FEIS.pdf.

BLM. 2018. Coastal Plain Oil and Gas Leasing Program Draft Environmental Impact Statement. Bureau of Land Management, US Department of the Interior. Anchorage, AK, USA.

BLM. 2022. National Petroleum Reserve in Alaska Integrated Activity Plan Record of Decision. Bureau of Land Management, US Department of the Interior. Anchorage, AK, USA. Available from: https://eplanning.blm.gov/public_projects/117408/200284263/20058238/250064420/2022_NPRA_IAP_ROD_508.pdf.

BLM. 2023. Ambler Road Draft Supplemental Environmental Impact Statement. Bureau of Land Management, US Department of the Interior. Fairbanks, AK, USA. Available form: https://eplanning.blm.gov/public_projects/57323/200091317/20087589/250093771/Ambler%20Road%20Draft%20SEIS%20Volume%201.pdf.

BLM. 2024a. Ambler Road Final Supplemental Environmental Impact Statement. Bureau of Land Management, US Department of the Interior. Fairbanks, AK, USA. Available from: https://eplanning.blm.gov/eplanning-ui/project/57323/570.

BLM. 2024b. Management and Protection of the National Petroleum Reserve in Alaska. Bureau of Land Management. Federal Register 89, 38712-38760. Available from: https://www.regulations.gov/document/BLM-2023-0006-89263.

Borish D, Cunsolo A, Snook J, Shiwak I, Wood M, HERD Caribou Project Steering Committee, Dewey C, Mauro I, Harper SL. 2021. "Caribou was the reason, and everything else happened after": Effects of caribou declines on Inuit in Labrador, Canada. Global Environmental Change 68, 102268. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0959378021000479.

Borish D, Cunsolo A, Snook J, Dewey C, Mauro I, Harper SL. 2022. Relationships between *Rangifer* and Indigenous well-being in the North American arctic and subarctic: a review based on the academic published literature. Arctic 75(1), 86-104. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/74870.

Boulanger J, Poole KG, Gunn A, Wierzchowski J. 2012. Estimating the zone of influence of industrial developments on wildlife: a migratory caribou *Rangifer tarandus groenlandicus* and diamond mine case study. Wildlife Biology 18, 164-179. Available from: https://nsojournals.onlinelibrary.wiley.com/doi/10.2981/11-045.

Boulanger J, Poole KG, Gunn A, Adamczewski J, Wierzchowski J. 2021. Estimation of trends in zone of influence of mine sites on barren-ground caribou populations in the Northwest Territories, Canada, using new methods. Wildlife Biology 2021(1), wlb.00719. Available from: https://bioone.org/journals/wildlife-biology/volume-2021/issue-1/wlb.00719/Estimation-of-trends-in-zone-of-influence-of-mine-sites/10.2981/wlb.00719.full.

Boulanger J, Kite R, Campbell M, Shaw J, Lee D, Atkinson S. 2024. Estimating the effects of roads on migration: a barren-ground caribou case study. Canadian Journal of Zoology 102, 476-493. Available from: https://cdnsciencepub.com/doi/10.1139/cjz-2023-0121.

Bradshaw CJA, Boutin S, Hebert DM. 1997. Effects of petroleum exploration on woodland caribou in northeastern Alberta. Journal of Wildlife Management 61(4), 1127-1133. Available from: https://www.jstor.org/stable/3802110?origin=crossref.

Bradshaw CJA, Boutin S, Hebert DM. 1998. Energetic implications of disturbance caused by petroleum exploration to woodland caribou. Canadian Journal of Zoology 76, 1319-1324. Available from: https://www.academia.edu/14699930/Energetic_implications_of_disturbance_caused_by_petroleum_exploration_to_woodland_caribou?f_ri=2008440.

Braem NM. 2012. Subsistence wildlife harvests in Ambler, Buckland, Kiana, Kobuk Shaktoolik and Shishmaref, Alaska, 2009-2010. Alaska Department of Fish and Game Division of Subsistence, Special Publication No. SP2012-003, Fairbanks, AK, USA. Available from: https://www.adfg.alaska.gov/specialpubs/SP2_SP2012-003.pdf.

Bråthen KA, Ims RA, Yoccoz NG, Fauchald P, Tveraa T, Hausner VH. 2007. Induced shift in ecosystem productivity? Extensive scale effects of abundant large herbivores. Ecosystems 10, 773-789. Available from: https://link.springer.com/article/10.1007/s10021-007-9058-3.

Brito D, Fernandez FAS. 2000. Dealing with extinction is forever: understanding the risks faced by small populations. Ciência e Cultura Journal of the Brazilian Association for the Advancement of Science 52(3), 161-170. Available from: https://www.researchgate.net/profile/Fernando-Fernandez-22/publication/313149427_Dealing_with_extinction_is_forever_Understanding_the_risks_faced_by_small_populations/links/593b0a6e0f7e9b33171413d6/Dealing-with-extinction-is-forever-Understanding-the-risks-faced-by-small-populations.pdf.

Brodersen J, Nicolle A, Nilsson PA, Skov C, Brönmark C, Hansson L-A. 2011. Interplay between temperature, fish partial migration and trophic dynamics. Oikos 120, 1838-1846. Available from: https://nsojournals.onlinelibrary.wiley.com/doi/full/10.1111/j.1600-0706.2011.19433.x.

Brönmark C, Hulthén K, Nilsson PA, Skov C, Hansson L-A, Brodersen J, Chapman BB. 2014. There and back again: migration in freshwater fishes. Canadian Journal of Zoology 92, 467–479. Available from: https://cdnsciencepub.com/doi/10.1139/cjz-2012-0277.

Caikoski JR. 2020. Porcupine caribou herd management report and plan, Game Management Unit 25A, 25B, 25D, and 26C: Report period 1 July 2012 – 30 June 2017, and plan period 1 July 2017 – 30 June 2022. Alaska Department of Fish and Game, Species Management Report and Plan ADF&G/DWC/SMR&P-2020-22, Juneau, AK, USA. Available from: https://www.adfg.alaska.gov/static/research/wildlife/speciesmanagementreports/pdfs/caribou_2012_2022_porcupine.pdf.

Cameron RD, Whitten KR. 1979. Effects of the Trans-Alaska Pipeline on caribou movements. Volume IV, Project Progress Report, Federal Aid in Wildlife Restoration Project W-17-10 (2nd half) and W-17-11 (1st half), Job No. 3.18R. Alaska Department of Fish and Game, Juneau, AK, USA. 38 pp. Available from: https://www.adfg.alaska.gov/index.cfm?adfg=librarypublications.wildlifepublicationsdetails&pubidentifier=2835.

Cameron RD, Whitten KR. 1980. Influence of the Trans-Alaska Pipeline corridor on the local distribution of caribou. In: Reimers E, Faare E, Skjenneberg S. (eds.). Proceedings of the 2nd International Reindeer/Caribou Symposium, Røros, Norway, 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim, Norway. Available from: https://www.arlis.org/docs/vol2/Susitna-temp/APA/31/APA3174.pdf.

Cameron RD, Whitten KR, Smith WT, Roby DD. 1979. Caribou distribution and group composition associated with construction of the Trans-Alaska Pipeline. Canadian Field-Naturalist 93(2), 155-162. Available from: https://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/propubs/79_cameron_etal_caribou_distribution_group_composition_tap.pdf.

Cameron RD, Whitten KR, Smith WT. 1986. Summer range fidelity of radio-collared caribou in Alaska's Central Arctic Herd. Rangifer 1, 51-55. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/582.

Cameron RD, Reed DJ, Dau JR, Smith WT. 1992. Redistribution of calving caribou in response to oil field development on the Arctic Slope of Alaska. Arctic 45(4), 338-342. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/64467.

Cameron RD, Smith WT, Fancy SG, Gerhart KL, White RG. 1993. Calving success of female caribou in relation to body weight. Canadian Journal of Zoology 71, 480-486. Available from: https://cdnsciencepub.com/doi/10.1139/z93-069.

Cameron RD, Lenart EA, Reed DJ, Whitten KR, Smith WT. 1995. Abundance and movements of caribou in the oilfield complex near Prudhoe Bay, Alaska. Rangifer 15(1), 3-7. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/1150.

Cameron RD, Smith WT, White RG, Griffith B. 2002. The Central Arctic Caribou Herd. Pages 38-45 [*In*] Douglas, D.C., Reynolds, P.E., Rhode, E.B., editors. Arctic Refuge coastal plain terrestrial wildlife research summaries. U.S. Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR-2002-0001. Available from: https://pubs.usgs.gov/publication/bsr20020001.

Cameron RD, Smith WT, White RG, Griffith B. 2005. Central Arctic caribou and petroleum development: distributional, nutritional, and reproductive implications. Arctic 58, 1-9. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/63443.

Cameron MD, Joly K, Breed GA, Mulder CPH, Kielland K. 2020. Pronounced fidelity and selection for average conditions of calving area suggestive of spatial memory in a highly migratory ungulate. Frontiers in Ecology and Evolution 8, 564567. Available from: https://www.frontiersin.org/journals/ecology-and-evolution/articles/10.3389/fevo.2020.564567/full.

Canadian Press. 2020. George River caribou herd shows first population gain in over 25 years. Canadian Broadcasting Corporation (CBC). Article posted 2020-10-16. Available from: https://www.cbc.ca/news/canada/newfoundland-labrador/george-river-caribou-population-increases-first-time-25-years-1.5764824 (accessed 2024-04-25).

Carroll G. 2005. Unit 26A caribou management report. Pages 246-268 in C. Brown, editor. Caribou management report of survey and inventory activities 1 July 2002 – 30 June 2004. Alaska Department of Fish and Game, Juneau, AK, USA. Available from: https://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/mgt_rpts/ca05_int_nth.pdf.

Carroll GM, Parrett LS, George JC, Yokel DA. 2005. Calving distribution of the Teshekpuk Caribou Herd, 1994-2003. Rangifer 16, 27-35. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/1767.

Chen W, Leblanc SG, White HP, Prevost C, Milakovic B, Rock C, Sharam G, O'Keefe H, Corey L, Croft B, Gunn A, van der Wielen S, Football A, Tracz B, Pellissey JS, Boulanger J. 2017. Does dust from arctic mines affect caribou forage? Journal of Environmental Protection 8, 258-276. Available from: https://www.scirp.org/journal/paperinformation?paperid=74747.

Child KN. 1973. The reactions of barren-ground caribou (*Rangifer tarandus granti*) to simulated pipeline and pipeline crossing structures at Prudhoe Bay, Alaska. Alaska Cooperative Wildlife Research Unit, University of Alaska, Fairbanks, Alaska. Available from: https://scholarworks.alaska.edu/handle/11122/4046 (accessed 2024-05-20).

Collinder B. 1949. The Lapps. Princeton University Press, New York, NY, USA. Cited in: Skoog RO. 1968. Ecology of the caribou (*Rangifer tarandus granti*) in Alaska. Ph.D. Dissertation. Univ. California, Berkeley, CA. 699 pp.

COSEWIC. 2016. COSEWIC assessment and status report on the caribou (*Rangifer tarandus*), Barren-ground population in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Canada, 136 pp. Available from: https://www.registrelep-sararegistry.gc.ca/virtual_sara/files/cosewic/sr_Caribou%20Barren-ground_2016_e.pdf (accessed 2024-05-20).

COSEWIC. 2017. COSEWIC assessment and status report on the caribou (*Rangifer tarandus*), Eastern Migratory population and Torngat Mountains population in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Canada, 85 pp. Available from: https://publications.gc.ca/collections/collection_2018/eccc/CW69-14-754-2017-eng.pdf (accessed 2024-08-16).

Crête M, Huot J. 1993. Regulation of a large herd of migratory caribou: summer nutrition affects calf growth and body reserves of dams. Canadian Journal of Zoology 71, 2291-2296. Available from: https://cdnsciencepub.com/doi/10.1139/z93-321.

Culler LE, Ayres MP, Virginia RA. 2015. In a warmer Arctic, mosquitoes avoid increased mortality from predators by growing faster. Proceedings of the Royal Society B 282, 20151549. Available from: https://royalsocietypublishing.org/doi/10.1098/rspb.2015.1549.

Cunsolo A, Borish D, Harper SL, Snook J, Shiwak I, Wood M, the HERD Caribou Project Steering Committee. 2020. "You can never replace the caribou": Inuit experiences of ecological grief from caribou declines. American Imago 77, 31–59. Available from: https://muse.jhu.edu/article/753060.

Dabros A, Pyper M, Castilla G. 2018. Seismic lines in the boreal and arctic ecosystems of North America: environmental impacts, challenges, and opportunities. Environmental Reviews 26, 214-229. Available from: https://cdnsciencepub.com/doi/10.1139/er-2017-0080.

Dale BW, Adams LG, Bowyer RT. 1994. Functional response of wolves preying on barren-ground caribou in a multiple-prey ecosystem. Journal of Animal Ecology 63:644–652. Available from: https://www.jstor.org/stable/5230?origin=crossref.

Dau J. 2011. Units 21D, 22A, 22B, 22C, 22D, 22E, 23, 24, and 26A caribou management report. In: Harper P, editor. Caribou management report of survey and inventory activities 1 July 2008–30 June 2010. Juneau: Alaska Department of Fish and Game. p.187–250. Available from: https://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/mgt_rpts/11_caribou.pdf

Dau J. 2015. Units 21D, 22A, 22B, 22C, 22D, 22E, 23, 24 and 26A. Chapter 14, pages 14-1 through 14-89 *In* Harper P, McCarthy LA, editors. Caribou management report of survey and inventory activities 1 July 2012–30 June 2014. Alaska Department of Fish and Game, Species Management Report ADF&G/DWC/SMR-2015-4, Juneau. Available from: https://www.adfg.alaska.gov/static/research/wildlife/speciesmanagementreports/pdfs/caribou_2015_smr_full_report.pdf.

Dau JR, Cameron RD. 1986. Effects of a road system on caribou distribution during calving. Rangifer 1, 95-101. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/588.

DeMars CA, Boutin S. 2018. Nowhere to hide: Effects of linear features on predator-prey dynamics in a large mammal system. Journal of Animal Ecology 87, 274-284. Available from: https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2656.12760.

Dickie M, Serrouya R, McNay RS, Boutin S. 2017. Faster and farther: wolf movement on linear features and implications for hunting behaviour. Journal of Applied Ecology 54, 253-263. Available from: https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2664.12732.

Dickie M, Serrouya R, Becker M, DeMars C, Noonan MJ, Steenweg R, Boutin S, Ford AT. 2024. Habitat alteration or climate: what drives the densities of an invading ungulate? Global Change Biology 30, e17286. Available from: https://onlinelibrary.wiley.com/doi/10.1111/gcb.17286.

Dingle H, Drake VA. 2007. What is migration? BioScience 57, 113–121. Available from: https://academic.oup.com/bioscience/article/57/2/113/228325.

Dyer SJ, O'Neill JP, Wasel SM, Boutin S. 2002. Quantifying barrier effects of roads and seismic lines on movements of female woodland caribou in northeastern Alberta. Canadian Journal of Zoology 80, 839-845. Available from: https://cdnsciencepub.com/doi/10.1139/z02-060.

ECC. n.d. Barren-ground Caribou: Bathurst Herd. Environment and Climate Change Wildlife Division, Government of Northwest Territories, Canada. Available from: https://www.gov.nt.ca/ecc/en/services/barren-ground-caribou/bathurst-herd (accessed 2024-04-25).

ECCC. 2020. Amended Recovery Strategy for the Woodland Caribou (Rangifer tarandus caribou), Boreal Population, in Canada. Species at Risk Act Recovery Strategy Series. Environment and Climate Change Canada, Ottawa, Canada. Available from: https://wildlife-species.az.ec.gc.ca/species-risk-registry/virtual_sara/files//plans/Rs-CaribouBorealeAmdMod-v01-2020Dec-Eng.pdf (accessed 2024-05-06).

Fagan WF, Holmes EE. 2006. Quantifying the extinction vortex. Ecology Letters 9, 51-60. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2005.00845.x.

Fall JA. 2018. Subsistence in Alaska: A Year 2017 Update. Division of Subsistence, Alaska Department of Fish and Game. Anchorage, AK, USA. Available from: https://www.adfg.alaska.gov/static/home/subsistence/pdfs/subsistence_update_2017.pdf.

Fancy SG. 1986. Daily energy budgets of caribou: a simulation approach. PhD Thesis, University of Alaska, Fairbanks. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/565.

Fancy SG, White RG. 1987. Energy expenditures for locomotion by barren-ground caribou. Canadian Journal of Zoology 65, 122-128. Available from: https://cdnsciencepub.com/doi/10.1139/z87-018.

Fancy SG, Pank LF, Whitten KR, Regelin WL. 1989. Seasonal movements of caribou in arctic Alaska as determined by satellite. Canadian Journal of Zoology 67, 644-650. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/850.

Fauchald P, Park T, Tømmervik H, Myneni R, Hausner VH. 2017. Arctic greening from warming promotes declines in caribou populations. Science Advances 3, e1601365. Available from: https://www.science.org/doi/10.1126/sciadv.1601365.

Ferguson MAD, Williamson RG, Messier F. 1998. Inuit knowledge of long-term changes in a population of Arctic tundra caribou. Arctic 51(3), 201-219. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/64118.

Festa-Bianchet M, Ray JC, Boutin S, Côté SD, Gunn A. 2011. Conservation of caribou (*Rangifer tarandus*) in Canada: an uncertain future. Canadian Journal of Zoology 89, 419–434. Available from: https://cdnsciencepub.com/doi/10.1139/z11-025.

FFA. 2022. Public Advisory: George River Caribou Population Remains at a Vulnerable Low. Department of Fisheries, Forestry and Agriculture, Government of Newfoundland and Labrador, Canada. Press release posted 2022-11-23. Available from: https://www.gov.nl.ca/releases/2022/ffa/1123n06/ (accessed 2024-04-25).

Forbes BC, Kumpula T, Meschtyb N, Laptander R, Macias-Fauria M, Zetterberg P, Verdonen M, Skarin A, Kim K-Y, Boisvert LN, Stroeve JC, Bartsch A. 2016. Sea ice, rain-on-snow and tundra reindeer nomadism in Arctic Russia. Biology Letters 12, 20160466. https://royalsocietypublishing.org/doi/10.1098/rsbl.2016.0466.

Fullman TJ, Joly K, Ackerman A. 2017. Effects of environmental features and sport hunting on caribou migration in northwestern Alaska. Movement Ecology 5, 4. Available from: https://movementecologyjournal.biomedcentral.com/articles/10.1186/s40462-017-0095-z.

Fullman TJ, Person BT, Prichard AK, Parrett LS. 2021a. Variation in winter site fidelity within and among individuals influences movement behavior in a partially migratory ungulate. PLoS ONE 16(9), e0258128. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0258128.

Fullman TJ, Sullender BK, Cameron MD, Joly K. 2021b. Simulation modeling accounts for uncertainty while quantifying ecological effects of development alternatives. Ecosphere 12(5), e03530. Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1002/ecs2.3530.

Fullman TJ, Wilson RR, Joly K, Gustine DD, Leonard P, Loya WM. 2021c. Mapping potential effects of proposed roads on migratory connectivity for a highly mobile herbivore using circuit theory. Ecological Applications 31(1), e02207. Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1002/eap.2207.

Gaillard J-M, Festa-Bianchet M, Yoccoz NG, Loison A, Toïgo C. 2000. Temporal variation in fitness components and population dynamics of large herbivores. Annual Review of Ecology and Systematics 31, 367-393. Available from: https://www.annualreviews.org/content/journals/10.1146/annurev.ecolsys.31.1.367.

Garner GW, Reynolds PE (eds.). 1986. Arctic National Wildlife Refuge Coastal Plain Resource Assessment: Final report baseline study of the fish, wildlife, and their habitats. Section 1002C Alaska National Interest Lands Conservation Act. U.S. Fish and Wildlife Service, U.S. Department of the Interior, Anchorage, Alaska. Available from: https://www.arlis.org/docs/vol1/FWS/ANWRCPRA/Baseline/ANWR-CPRA-Baseline-Final-v2.pdf.

Georgette S, Loon H. 1988. The Noatak River: Fall Caribou Hunting and Airplane Use. Technical Paper No. 162. Alaska Department of Fish and Game, Division of Subsistence, Kotzebue, AK, USA. Available from: https://www.adfg.alaska.gov/techpap/tp162.pdf.

Golovnev AV. 2017. Challenges to Arctic nomadism: Yamal Nenets facing climate change era calamities. Arctic Anthropology 54(2), 40-51. Available from: https://aa.uwpress.org/content/54/2/40.

Griffith B, Douglas DC, Walsh NE, Young DD, McCabe TR, Russell DE, White RG, Cameron RD, Whitten KR. 2002. The Porcupine caribou herd. Pages 8-37 [*In*] Douglas DC, Reynolds PE, Rhode EB, editors. Arctic Refuge coastal plain terrestrial wildlife research summaries. U.S. Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR-2002-0001. Available from: https://pubs.usgs.gov/bsr/2002/0001/report.pdf.

Gunn A, Miller FL. 1986. Traditional behaviour and fidelity to caribou calving grounds by barren-ground caribou. Rangifer 1, 151-158. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/640.

Gunn A, Russell D. 2022. Update on the global status of wild reindeer and caribou. IUCN Deer Specialist Group (DSG) Newsletter 33, 14-29. Available from: https://www.deerspecialistgroup.org/article/1060/.

Gurarie E, Hebblewhite M, Joly K, Kelly A, Adamczewski J, Davidson SC, Davison T, Gunn A, Suitor MJ, Fagan WF, Boelman N. 2019. Tactical departures and strategic arrivals: divergent effects of climate and weather on caribou spring migrations. Ecosphere 10(12), e02971.Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1002/ecs2.2971.

Gustine D, Barboza P, Adams L, Griffith B, Cameron R, Whitten K. 2017. Advancing the match-mismatch framework for large herbivores in the Arctic: evaluating the evidence for a trophic mismatch in caribou. PLoS ONE 12, e0171807. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0171807.

Halas G. 2015. Caribou migration, subsistence hunting, and user group conflicts in northwest Alaska: a traditional knowledge perspective. MS Thesis. University of Alaska Fairbanks, Fairbanks, AK, USA. Available from: https://www.cclmportal.ca/resource/caribou-migration-subsistence-hunting-and-user-group-conflicts-northwest-alaska.

Hansen A. 2023. WAH Caribou Overview. Alaska Department of Fish and Game. Presentation to the Western Arctic Caribou Herd Working Group, 2023-12-13. Available from: https://westernarcticcaribou.net/wp-content/uploads/2023/12/00-2023-WACH-Binder.r.pdf (accessed 2024-04-25).
Hansen BB, Aanes R. 2015. Habituation to humans in a predator-free wild ungulate. Polar Biology 38, 145-151. Available from: https://link.springer.com/article/10.1007/s00300-014-1572-0.
Hansen BB, Aanes R, Herfindal I, Kohler J, Sæther B-E. 2011. Climate, icing, and wild arctic reindeer: past relationships and future prospects. Ecology 92, 1917-1923. Available from: https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/11-0095.1.
Hansen BB, Grøtan V, Aanes R, Sæther B-E, Stien A, Fuglei E, Ims RA, Yoccoz NG, Pedersen ÅØ. 2013. Climate events synchronize the dynamics of a resident vertebrate community in the High Arctic. Science 339, 313-315. Available from: https://www.science.org/doi/10.1126/science.1226766.
Hansen BB, Isaksen K, Benestad RE, Kohler J, Pedersen ÅØ, Loe LE, Coulson SJ, Larsen JO, Varpe Ø. 2014. Warmer and wetter winters: characteristics and implications of an extreme weather event in the High Arctic. Environmental Research Letters 9, 114021. https://iopscience.iop.org/article/10.1088/1748-9326/9/11/114021.
Harper P, McCarthy LA, editors. 2015. Caribou management report of survey and inventory activities 1 July 2012–30 June 2014. Alaska Department of Fish and Game, Species Management Report ADF&G/DWC/SMR-2015-4, Juneau. Available from: https://www.adfg.alaska.gov/static/research/wildlife/speciesmanagementreports/pdfs/caribou_2015_smr_full_report.pdf.
Haskell SP, Ballard WB. 2008. Annual re-habituation of calving caribou to oilfields in northern Alaska: implications for expanding development. Canadian Journal of Zoology 86, 627-637. Available from: https://cdnsciencepub.com/doi/10.1139/Z08-039.
Haskell SP, Nielson RM, Ballard WB, Cronin MA, McDonald TL. 2006. Dynamic responses of calving caribou to oilfields in northern Alaska. Arctic 59, 179-190. https://journalhosting.ucalgary.ca/index.php/arctic/article/view/63402.
Hasselbach L, Ver Hoef JM, Ford J, Neitlich P, Crecelius E, Berryman S, Wolk B, Bohle T. 2005. Spatial patterns of cadmium and lead deposition on and adjacent to National Park Service lands in the vicinity of Red Dog Mine, Alaska. Science of the Total Environment 348, 211-230. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0048969705000082?via%3Dihub.

Heard DC, Williams TM, Melton DA. 1996. The relationship between food intake and predation risk in migratory caribou and implications to caribou and wolf population dynamics. Rangifer 9, 37-44. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/1219.

Hebblewhite M. 2017. Billion dollar boreal woodland caribou and the biodiversity impacts of the global oil and gas industry. Biological Conservation 206, 102-111. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0006320716310308.

Heggenes J, Odland A, Bjerketvedt DK. 2018. Are trampling effects by wild tundra reindeer understudied? Rangifer 38:1–12. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/4121.

Hervieux D, Hebblewhite M, DeCesare NJ, Russell M, Smith K, Robertson S, Boutin S. 2013. Widespread declines in woodland caribou (*Rangifer tarandus caribou*) continue in Alberta. Canadian Journal of Zoology 91, 872-882. Available from: https://cdnsciencepub.com/doi/10.1139/cjz-2013-0123.

Hobbs NT. 1989. Linking energy balance to survival in mule deer: development and test of a simulation model. Wildlife Monographs 101, 1-39. Available from: https://www.jstor.org/stable/3830599.

IPCB. 1993. Sensitive Habitats of the Porcupine Caribou Herd. International Porcupine Caribou Board. Available from: https://pcmb.ca/wp-content/uploads/2020/06/Sensitive-Habitats-of-the-Porcupine-Caribou-Herd-booklet-1.pdf (accessed 2024-05-22).

IPCC [Intergovernmental Panel on Climate Change]. 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Eds. Stocker TF, Qin D, Plattner D-G, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM. Cambridge University Press, Cambridge, UK and New York, NY, USA. Available from: https://www.ipcc.ch/report/ar5/wg1/.

Johnson CJ, Russell DE. 2014. Long-term distribution responses of a migratory caribou herd to human disturbance. Biological Conservation 177, 52-63. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0006320714002341.

Johnson HE, Golden TS, Adams LG, Gustine DD, Lenart EA. 2020. Caribou use of habitat near energy development in Arctic Alaska. The Journal of Wildlife Management 84(3), 401-412. Available from: https://wildlife.onlinelibrary.wiley.com/doi/10.1002/jwmg.21809.

Johnson HE, Lenart EA, Gustine DD, Adams LG, Barboza PS. 2022. Survival and reproduction in Arctic caribou are associated with summer forage and insect harassment. Frontiers in Ecology and Evolution 10, 899585. Available from: https://www.frontiersin.org/journals/ecology-and-evolution/articles/10.3389/fevo.2022.899585/full.

Joly K, Cameron MD. 2023. Caribou vital sign annual report for the Arctic Network Inventory and Monitoring Program: September 2022–August 2023. Natural Resource Report NPS/ARCN/NRR—2023/2612. National Park Service, Fort Collins, Colorado.

Joly K, Nellemann C, Vistnes I. 2006. A reevaluation of caribou distribution near an oilfield road on Alaska's North Slope. Wildlife Society Bulletin 34(3), 866-869. Available from: https://onlinelibrary.wiley.com/doi/abs/10.2193/0091-7648%282006%2934%5B866%3AAROCDN%5D2.0.CO%3B2.

Joly K, Klein DR, Verbyla DL, Rupp TS, Chapin III FS. 2011. Linkages between large-scale climate patterns and the dynamics of Arctic caribou populations. Ecography 34, 345-352. Available from: https://nsojournals.onlinelibrary.wiley.com/doi/epdf/10.1111/j.1600-0587.2010.06377.x.

Joly K, Duffy PA, Rupp TS. 2012. Simulating the effects of climate change on fire regimes in Arctic biomes: implications for caribou and moose habitat. Ecosphere 3(5), 36. Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1890/ES12-00012.1.

Joly K, Gurarie E, Sorum MS, Kaczensky P, Cameron MD, Jakes AF, Borg BL, Nandintsetseg D, Hopcraft JGC, Buuveibaatar B, Jones PF, Mueller T, Walzer C, Olson KA, Paynce JC, Yadamsuren A, Hebblewhite M. 2019. Longest terrestrial migrations and movements around the world. Scientific Reports 9, 15333. Available from: https://www.nature.com/articles/s41598-019-51884-5.

Joly K, Couriot O, Cameron MD, Gurarie E. 2020. Behavioral, physiological, demographic and ecological impacts of hematophagous and endoparasitic insects on an arctic ungulate. Toxins 12, 334. Available from: https://www.mdpi.com/2072-6651/12/5/334.

Joly K, Gunn A, Côté SD, Panzacchi M, Adamczewski J, Suitor MJ, Gurarie E. 2021a. Caribou and reindeer migrations in the changing Arctic. Animal Migration 8, 156-167. Available from: https://www.degruyter.com/document/doi/10.1515/ami-2020-0110/html.

Joly K, Gurarie E, Hansen DA, Cameron MD. 2021b. Seasonal patterns of spatial fidelity and temporal consistency in the distribution and movements of a migratory ungulate. Ecology and Evolution 11, 8183-8200. Available from: https://onlinelibrary.wiley.com/doi/10.1002/ece3.7650.

Jones BM, Hinkel KM, Arp CD, Eisner WR. 2008. Modern erosion rates and loss of coastal features and sites, Beaufort Sea coastline, Alaska. Arctic 61(4), 361-372. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/63112.

Jugo S. 1977. Metabolism of toxic heavy metals in growing organisms: A review. Environmental Research 13(1), 36-46. https://www.sciencedirect.com/science/article/abs/pii/0013935177900020.

Kafle P, Peacock SJ, Grond S, Orsel K, Kutz S. 2018. Temperature-dependent development and freezing survival of protostrongylid nematodes of Arctic ungulates: implications for transmission. Parasites & Vectors 11, 400. Available from: https://parasitesandvectors.biomedcentral.com/articles/10.1186/s13071-018-2946-x.

Kock RA, Orynbayev M, Robinson S, Zuther S, Singh NJ, Beauvais W, Morgan ER, Kerimbayev A, Khomenko S, Martineau HM, Rystaeva R, Omarova Z, Wolfs S, Hawotte F, Radoux J, Milner-Gulland EJ. 2018. Saigas on the brink: Multidisciplinary analysis of the factors influencing mass mortality events. Science Advances 4, eaao2314. Available from: https://www.science.org/doi/10.1126/sciadv.aao2314.

Kolpashchikov LA, Bondar MG, Mikhailov VV. 2019. Contemporary history of the Taimyr population of wild reindeer: patterns, management, threats and conservation options. Proceedings of the Karelian Research Centre of the Russian Academy of Sciences 11, 5. Available from: http://journals.krc.karelia.ru/index.php/ecology/article/view/1045.

Kostial K, Kello D, Jugo S, Rabar I, Maljković T. 1978. Influence of age on metal metabolism and toxicity. Environmental Health Perspectives 25, 81-86. https://ehp.niehs.nih.gov/doi/10.1289/ehp.782581.

Lambden J, Receveur O, Kuhnlein HV. 2007. Traditional food attributes must be included in studies of food security in the Canadian Arctic. International Journal of Circumpolar Health 66:308–319. Available from: https://www.tandfonline.com/doi/abs/10.3402/ijch.v66i4.18272.

Latham ADM, Latham MC, Boyce MS, Boutin S. 2011. Movement responses by wolves to industrial linear features and their effect on woodland caribou in northeastern Alberta. Ecological Applications 21(8), 2854-2865. Available from: https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/11-0666.1.

Le Corre M, Dussault C, Côté SD. 2017. Weather conditions and variation in timing of spring and fall migrations of migratory caribou. Journal of Mammalogy 98(1), 260-271. Available from: https://academic.oup.com/jmammal/article/98/1/260/2454646?login=false.

Leblond M, St-Laurent M-H, Côté SD. 2016. Caribou, water, and ice – fine-scale movements of a migratory arctic ungulate in the context of climate change. Movement Ecology 4, 14. Available from: https://movementecologyjournal.biomedcentral.com/articles/10.1186/s40462-016-0079-4.

Lenart EA. 2015. Units 26B and 26C caribou. Chapter 18, pages 18–1 through 18–38 [*In*] Harper P, McCarthy LA, editors. Caribou management report of survey and inventory activities 1 July 2012–30 June 2014. Alaska Department of Fish and Game, Species Management Report ADF&G/DWC/SMR-2015-4, Juneau. Available from: https://www.adfg.alaska.gov/static/research/wildlife/speciesmanagementreports/pdfs/caribou_2015_chapter_18_central.pdf.

Lenart E. 2021. Central Arctic caribou management report and plan, Game Management Unit 26B: Report period 1 July 2012 – 30 June 2017, and plan period 1 July 2017 – 30 June 2022. Alaska Department of Fish and Game, Species Management Report and Plan ADF&G/DWC/SMR&P-2021-2, Juneau, AK, USA. Available from: https://catalog.northslopescience.org/dataset/535.

Lent PC. 1964. Calving and related social behavior in the barren-ground caribou. PhD Thesis, Department of Zoology, University of Alberta, Edmonton, Alberta, Canada. Available from: https://archive.org/details/calvingrelatedso00pete/page/n5/mode/1up.

Magoun AJ, Laird CR, Keech MA, Valkenburg P, Parrett LS, Robards MD. 2018. Predation on caribou (*Rangifer tarandus*) by wolverines (*Gulo gulo*) after long pursuits. The Canadian Field-Naturalist 132(4). Available from: https://www.canadianfieldnaturalist.ca/index.php/cfn/article/view/2050.

Mahoney SP, Lewis KP, Weir JN, Morrison SF, Luther JG, Schaefer JA, Pouliot D, Latifovic R. 2016. Woodland caribou calf mortality in Newfoundland: insights into the role of climate, predation and population density over three decades of study. Population Ecology 58, 91-103. Available from: https://esj-journals.onlinelibrary.wiley.com/doi/10.1007/s10144-015-0525-y.

Mallory CD, Boyce MS. 2018. Observed and predicted effects of climate change on Arctic caribou and reindeer. Environmental Reviews 26, 13–25. Available from: https://cdnsciencepub.com/doi/full/10.1139/er-2017-0032.

Mallory CD, Campbell MW, Boyce MS. 2018. Climate influences body condition and synchrony of barren-ground caribou abundance in northern Canada. Polar Biology 41, 855-864. Available from: https://link.springer.com/article/10.1007/s00300-017-2248-3.

Mars JC, Houseknecht DW. 2007. Quantitative remote sensing study indicates doubling of coastal erosion rate in past 50 yr along a segment of the Arctic coast of Alaska. Geology 35(7), 583-586. Available from: https://pubs.geoscienceworld.org/gsa/geology/article-abstract/35/7/583/129876/Quantitative-remote-sensing-study-indicates?redirectedFrom=fulltext.

Martin S. 2015. Indigenous social and economic adaptations in northern Alaska as measures of resilience. Ecology and Society 20, 8. Available from: https://www.ecologyandsociety.org/vol20/iss4/art8/.

MCHIMG. 2022. Notice: RC503 Mulchatna caribou hunting remains closed. Mulchatna Caribou Herd Interagency Management Group. Available from: https://www.adfg.alaska.gov/static/hunting/caribouhunting/pdfs/RC503_closed_postcard_2022.pdf (accessed 2024-04-25).

McKenzie HW, Merrill EH, Spiteri RJ, Lewis MA. 2012. How linear features alter predator movement and the functional response. Interface Focus, 2(2), 205–216. Available from: https://royalsocietypublishing.org/doi/10.1098/rsfs.2011.0086.

McLoughlin PD, Dzus E, Wynes BOB, Boutin S. 2003. Declines in populations of woodland caribou. Journal of Wildlife Management 67(4), 755–761. Available from: https://www.jstor.org/stable/3802682?origin=crossref.

Merkle JA, Monteith KL, Aikens EO, Hayes MM, Hersey KR, Middleton AD, Oates BA, Sawyer H, Scurlock BM, Kauffman MJ. 2016. Large herbivores surf waves of green-up during spring. Proceedings of the Royal Society B 283, 20160456. Available from: https://royalsocietypublishing.org/doi/10.1098/rspb.2016.0456.

Moskovitz D. 2019. The contiguous United States just lost its last wild caribou. Science Magazine news article. Available from: https://www.sciencemag.org/news/2019/01/contiguous-united-states-just-lost-its-last-wild-caribou (accessed 2024-05-22).

Mowat G, Heard DC. 2006. Major components of grizzly bear diet across North America. Canadian Journal of Zoology 84, 473–489. Available from: https://cdnsciencepub.com/doi/10.1139/z06-016.

Myers-Smith IH, Arnesen BK, Thompson RM, Chapin III, FS. 2006. Cumulative impacts on Alaskan arctic tundra of a quarter century of road dust. Ecoscience 13(4), 503-510. Available from: https://bioone.org/journals/ecoscience/volume-13/issue-4/1195-6860(2006)13%5b503%3aCIOAAT%5d2.0.CO%3b2/Cumulative-impacts-on-Alaskan-arctic-tundra-of-a-quarter-century/10.2980/1195-6860(2006)13[503:CIOAAT]2.0.CO;2.short.

Naiden A. 2024. State adopts reduced subsistence hunting limits for Western Arctic caribou of 15 animals a year. Anchorage Daily News, 2024-02-01. Available from: https://www.adn.com/alaska-news/wildlife/2024/02/01/state-adopts-reduced-subsistence-hunting-limit-for-western-arctic-caribou-of-15-animals-a-year/ (accessed 2024-04-25).

Neitlich PN, Berryman S, Geiser LH, Mines A, Shiel AE. 2022. Impacts on tundra vegetation from heavy metal-enriched fugitive dust on National Park Service lands along the Red Dog Mine haul road, Alaska. PLoS ONE 17(6), e0269801. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0269801.

Nellemann C, Cameron RD. 1996. Effects of petroleum development on terrain preferences of calving caribou. Arctic 49(1), 23-28. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/64235.

Nellemann C, Cameron RD. 1998. Cumulative impacts of an evolving oil-field complex on the distribution of calving caribou. Canadian Journal of Zoology 76, 1425-1430. https://cdnsciencepub.com/doi/10.1139/z98-078.

Nellemann C, Vistnes I, Jordhøy P, Støen O-G, Kaltenborn BP, Hanssen F, Helgesen R. 2010. Effects of recreational cabins, trails and their removal for restoration of reindeer winter ranges. Restoration Ecology 18(6), 873-881. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1526-100X.2009.00517.x.

Nicholson KL, Arthur SM, Horne JS, Garton EO, Del Vecchio PA. 2016. Modeling caribou movements: Seasonal ranges and migration routes of the Central Arctic Herd. PLoS One 11(4), e0150333. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0150333.

Noel LE, Parker KR, Cronin MA. 2004. Caribou distribution near an oilfield road on Alaska's North Slope, 1978-2001. Wildlife Society Bulletin 32(3), 757-771. Available from: https://wildlife.onlinelibrary.wiley.com/doi/abs/10.2193/0091-7648(2004)032[0757:CDNAOR]2.0.CO;2.

Northrup JM, Anderson Jr. CR, Wittemyer G. 2015. Quantifying spatial habitat loss from hydrocarbon development through assessing habitat selection patterns of mule deer. Global Change Biology 21(11), 3961-3970. Available from: https://onlinelibrary.wiley.com/doi/10.1111/gcb.13037.

NRC [National Research Council]. 2003. Cumulative environmental effects of oil and gas activities on Alaska's North Slope. National Academies Press, Washington D.C., USA. Available from: https://nap.nationalacademies.org/catalog/10639/cumulative-environmental-effects-of-oil-and-gas-activities-on-alaskas-north-slope.

Panzacchi M, Van Moorter B, Strand O. 2013. A road in the middle of one of the last wild reindeer migration routes in Norway: crossing behaviour and threats to conservation. Rangifer 33(21), 15-26. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/2521.

Parker KL, Barboza PS, Gillingham MP. 2009. Nutrition integrates environmental responses of ungulates. Functional Ecology 23, 57-69. Available from: https://besjournals.onlinelibrary.wiley.com/doi/10.1111/j.1365-2435.2009.01528.x.

Parrett LS. 2021. Teshekpuk caribou herd management report and plan, Game Management Units 23, 24, and 26: Report period 1 July 2012 – 30 June 2017, and plan period 1 July 2017 – 30 June 2022. Alaska Department of Fish and Game, Species Management Report and Plan ADF&G/DWC/SMR&P-2021-43, Juneau, AK, USA. Available from: http://www.adfg.alaska.gov/static/research/wildlife/speciesmanagementreports/pdfs/caribou_2012_2022_gmu_26_a_teshekpuk.pdf.

Person BT, Prichard AK, Carroll GM, Yokel DA, Suydam RS, George JC. 2007. Distribution and movements of the Teshekpuk Caribou Herd 1990-2005: Prior to oil and gas development. Arctic 60, 238-250. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/63278.

Plante S, Dussault C, Richard JH, Côté SD. 2018. Human disturbance effects and cumulative habitat loss in endangered migratory caribou. Biological Conservation 224, 129-143. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0006320718300442?via%3Dihub.

Pimm SL, Jones HL, Diamond J. 1988. On the risk of extinction. The American Naturalist 132(6), 757-785. Available from: https://www.journals.uchicago.edu/doi/10.1086/284889.

Pollard RH, Ballard WB, Noel LE, Cronin MA. 1996. Summer distribution of caribou, *Rangifer tarandus granti*, in the area of the Prudhoe Bay Oil Field, Alaska, 1990-1994. The Canadian Field-Naturalist 110, 659-674. Available from: https://www.biodiversitylibrary.org/part/357545.

Prichard AK, Yokel DA, Rea CL, Person BT, Parrett LS. 2014. The effect of frequency of telemetry locations on movement-rate calculations in arctic caribou. Wildlife Society Bulletin 38, 78-88. Available from: https://wildlife.onlinelibrary.wiley.com/doi/abs/10.1002/wsb.357.

Prichard AK, Klimstra RL, Person BT, Parrett LS. 2019 Aerial survey and telemetry data analysis of a peripheral caribou calving area in northwestern Alaska. Rangifer 39(1), 43-58. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/4572.

Prichard AK, Lawhead BE, Lenart EA, Welch JH. 2020. Caribou distribution and movements in a northern Alaska oilfield. Journal of Wildlife Management 84, 1483-1499. Available from: https://wildlife.onlinelibrary.wiley.com/doi/full/10.1002/jwmg.21932.

Prichard AK, Welch JH, Lawhead BE. 2022. The effect of traffic levels on the distribution and behavior of calving caribou in an arctic oilfield. Arctic 75(1), 1-19. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/74609.

Purvis A, Gittleman JL, Cowlishaw G, Mace GM. 2000. Predicting extinction risk in declining species. Proceedings of the Royal Society of London, Series B, Biological Sciences 267, 1947-1952. Available from: https://royalsocietypublishing.org/doi/10.1098/rspb.2000.1234.

Raynolds MK, Walker DA, Ambrosius KJ, Brown J, Everett KR, Kanevskiy M, Kofinas GP, Romanovsky VE, Shur Y, Webber PJ. 2014. Cumulative geoecological effects of 62 years of infrastructure and climate change in ice-rich permafrost landscapes, Prudhoe Bay Oilfield, Alaska. Global Change Biology 20(4), 1211-1224. Available form: https://onlinelibrary.wiley.com/doi/10.1111/gcb.12500.

Reimers E, Colman JE, Dervo L, Eftestol S, Kind J, Muniz A. 2000. [in Norwegian], cited in Reimers E, Loe LE, Eftestøl S, Colman JE, Dahle B. 2009. Effects of hunting on response behaviors of wild reindeer. Journal of Wildlife Management 73(6), 844-851. Available from: https://wildlife.onlinelibrary.wiley.com/doi/10.2193/2008-133.

Reynolds III HV, Garner GW. 1987. Patterns of Grizzly Bear Predation on Caribou in Northern Alaska. International Conference on Bear Research and Management 7, 59-67. Available from: https://www.jstor.org/stable/3872608?origin=crossref.

Robbins F, Hatcher H. 2015. Unit 13 and 14B, Nelchina Caribou Herd. Chapter 9, p.9-1 through 9-20 in Harper P, McCarthy LA, eds. Caribou management report of survey and inventory activities 1 July 2012 – 30 June 2014. Alaska Department of Fish and Game, Species Management Report ADF&G/DWC/SMR-2015-4, Juneau, AK, USA. Available from: https://www.adfg.alaska.gov/static/research/wildlife/speciesmanagementreports/pdfs/caribou_2015_smr_full_report.pdf.

Russell D, Gunn A. 2019. Vulnerability analysis of the Porcupine Caribou Herd to potential development of the 1002 lands in the Arctic National Wildlife Refuge, Alaska. Report prepared for: Environment Yukon, Canadian Wildlife Service, and NWT Environment and Natural Resources. 143 pp. Available from: https://pcmb.ca/wp-content/uploads/2021/10/Russell-and-Gunn-PCH-vulnerability-analysis-2019.pdf.

Russell DE, McNeil P. 2005. Summer ecology of the Porcupine Caribou Herd. Report published by the Porcupine Caribou Management Board, 2nd edition, March 2005. Available from: https://pcmb.ca/wp-content/uploads/2020/06/PCH-Summer-Ecology-2005.pdf.

Russell DE, Martell AM, Nixon WAC. 1993. Range ecology of the Porcupine Caribou Herd in Canada. Rangifer 13(8), 1-168. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/1057.

Russell DE, Gunn A, White RG. 2015. CircumArctic collaboration to monitor caribou and wild reindeer. Arctic 61, 6-10. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/67538.

Russell DE, Gunn A, Kutz S. 2018: Migratory Tundra Caribou and Wild Reindeer. In: Arctic Report Card 2018, p.67-73. Available from: https://arctic.noaa.gov/wp-content/uploads/2023/04/ArcticReportCard_full_report2018.pdf (accessed 2024-06-10).

Russell D, Gunn A, White R. 2021. A decision support tool for assessing cumulative effects on an Arctic migratory tundra caribou population. Ecology and Society 26(1), 4. Available from: https://www.ecologyandsociety.org/vol26/iss1/art4/.

Savchenko AP, Soukhovolsky VG, Savchenko PA, Muravyov AN, Dubintsov SA, Karpova NV, Tarasova OV. 2020. The current state of Taimyr reindeer (Taimyr-Evenk population) and the probable reasons for its reduction. IOP Conference Series: Earth and Environmental Science 421, 052004. Available from: https://iopscience.iop.org/article/10.1088/1755-1315/421/5/052004.

Sawyer H, Korfanta NM, Nielson RM, Monteith KL, Strickland D. 2017. Mule deer and energy development – Long-term trends of habituation and abundance. Global Change Biology 23, 4521-4529. Available from: https://onlinelibrary.wiley.com/doi/10.1111/gcb.13711.

Schaefer JA. 2003. Long-term range recession and the persistence of caribou in the taiga. Conservation Biology 17(5), 1435-1439. Available from: https://conbio.onlinelibrary.wiley.com/doi/10.1046/j.1523-1739.2003.02288.x.

Serrouya R, McLellan BN, van Oort H, Mowat G, Boutin S. 2017. Experimental moose reduction lowers wolf density and stops decline of endangered caribou. Peer J 5, e3736. Available from: https://peerj.com/articles/3736/.

Severson JP, Johnson HE, Arthur SM, Leacock WB, Suitor MJ. 2021. Spring phenology drives range shifts in a migratory Arctic ungulate with key implications for the future. Global Change Biology 27, 4546-4563. Available from: https://onlinelibrary.wiley.com/doi/10.1111/gcb.15682.

Severson JP, Vosburgh TC, Johnson HE. 2023. Effects of vehicle traffic on space use and road crossings of caribou in the Arctic. Ecological Applications 33(8), e2923. Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1002/eap.2923.

Skoog RO. 1968. Ecology of the caribou (*Rangifer tarandus granti*) in Alaska. Ph.D. Dissertation. Univ. California, Berkeley, CA. 699 pp. https://www.adfg.alaska.gov/index.cfm?adfg=librarypublications.wildlifepublicationsdetails&pubidentifier=3598.

Smith WT, Cameron RD. 1985. Reactions of large groups of caribou to a pipeline corridor on the arctic Coastal Plain of Alaska. Arctic 38(1), 53-57. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/65159.

Smith A, Johnson CJ. 2023. Why didn't the caribou (*Rangifer taradus groenlandicus*) cross the winter road? The effect of industrial traffic on the road-crossing decisions of caribou. Biodiversity and Conservation 8-9. Available from: https://link.springer.com/article/10.1007/s10531-023-02637-4.

Smith WT, Cameron RD, Reed DJ. 1994. Distribution and movements of caribou in relation to roads and pipelines, Kuparuk Development Area, 1978-90. Wildlife Technical Bulletin No. 12, Alaska Department of Fish and Game, Juneau, AK, USA. 54 pp. Available from: https://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/research_pdfs/smith_et_al_1994_adfg_tech_bull_12_distribution_and_movements_of_caribou_in_relation_to_roads.pdf.

Smith J, Saylor B, Easton P, Wiedman D, Elders from the Alaska Villages of Buckland and Deering. 2009. Measurable benefits of traditional food customs in the lives of rural and urban Alaska Iñupiaq elders. Alaska Journal of Anthropology 7, 89–99. Available from: http://www.alaskaanthropology.org/wp-content/uploads/2017/08/akanth-articles_275_v7_n1_Smith-Saylor-Easton-Wiedmen-Elders.pdf.

Smith A, Johnson CJ, Clark K. 2023. Behavioral and physiological stress responses of barren-ground caribou (*Rangifer taradus groenlandicus*) to industrial ice roads. Polar Biology 46, 1053-1067. Available from: https://link.springer.com/article/10.1007/s00300-023-03185-x.

Snyder-Conn E, Densmore D, Moitoret C, Stroebele J. 1990. Persistence of trace metals in shallow arctic marine sediments contaminated by drilling effluents. Oil and Chemical Pollution 7(3), 225-247. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0269857905800280?via%3Dihub.

Snyder-Conn E., Garbarino JR, Hoffman GL, Oelkers A. 1997. Soluble trace elements and total mercury in arctic Alaskan snow. Arctic 50(3), 201-215. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/64158.

Southwood A, Avens L. 2010. Physiological, behavioral, and ecological aspects of migration in reptiles. Journal of Comparative Physiology B: Biochemical, Systemic, and Environmental Physiology 180, 1–23. Available from: https://link.springer.com/article/10.1007/s00360-009-0415-8.

Stark S, Männistö MK, Eskelinen A. 2015. When do grazers accelerate or decelerate soil carbon and nitrogen cycling in tundra? A test of theory on grazing effects in fertile and infertile habitats. Oikos 124, 593–602. Available from: https://nsojournals.onlinelibrary.wiley.com/doi/10.1111/oik.01355.

Stinchcomb TR, Brinkman TJ, Fritz SA. 2019. A review of aircraft-subsistence harvester conflict in Arctic Alaska. Arctic 72(2), 131-150. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/68228.

Stinchcomb TR, Brinkman TJ, Betchkal D. 2020. Extensive aircraft activity impacts subsistence areas: acoustic evidence from Arctic Alaska. Environmental Research Letters 15, 115005. Available from: https://iopscience.iop.org/article/10.1088/1748-9326/abb7af.

Syroechkovski EE. 2000. Wild and semi-domesticated reindeer in Russia: status, population dynamics and trends under the present social and economic conditions. Rangifer 20(2-3), 113-126. Available from: https://septentrio.uit.no/index.php/rangifer/article/view/1507.

Taillon J, Festa-Bianchet M, Côté SD. 2012. Shifting targets in the tundra: protection of migratory caribou calving grounds must account for spatial changes over time. Biological Conservation 147, 163-173. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0006320711004903?via%3Dihub.

Taillon J, Barboza PS, Côté SD. 2013. Nitrogen allocation to offspring and milk production in a capital breeder. Ecology 94(8), 1815-1827. Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1890/12-1424.1.

Tape KD, Gustine DD, Ruess RW, Adams LG, Clark JA. 2016. Range expansion of moose in arctic Alaska linked to warming and increased shrub habitat. PLoS ONE 11, e0152636. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0152636.

Tews J, Ferguson MAD, Fahrig L. 2007. Potential net effects of climate change on High Arctic Peary caribou: lessons from a spatially explicit simulation model. Ecological Modelling 207, 85-98. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0304380007002359?via%3Dihub.

Trammell EJ, Carlson ML, Fresco N, Gotthardt T, McTeague ML, Vadapalli D, eds. 2015. *North Slope Rapid Ecoregional Assessment*. Prepared for the Bureau of Land Management, U.S. Department of the Interior. Anchorage, Alaska, USA. Available from: https://accscatalog.uaa.alaska.edu/sites/default/files/REA_NorthSlope_Report.pdf.

Trondrud LM, Ugland C, Ropstad E, Loe LE, Albon S, Stien A, Evans AL, Thorsby PM, Veiberg V, Irvine RJ, Pigeon G. 2022. Stress responses to repeated captures in a wild ungulate. Scientific Reports 12, 16289. Available from: https://www.nature.com/articles/s41598-022-20270-z.

Uboni A, Horstkotte T, Kaariejärvi E, Sévêque A, Stammler F, Olofsson J, Forbes BC, Moen J. 2016. Long-term trends and role of climate in the population dynamics of Eurasian reindeer. PLoS ONE 11, e0158359. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0158359.

USFWS [U.S. Fish and Wildlife Service]. 2015. Arctic National Wildlife Refuge Revised Comprehensive Conservation Plan, Final Environmental Impact Statement, Wilderness Review, Wild and Scenic River Review. U.S. Fish and Wildlife Service, Alaska. Available from: https://www.sciencebase.gov/catalog/item/5771b8aee4b07657d1a6cdae.

Veiberg V, Loe LE, Albon SD, Irvine RJ, Tveraa T, Ropstad E, Stien A. 2017. Maternal winter body mass and not spring phenology determine annual calf production in an Arctic herbivore. Oikos 126, 980-987. Available from: https://nsojournals.onlinelibrary.wiley.com/doi/10.1111/oik.03815.

Vistnes I, Nellemann C. 2008. A matter of spatial and temporal scales: a review of reindeer and caribou response to human activity. Polar Biology 31, 399-407. Available from: https://link.springer.com/article/10.1007/s00300-007-0377-9.

Vors LS, Boyce MS. 2009. Global declines of caribou and reindeer. Global Change Biology 15, 2626-2633. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2009.01974.x.

Vuillaume B, Richard JH, Hamel S, Taillon J, Festa-Bianchet M, Côté SD. 2023. Birth date determines early calf survival in migratory caribou. Oecologia 202, 819-830. Available from: https://link.springer.com/article/10.1007/s00442-023-05441-7.

WACHWG [Western Arctic Caribou Herd Working Group]. 2019. Western Arctic Caribou Herd Working Group comments on the draft Integrated Activity Plan/Environmental Impact Statement for the National Petroleum Reserve – Alaska. Submitted to the Bureau of Land Management on 2019-12-17. Available from: https://www.adfg.alaska.gov/static/research/plans/pdfs/wah_management_plan_final_2019.pdf.

Walker DA, Everett KR. 1987. Road dust and its environmental impact on Alaskan taiga and tundra. Arctic and Alpine Research 19(4), 479-489. Available at: https://www.resolutionmineeis.us/sites/default/files/references/walker-everett-1987.pdf.

West RL, Synder-Conn E. 1987. Effects of Prudhoe Bay reserve pit fluids on water quality and macroinvertebrates of Arctic tundra ponds in Alaska. Biological Report 87(7), U.S. Fish and Wildlife Service, Washington DC, USA. 48 pp. Available at: https://apps.dtic.mil/sti/tr/pdf/ADA323422.pdf.

Whitten KR, Cameron RD. 1983. Movements of collared caribou, *Rangifer tarandus*, in relation to petroleum development on the Arctic Slope of Alaska. Canadian Field-Naturalist 97(2), 143-146. Available from: https://www.biodiversitylibrary.org/page/28008841#page/157/mode/1up.

Whittington J, Hebblewhite M, DeCesare NJ, Neufeld L, Bradley M, Wilmshurst J, Musiani M. 2011. Caribou encounters with wolves increase near roads and trails: a time-to-event approach. Journal of Applied Ecology 48, 1535-1542. Available from: https://besjournals.onlinelibrary.wiley.com/doi/10.1111/j.1365-2664.2011.02043.x.

Wilson RR, Prichard AK, Parrett LS, Person BT, Carroll GM, Smith MA, Rea CL, Yokel DA. 2012. Summer Resource Selection and Identification of Important Habitat Prior to Industrial Development for the Teshekpuk Caribou Herd in Northern Alaska. PLOS One 7, e48697. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0048697.

Wilson RR, Liebezeit JR, Loya WM. 2013. Accounting for uncertainty in oil and gas development impacts to wildlife in Alaska. Conservation Letters 6, 350-358. Available from: https://conbio.onlinelibrary.wiley.com/doi/10.1111/conl.12016.

Wilson RR, Parrett LS, Joly K, Dau JR. 2016. Effects of roads on individual caribou movements during migration. Biological Conservation 195, 2-8. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0006320715302147?via%3Dihub.

Wolfe SA. 2000. Habitat selection by calving caribou of the Central Arctic Herd, 1980-95. M.S. Thesis, University of Alaska Fairbanks, Fairbanks, Alaska, USA. Available from: https://www.adfg.alaska.gov/index.cfm?adfg=librarypublications.wildlifepublicationsdetails&pubidentifier=6103.

Wolfe SA, Griffith B, Wolfe CAG. 2000. Response of reindeer and caribou to human activities. Polar Research 19, 63-73. Available from: https://polarresearch.net/index.php/polar/article/view/2186.

Woodward DF, Snyder-Conn E, Riley RG, Garland TR. 1988. Drilling fluids and the arctic tundra of Alaska: Assessing contamination of wetlands habitat and the toxicity to aquatic invertebrates and fish. Archives of Environmental Contamination and Toxicology 17(5), 683-697. Available from: https://link.springer.com/article/10.1007/BF01055838.

Zalatan R, Gunn A, Henry GHR. 2006. Long-term abundance patterns of barren-ground caribou using trampling scars on roots of *Picea mariana* in the Northwest Territories, Canada. Arctic, Antarctic, and Alpine Research 38(4), 624-630. Available from: https://www.tandfonline.com/doi/full/10.1657/1523-0430(2006)38[624:LAPOBC]2.0.CO;2.

Zhou J, Tape KD, Prugh L, Kofinas G, Carroll G, Kielland K. 2020. Enhanced shrub growth in the Arctic increases habitat connectivity for browsing herbivores. Global Change Biology 26(7), 3809-3820. Available from: https://onlinelibrary.wiley.com/doi/10.1111/gcb.15104.

3b: Arctic Fish and Subsistence Fisheries

Highlights:

- Whitefish species remain an important subsistence and cultural resource for Arctic Iñupiat communities surrounding the NPR-A.
- Critical habitats such as spawning and rearing areas are limited in the Arctic for certain important fish species such as Broad Whitefish.
- The Colville River Special Area in combination with adjoining watersheds provides abundant spawning and rearing habitat for Broad Whitefish in the Alaska Beaufort Sea region.
- Developing durable watershed protections that maintain a suite of Broad Whitefish spawning and rearing habitats is essential for the conservation of Arctic subsistence fish resources.

Overview of the importance of fish and fisheries for NPR-A coastal communities

Fish remain an important subsistence and cultural resource for Indigenous communities across the Arctic. Subsistence fishers catch a diversity of freshwater and anadromous fishes such as grayling, whitefish, salmon, char, smelt, and cod, but the abundance and species harvested vary by fishery (Craig 1989; Berkes 1990; Fall et al. 2017). These fisheries significantly contribute to food security in the Arctic by providing substantial and reliable food resources (Fall 2016; Lysenko and Schott 2019; Carothers et al. 2019) that can be obtained to compensate for harvest fluctuations of other resources like mammals and birds. Within many Arctic communities, wage employment opportunities are limited and store-bought food is prohibitively expensive due to the high transportation costs required to ship food to remote locations (Caulfield 2002). Subsistence fish provide an important protein-rich resource for Arctic communities. Additionally, subsistence fisheries also promote individual and community health through harvesting activities and shared work (Receveur et al. 1997; Kuhnlein et al. 2004; Bersamin et al. 2007), create cohesion within communities through extensive sharing and cooperative harvest (Kofinas et al. 2016), and facilitate the sharing of cultural values and skills (Inuit Circumpolar Council-Alaska 2015).

The majority of adults within Arctic communities currently participate in some type of fishery, and most subsistence harvest is shared among families and communities (Bacon et al. 2009; Brown et al. 2016; Kofinas et al. 2016). The annual mass of fish harvested by Arctic Alaska coastal communities is significant and communities such as Utqiaġvik and Nuiqsut (Table 3b.1) harvest more fish resources than others due to their proximity to large rivers used as migration corridors by anadromous fishes (Brown et al. 2016). Next to marine mammals and large land mammals, fish resources are the most utilized wild food resource for Arctic Coastal Plain communities (Brown et al. 2016). Harvest amounts can fluctuate annually due to environmental conditions and harvest effort by communities, but on certain years when the harvest of other species is lower, fish resources can make up a greater proportion of total wild food resources harvested.

Table 3b.1. Recent subsistence fish species harvest amounts by community from Alaska Department of Fish and Game, Community Subsistence Information System (CSIS).

	Community Subsistence Harvest (Estimated total kg)					
Fish Species	**Nuiqsut (2014)**	**Atqasuk (2018)**	**Utigavik (2014)**	**Point Lay (2012)**	**Wainwright (2009)**	
Anadromous species						**Total**
Broad Whitefish (*Coregonus nasus*)	16,603	6,086	63,799	0	440	86,928
Humpback Whitefish (*Coregonus pidschian*)	113	1,222	1,428	5	142	2,910
Arctic Cisco (*Coregonus autumnalis*)	14,693	0	5,558	88	27	20,366
Least Cisco (*Coregonus sardinella*)	4,223	0	4,246	0	985	9,454
Bering Cisco (*Coregonus laurettae*)	6	0	0	0	0	6
Round Whitefish (*Prosopium cylindraceum*)	6	0	207	0	36	249
Rainbow Smelt (*Osmerus mordax*)	414	0	612	0	9,285	10,311
Dolly Varden (*Salvelinus malma*)	610	42	274	737	181	1,844
Chum Salmon (*Oncorhynchus keta*)	1,590	1,074	11,025	1,698	212	15,599
Pink Salmon (*Oncorhynchus gorbuscha*)	119	23	1,631	1,371	44	3,188
Coho Salmon (*Oncorhynchus keta*)	26	595	3,869	817	265	5,572
Chinook Salmon (*Oncorhynchus keta*)	0	6	668	62	210	946
Sockeye salmon (Oncorhynchus nerka)	17	3	8,465	0	0	8,485
Freshwater species						
Lake Trout (*Salvelinus nanaycush*)	50	0	221	0	0	271
Arctic Grayling (*Thymallus arcticus*)	663	1,810	4,560	793	2,022	9,848
Burbot (*Lota lota*)	739	428	1,386	0	314	2,867
Arctic Char (*Salvelinus aplinus*)	359	0	320	0	0	679
Northern Pike (*Esox lucius*)	17	82	82	0	0	181
Total kg harvested	40,248	11,371	108,351	5,571	14,163	179,704

Data represents the most current data on ADFG CSIS (https://www.adfg.alaska.gov/sb/CSIS/), but might not be representative of every year of harvest. Nuiqsut = ADFG CSIS 2014 data, Atqasuk =ADFG CSIS 2018 data, Utigavik = ADFG CSIS 2014 data, Point Lay = ADFG CSIS 2012 data, Wainwright = ADFG CSIS 2009 data

Freshwater and anadromous fish are harvested by Arctic coastal communities at a suite of locations across the NPR-A. The majority of subsistence fishing occurs within close proximity of communities, but fishing also occurs at distant traditional fish camps. Indigenous fishers from Point Lay mainly harvest fish from the coastal water of Kasegaluk Lagoon, a portion of which is an NPR-A Special Area, and the Utukok, Kokolik, and Kukpowruk rivers (Craig 1989). Fishing by the community of Wainwright mainly occurs within nearshore marine water between Point Franklin and Icy Cape and within the Kuk and Kugrua rivers (Craig 1989). Utqiaġvik fishers mainly harvest fish in the lower sections of Inaru, Nigisaktuvik, Topagoruk, and Ikpikpuk rivers within 95 km of the community (Brown et al. 2016). Fishing sites along the Miguakiak River (a tributary of the Ikpikpuk River) are within the Teshekpuk Lake Special Area. Most fishing by Atqasuk fishers occurs on the Meade River, but distant fish camps are also located on the Usuktuk and Nigisakituvik rivers (Craig 1989). Nuiqsut fishers primarily harvest fish in the lower Colville River in the Niqliq Channel, Kupigruak Channel, and in the Colville River main channel at Itkillikpaat, Tiragruak, and Kayuktisiluk traditional sites (Craig 1989; Brown et al. 2016)

Nuiqsut fishers also harvest a small percentage of fish from distant locations on the main Colville River and in the nearby watersheds of Fish Creek and Judy Creek (Brown et al. 2016). With the exception of Fish Creek and Judy Creek, the headwaters of all these important fishing sites are located in the Colville River Special area.

Pacific salmon *Oncorhynchus* spp. are a primary subsistence resource in much of Alaska (Fall et al. 2017), but environmental conditions have limited the establishment of Pacific salmon populations across much of the Arctic (Irvine et al. 2009; Nielsen et al. 2013). Pacific salmon (mainly Chum and Pink Salmon) are harvested by communities in northwestern Alaska along the Chukchi Sea, such as Point Lay and Utqiaġvik (Fall et al. 2017), where marine conditions are relatively warm and productive (Table 3b.1). Salmon harvest levels are highly variable and can range from 2%–37% of the total fish harvest (Fall et al. 2017). However, communities to the east, along the colder, less productive Beaufort Sea (e.g., Nuiqsut), harvest only minor quantities of Pacific salmon (<3% of total harvest) and instead capture mostly nonsalmon fishes (Fall 2016) (Table 3b.1).

Iñupiat living within the Arctic continue to rely on nonsalmon fishes as an important staple food resource (Brewster et al. 2008; Bacon et al. 2011). Harvest of nonsalmon fishes varies in composition and magnitude among Arctic Alaska communities, which in recent estimates accounted for 8–23% of harvested wild resources used by communities and totaled thousands of kilograms annually (Fall et al. 2017). Within Beaufort and Chukchi Sea communities, several nonsalmon fishes are particularly important subsistence resources (Table 3b.1). Broad Whitefish *Coregonus nasus*, referred to as *Aanaakłiq* in the Iñupiaq language, is valued for its relatively large size, versatility of preparation options, and abundance during migrations. They are harvested from June–October and account for about half the total mass of fishes harvested across all Beaufort Sea communities (Bacon et al. 2011; ADFG 2018). Similarly, Arctic Cisco *C. autumnalis* and Least Cisco *C. sardinella* are harvested in large numbers, with only slightly less per-capita harvest (Bacon et al. 2011; Brown et al. 2016). Least Cisco and

Arctic Cisco, known as *Iqalusaaq* and *Qaaktaq*, respectively, in Iñupiaq, are harvested in river deltas (mostly under the ice with gill nets) and are mostly consumed as *quaq*, with the latter species being the preferred cisco to eat frozen. Arctic Grayling *Thymallus arcticus*, or *Sulukpaugaq* in Iñupiaq, is also harvested by all Arctic coastal communities (mostly with hook and line), but constitutes a minor proportion (<10%) of the total nonsalmon harvest (Brown et al. 2016). Most fishing for Arctic Grayling is periodic and mainly used to supplement other nonsalmon fish harvest. While not harvested in all communities, Rainbow Smelt (*Osmerus mordax*) or *Iłhuanniq* is an important fish species for certain communities such as a Wainwright, which harvests thousands of fish annually (Fall et al. 2017).

Overview of the Nuiqsut Subsistence Fishery

Nuiqsut is an Iñupiaq village (population 535) located near the Colville River delta on the Niglik Channel. Iñupiat fishers have harvested fish from the Colville River for hundreds, if not thousands of years. The lower Colville River is home to the *Kuukpikmiut* people who have extensively fished at traditional sites such as *Kayuktisluk*, *Tiraagruak*, and *Itkillikpaat*. Historically, nonsalmon fish, such as Broad Whitefish, were caught in large numbers during the summer and were preserved using drying racks along the rivers. Fish caught in the fall under the ice were frozen whole. Fish size, abundance, run timing, and the ability to preserve fish has shaped the subsistence fishery (Kunaknana, personal communication). Similar to the past, fishing occurs during the summer in open water (July–September) and in fall (October–November) under river ice. Nonsalmon fish harvest is greatest per capita in Nuiqsut (Table 3b.1) and on certain years the household harvest of nonsalmon fish can be as high as 375 kg (Brown et al. 2016). The amount of fish caught and species harvested has historically fluctuated annually, but nonsalmon species have always dominated the fishery.

In the modern summer fishery, subsistence fishers use small motorboats to position gill nets perpendicular to streamflow in the lower river; one end of the net is then anchored to shore. Fishers set gill nets to target the upstream migration of adult Broad Whitefish as fish move to foraging and spawning habitats. Fishing effort is concentrated in the Niglik Channel of the Colville River delta and mainstem Colville River upstream of Nuiqsut between Itkillikpat and Kayuktisiluk. Fishing also occurs in the nearby watershed of Fish Creek, just west of the Colville River delta and remains an important part of the fishery. Although other species such as Dolly Varden, Humpback Whitefish, and Chum Salmon are caught in small quantities as bycatch, the harvest is dominated by Broad Whitefish (Fall et al. 2017), which averages 16, 603 kg/year (Brown et al. 2016) (Table 3b.2).

In the fall fishery, Arctic Cisco and Least Cisco are harvested in large numbers using gill nets set under the ice on the Colville River delta (Table 3b.1). Ciscoes overwinter in brackish waters of the delta and subsistence fishers catch them as they migrate to lower salinity habitat to avoid subfreezing temperatures within the Beaufort Sea (Craig 1984). Fishing effort is concentrated in the Colville River delta downstream of Nuiqsut including several sites on the Niglik Channel and the east channel of the Colville River (Craig 1989). Both Cisco species use lakes in the Colville delta and Least Ciscos have been documented in the upper Colville River watershed (Bendock 1979), but they are typically not targeted by subsistence users outside the delta. In addition to Cisco's, other species such as Arctic Grayling and Burbot are caught under the ice in deep sections of the Colville River using rod and reel during the fall and spring (Table 3b.1).

Importance of the Colville River watershed for Broad Whitefish

Situated in the central Beaufort Sea coast of Arctic Alaska, the Colville River flows about 600 km northward from its headwaters in the Brooks Range to a large delta on the edge of the Beaufort Sea near the Native Village of Nuiqsut. The Colville, the largest river in Arctic Alaska, contains a diversity of channel types due in part to the size of the watershed, diverse geological strata, extensive permafrost, and the different physiographic regions that the river traverses (Figure 2.5; Jorgenson and Grunblatt 2013). The diversity of channel types provides abundant habitat for Broad Whitefish to support all life stages and life history types. Headwater streams mostly flow out of the steep and rugged Brooks Range mountains and provide coarse glacial and noncarbonated sedimentary inputs (Figure 2.4; Jorgenson and Grunblatt 2013). Large tributaries with steep gradients transport coarse alluvium from mountainous areas to foothill valleys, where larger substrate collects in braided channel networks and fine sediment is transported downstream (Figure 2.7). As the watershed slope decreases, the Colville River gains volume and is routed through deep single channels to wide braided floodplain networks. Generally unconstrained on the east bank, the Colville River deposits bedload material, creating complex braided features, with numerous side channels, remnant channels, and oxbow lakes. Large bluffs on the west side of the river constrain the Colville River and the now deep river cuts through deltaic sediment, forming a single large channel before it expands and forms a large complex delta, pouring into the Beaufort Sea. Local geology and previous glaciation have greatly influenced the Colville River drainage. These factors, coupled with the size and position in the watershed influenced channel attributes in systematic ways and provides a diverse mosaic of important fish habitats.

Table 3b.2. Arctic fish species found in the Colville River watershed and habitat types utilized. Sources: (Bendock 1979; Craig and Griffiths 1981; Craig 1984; Moulton and Carpenter 1985; Craig et al. 1985; Morris 2000, 2003; Viavant 2005, 2009; Moulton and Mueter 2008; Moulton et al. 2010; Zimmerman et al. 2013; Leppi et al. 2022a, 2022b, 2022c).

Fish Species		**Important habitats used by fish in the Colville River watershed**			
Anadromous species	**Iñupiaq name**	**Foraging**	**Spawning**	**Rearing**	**Overwinter**
Broad Whitefish (*Coregonus nasus*)	*Aanaakłiq+*	X	X	X	X
Humpback Whitefish (*Coregonus pidschian*)	*Pikuktuuq+*		X	X	
Arctic Cisco (*Coregonus autumnalis*)	*Qaaktaq+*			X	X
Least Cisco (*Coregonus sardinella*)	*Iqalusaaq+*	X	X	X	X
Bering Cisco (*Coregonus laurettae*)*	*Tiipuq+*				X
Round Whitefish (*Prosopium cylindraceum*)	*Savigunnaq+*	X	X	X	X
Rainbow Smelt (*Osmerus mordax*)	*Ilhuanniq+*				X
Dolly Varden (*Salvelinus malma*)	*Iqalukpik+*	X	X	X	X
Chum Salmon (*Oncorhynchus keta*)	*Iqalugruaq+*	No evidence of self-sustaining salmon populations in the Colville River			
Pink Salmon (*Oncorhynchus gorbuscha*)	*Amaqtuuq+*				
Coho Salmon (*Oncorhynchus keta*)*	+				
Chinook Salmon (*Oncorhynchus keta*)*	*Iqalugruaq+*				
Sockeye salmon (Oncorhynchus nerka)*	+				
Ninespine Stickleback (*Pungitius pungitius*)	*Kakalisauraq*	X	X	X	X
Freshwater species					
Lake Trout (*Salvelinus nanaycush*)	*Iqaluaqpak+*	X			
Arctic Grayling (*Thymallus arcticus*)	*Sulukpaugaq+*	X	X	X	X
Burbot (*Lota lota*)	*Tittaaliq+*	X	X	X	X
Arctic Char (S*alvelinus aplinus*)	*Paikłuk+*	X	X	X	X
Northern Pike (*Esox lucius*)	*Siulik+*				
Longnose Sucker (*Catostomus catostomus*)	*Milugiaq*	X	X	X	X
Slimy Sculpin (*Cottus cognatus*)	*Kanayuq*	X	X	X	X

Notes:+ = subsistence fish, * = rare occurence, X = confirmed use of habitat.

Figure 3b.1. Broad Whitefish (*Coregonus nasus*) caught migrating within the Colville River, near Umiat, Alaska, USA. Photo Credit: Jason C. Leppi.

Broad Whitefish move between a variety of freshwater, estuarine, and marine habitats across their lives for spawning, foraging, and refugia (Brown et al. 2012; Harris et al. 2012; Leppi et al. 2022b). As a long-lived iteroparous species, Broad Whitefish conduct long-distance migrations toward spawning areas from June–September from a variety of foraging areas (Tallman and Howland 2008; Leppi et al. 2022a). Iñupiat fishers have harvested prespawn Broad Whitefish migrating within Alaska's Colville River for millennia and we suspect that it may be used by Whitefish from across the Beaufort Sea region for reproduction. Important foraging areas are unknown, but previous research suggests that Broad Whitefish likely use a suite of foraging habitats outside the Colville River watershed such as in the nearby watershed of Fish Creek (Morris 2003) and as far away as the Meade River (Bradley et al. 2016). While recent research has revealed some insights (Leppi et al. 2022c), more research needs to be done to determine important foraging areas among watersheds, life history types, and age classes. Adult fish travel to riverine spawning areas and, as river temperatures decline to near 0°C, they broadcast gametes over gravel substrates (Brown et al. 2012). Broad Whitefish require specific instream conditions and gravel substrate for spawning and incubation and will migrate hundreds of kilometers to reach preferred spawning locations (Tallman and Howland 2008; Brown et al. 2012). Spawning has mostly been observed in large rivers with floodplain habitats (Tallman et al. 2002; Carter 2010; Brown et al. 2012; Harper et al. 2012; Leppi et al. 2022a), which typically have localized areas with upwellings and stable water temperatures (Hauer et al. 2016) that facilitate egg incubation (Bjornn and Reiser 1991; Baxter and Hauer 2000; Bean et al. 2015). Differentially sized gravel substrate and unconfined channels likely provide eggs protection from predators (Etheridge et al. 2011), physical disturbance and burial (Czuba et al. 2018). The resulting embryos incubate in the substrate from October–May and larvae begin to hatch when a threshold of accumulated water temperature is reached, which typically corresponds with the start of spring river breakup (Bogdanov and Bogdanova 2012). Larvae are passively carried downstream to a variety of aquatic habitats, but most are likely carried to estuarine habitat in deltas (Bond and Erickson 1985; Bogdanov and Bogdanova 2012; Leppi et al. 2022b), where they take advantage of shallow low-velocity habitat and higher productivity as they develop into juvenile fish (Craig 1984).

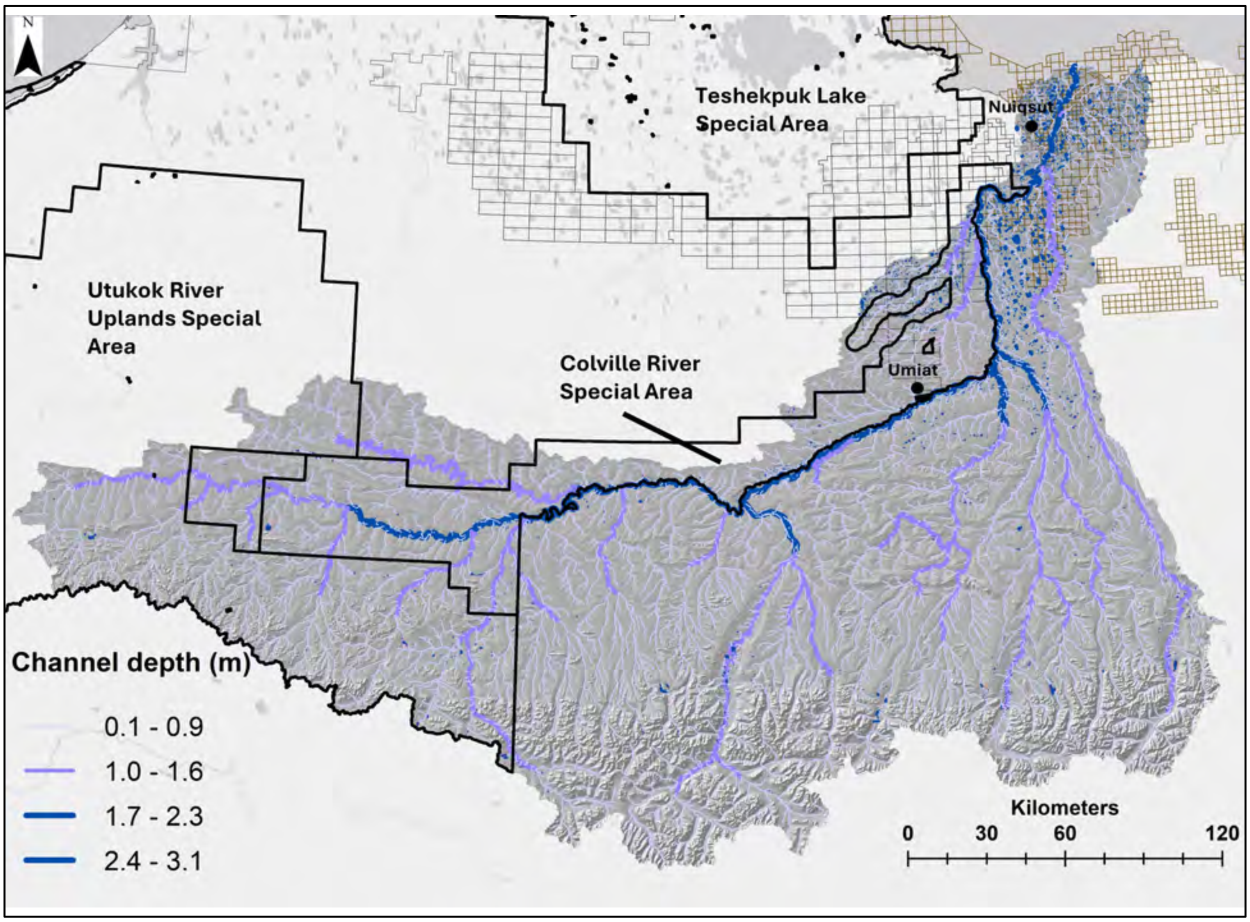

Figure 3b.2. Estimated channel depth for the Colville River watershed within the Colville River Special Area and the Utukok River Uplands Special Area. Channel segments with higher channel depth segments are represented by darker colors (blues), while areas with lower depth are represented with lighter colors (purple, grey). Light grey rectangles represent oil leases near the Colville River watershed within the NPR-A and gold rectangles represent oil leases on surrounding lands near NPR-A Special Areas (thick black lines). Please see Appendix B for a higher resolution version of this figure.

The Colville River watershed contains important habitats for Broad Whitefish that are unique within the NPR-A. The Colville River watershed drains from the Brooks Range mountains and foothills regions and due to its sheer size (60,000 km^2) it contains abundant deep river sections that provide overwintering habitat. Across the NPR-A, there is a lot of lacustrine overwintering habitat available such as Teshekpuk Lake (Morris et al. 2006), but less is known about riverine habitats. Ice growth in the winter varies based on snow cover, winter temperatures, and type of water features (e.g., lake versus river), but in general maximum ice growth can be between 1–2 m thick (Arp et al. 2020a). The Colville River watershed contains over 700 km of river habitat which is estimated to be > 1.6 m in depth (Figure 3b.2) (J.C. Leppi, unpublished data) and has the potential to provide overwintering habitat for numerous fish species (Table 3b.2). To date, limited riverine overwintering habitats have been identified in the NPR-A and more information is needed to identify how fish species and life stages seasonally use the mosaic of freshwater and brackish habitat available. Geology and previous glaciation have influenced the Colville River channel network and created a mosaic of braided gravel features that serve as fish spawning habitats for fish such as Broad Whitefish, Humpback Whitefish, and Arctic Grayling (Table 3b.3). The Colville River watershed contains over 1,548 km of high-quality Broad Whitefish spawning habitat (Figure 3b.3) (Leppi et al. 2022a), but specific spawning areas are yet to be identified. More research needs to be done to refine our understanding of spawning areas and determine if fish use channel segments with high spawning habitat potential. A channel segment with an estimated low spawning IP value doesn’t necessarily mean that fish do not spawn within the segment, but the probability will likely be lower based on our understanding of habitat suitability (Leppi et al. 2022a). However, it is important to note that to date, no other Broad Whitefish spawning areas have been identified in the NPR-A. Mature fish in spawning condition have been caught, radio-tagged, and tracked within Fish Creek (Morris 2003), Teshekpuk Lake (Morris et al. 2006), Topagoruk, Chipp and Meade rivers (Bradley et al. 2016), but evidence is still lacking if these sites are suitable for spawning and whether these relocated individuals spawned. Last, the Colville River watershed contains large amounts of floodplain, tributary, and river delta habitats that are suitable for larvae and juvenile fish rearing (Figure 3b.4) (Moulton and Carpenter 1985); J.C. Leppi, unpublished data). Nursery areas provide food and refuge for rearing fish that hatch in the watershed. Further research should be done to identify sections of the river that are being used by juvenile fish in relation to different identified life history types (Leppi et al. 2022b).

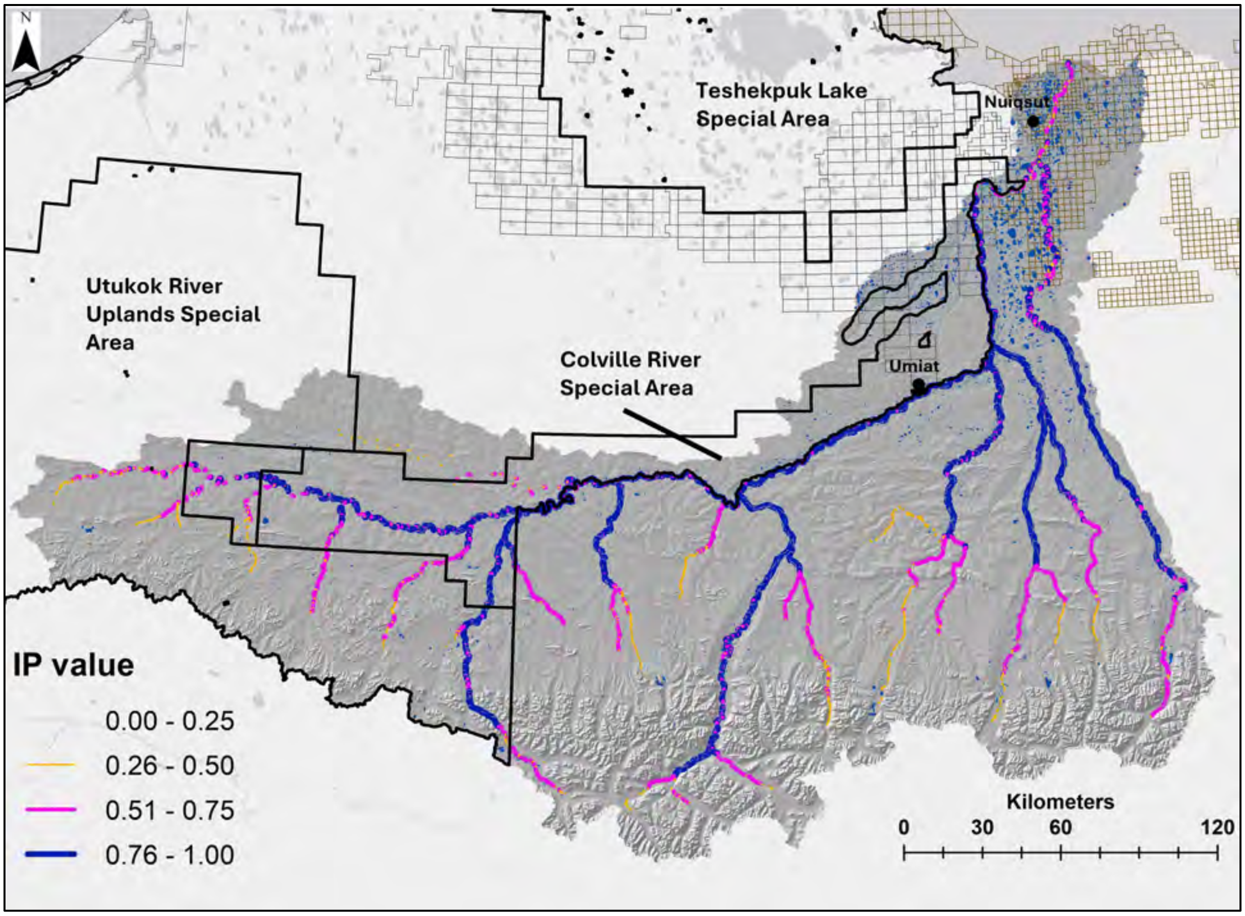

Figure 3b.3. Predicted intrinsic potential (IP) for Broad Whitefish spawning habitat within the Colville River Special Area and the Utukok River Uplands Special Area. Channel segments with low IP values (light grey color), moderate IP values (yellow color), high IP values (pink color), and very high (dark blue color) are shown for the Colville River watershed. Light grey rectangles represent oil leases near the Colville River watershed within the NPR-A and near surrounding lands and overlap with NPR-A Special Areas (thick black lines). Please see Appendix B for a higher resolution version of this figure.

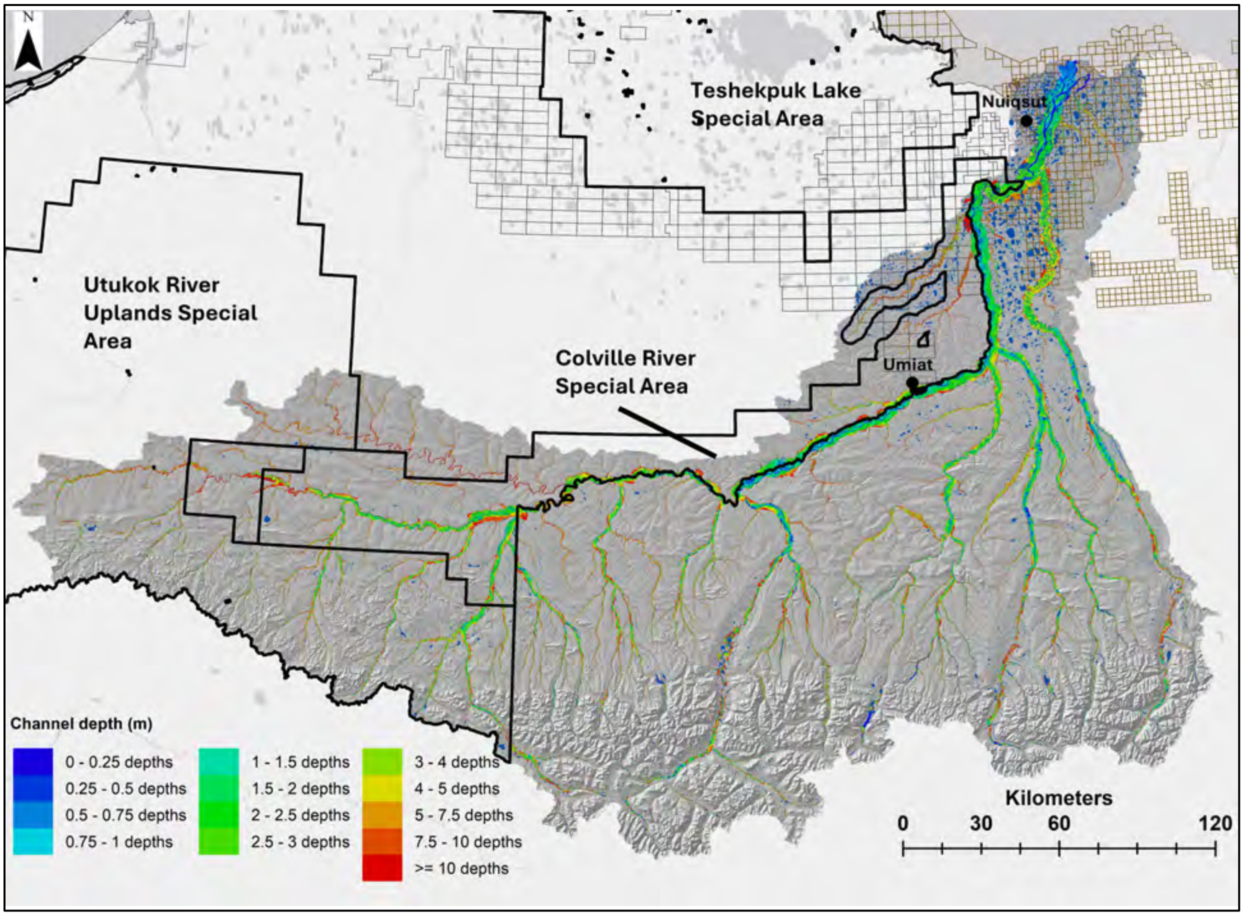

Figure 3b.4. Estimated floodplains and terraces for Colville River watershed within the Colville River Special Area and the Utukok River Uplands Special Area. Floodplains and terraces are in increments of bankfull depths up to 3 km from the river channel centerline. Bankfull depths < 1 represent the active channel (Dark blue – light blue colors), bankfull depths 1—3 represent the active floodplain (turquoise—light green colors), bankfull depths 4 (yellow color) represent floodplains that are occasionally flooded, and bankfull depths > 4 represent terraces (Orange—red colors). Light grey rectangles represent oil leases near the Colville River watershed within the NPR-A and near surrounding lands and overlap with NPR-A Special Areas (thick black lines). Please see Appendix B for a higher resolution version of this figure.

Potential anthropogenic impacts on freshwater ecosystems in the central Beaufort Sea region and the Colville River watershed

The Colville River watershed, and much of the North Slope region, has been minimally altered, but as development continues to expand and modify the landscape, it will be important for land managers and conservation planners to work toward maintaining the ecological integrity (Karr and Dudley 1981; Karr et al. 2022) of aquatic habitats. Oil and gas discoveries within the Colville River Special Area (i.e., Harrier-1, Merlin-1, Umiat) and in surrounding watersheds (i.e., Greater Mooses Tooth, Pika, Bear tooth, Horseshoe, Bear) along with linear development to support oil and gas extraction posed an immediate and future risk to freshwater ecosystems and fish species. Current major habitat stressors to freshwater ecosystems include oil and gas development activities, mineral resource extraction, pollution, and climate change.

Oil and gas development in the central Beaufort Sea region has caused cumulative impacts to permafrost, such as flooding and pooling of water, and loss of vegetation due to heavy road dust (Walker et al. 1987, 2022; Raynolds et al. 2014), which can cause flow modifications that affect habitat quality and connectivity of important fish habitat used for spawning, rearing, or overwintering. Arctic oil and gas infrastructure such as roads and pipelines fragments and disrupts aquatic ecosystems along linear paths (Cott et al. 2015), which can further introduce stressors to juvenile and adult fishes (Trombulak and Frissell 2000; Cott et al. 2015), such as increased sedimentation (Chapman 1988; Burkhead and Jelks 2001; Sutherland and Meyer 2007; Chapman et al. 2014; Kjelland et al. 2015), modifications of streamflow (Flowers et al. 2009), obstructions to passage (Gibson et al. 2005; Price et al. 2010; MacPherson et al. 2012), acoustic disturbances (de Jong et al. 2018, 2020; Mickle and Higgs 2018; Popper and Hawkins 2019), reduced instream habitat quality (Maitland et al. 2016), and pollution (Kime 1995). Winter ice roads and bridges also present a potential impact on aquatic ecosystems if the linear feature alters the natural flow regime and restricts fish movement. While it is generally assumed that fish winter movement is minimal in the Arctic (West et al. 1992; Weber et al. 2013; Brown et al. 2014; Smith et al. 2022), little is known about fish habitat use and movement so it is difficult to discern if impacts are likely to occur from ice roads and ice bridges. Further research needs to be done in the NPR-A to understand ecosystem processes and quantify the risks and impacts on freshwater ecosystems and fish species from oil and gas infrastructure. Detailed baseline information needs to be collected on lotic and lentic ecosystems in order to understand ecosystem processes before it is possible to quantify future anthropogenic impacts. In addition, monitoring should be at development infrastructure sites that intersect with aquatic ecosystems in order to assess if impacts are occurring and quantify any changes from baseline conditions.

Mineral aggregate resource extraction risks mainly consist of streambed gravel and sand mining in the Colville River watershed. Gravel is a limited resource in the Arctic Coastal Plain due to the geology and permafrost extent (Figure 2.4; Figure 2.5) and there is little streambed gravel outside the Colville River watershed. Sand is abundant across the NPR-A and can be extracted at significantly more locations to support development infrastructure in the Arctic. To build permanent facilities and roads over permafrost, large quantities of gravel need to be acquired onsite or shipped in from other locations. Common methods to extract gravel include blasting permafrost and creating an open-pit quarry, mining gravel from rivers using a sling-line bucket dredge, and bulldozing floodplains during low-flow periods. Streambed gravel removal has been shown to alter physical and biological qualities of rivers such as channel form and substrate, surface streamflow and hyporheic flow patterns, and invertebrate and fish communities (Brown et al. 1998; Meador and Layher 1998; Packer et al. 2005). However, the extent of the impact on Arctic Rivers needs to be studied further. Gravel removal and channel modification could have a negative impact on Broad Whitefish spawning habitat and spawning activity if gravel extraction negatively alters the physical instream conditions of spawning sites. Spawning locations are often limited for Whitefish and therefore modifying spawning channels poses a higher risk for population impacts to occur (Brown et al. 2012). Further research needs to be done in the NPR-A to understand important fish habitats and quantify the risks and impacts on freshwater ecosystems and fish species that spawn in the Colville River watershed.

Oil and gas exploration and development have the potential to release petroleum hydrocarbons into the Colville River watershed. Oil and gas discoveries such as Harrier-1, Merlin-1, Umiat, Horseshoe, and Bear posed an immediate and future threat to fish species. Pollution impacts depend upon the amount and type of contaminant released, but the effects on aquatic habitats can persist for decades. Pollution sources can have direct or indirect sources. Polycyclic aromatic hydrocarbons (PAHs) are hydrophobic, semi-volatile organic contaminants comprising at least two fused aromatic rings, containing only carbon and hydrogen (Balmer et al. 2019). PAHs are derived from natural sources such as forest fires and volcanic eruptions and human activities that require fossil fuel combustion (De Luca et al. 2005). PAHs can have local or distant sources and are deposited on snow, surface waters, and sediments within the Arctic (Wang et al. 2010). PAHs accumulate in snow cover during cold periods (Lebedev et al. 2015) and are released during spring snowmelt (Meyer et al. 2011; Kozhevnikov et al. 2021). PAHs are toxic for fish (Carls et al. 1999; Carls and Meador 2009) and exposure at early life stages can lead to mortality, larval deformities (Colavecchia et al. 2004) as well as neoplasia, reduced reproduction success, and endocrine disruption (Collier et al. 2013). While previous and ongoing research has analyzed PAHs in sediment and fish tissues including Broad Whitefish, Burbot (*Lota lota*), Lake Trout (*Salvelinus namaycush*), Sculpin (*Gymnocanthus pistilliger*), Round Whitefish (*Prosopium cylindraceum*), Arctic Grayling, and Rainbow Smelt in the Colville River watershed (Wetzel and Mercurio 2007; Seigle and Gottschalk 2013); K. S. Drew, personal communication), additional research needs to be done to sample snow and water as well as other fish species. Additionally, further research needs to be done in the NPR-A to understand important fish habitats and quantify the risks and impacts from pollution on freshwater ecosystems and fish species that rear in the Colville River watershed.

Climate affects fish habitat across the Arctic through a multitude of physical, chemical, and biological processes (Ficke et al. 2007; Lynch et al. 2016; Myers et al. 2017). Climate change is also altering Arctic hydrologic regimes; variability in runoff is increasing (Stuefer et al. 2017), and discharge from large Arctic rivers is increasing both annually (Peterson et al. 2002; Shiklomanov et al. 2007) and during winter (Smith et al. 2007), and snow-dominated runoff regimes are shifting toward rainfall-dominated regimes (Arp et al. 2020b). Changes in streamflow or temperature, for example, can directly and indirectly alter habitat suitability for fish species and life stages (Reist et al. 2006b, 2006a; Weber et al. 2013; Leppi et al. 2014, 2023) and can reorganize the abundance and distribution of food resources (Woodward et al. 2010). These changes have the potential to alter the foraging and behavioral ecology of Arctic fishes. Understanding the implications of change is especially challenging in northern latitudes, where climate change is rapidly altering physical, biogeochemical, biological, and ecological processes within freshwater ecosystems (Wrona et al. 2006; Schoen et al. 2017; Jones et al. 2020). In northern areas, climate change is causing eutrophication

(Hayden et al. 2017) and browning of lakes (Hayden et al. 2019; Huser et al. 2022), allowing for the northward range expansion of eurythermic (Comte et al. 2013; Campana et al. 2020) and invasive species (Goldsmit et al. 2018). Unfortunately for many Boreal and Arctic regions, there is insufficient information on freshwater stream connectivity (Johaneman et al. 2020; Harlan et al. 2023), little is known about the direct impacts such as changes to stream temperature, and even less about the indirect impacts such as changes in food web composition, abundance, and linkages on fish species (Poesch et al. 2016). Further research needs to be done in the NPR-A to understand ecosystem processes and quantify climate change impacts on freshwater ecosystems and fish species.

Existing Integrated Activity Plan protection measures and options for strengthening protections for Broad Whitefish within the Colville River Special Area

The NPR-A Integrated Activity Plan (IAP) has numerous general protection measures for fish and their habitats. Many Arctic freshwater fish species depend upon a variety of floodplain habitats during their lives for spawning, rearing, foraging, or refugia (Leppi et al. 2022, Bradley et al. 2016, Heim et al. 2016; Brown et al. 2018). Executive order 11988 allows for directive and cumulative impacts to occur in floodplain habitats, but it generally protects against major impacts that will result in long-term changes in the physical and biological processes associated with natural floodplain ecosystems. IAP Lease stipulations (LS) that limit permanent oil and gas infrastructure near rivers, (LS K-1), in deep water lakes (LS K-2), and along nearshore marine areas (LS K-5) and regulate where exploratory drilling can occur (LS K-3) generally protect fish habitat from significant impacts of permanent infrastructure. While these lease stipulations are protective, they also allow for permanent essential infrastructure such as roads and pipelines and sand and gravel mining, which can potentially cause adverse impacts to aquatic ecosystems. Numerous IAP required operating procedures (ROPs) also generally add additional protective measures for fish and fish habitats to limit the impacts of oil and gas development on water use (ROP B-1, ROP B-2), winter overland moves and seismic work (ROP C-2, ROP C-3, ROP C-4, ROP C-5), and facility design and construction (ROP E-2, ROP E-3, ROP E-6, ROP E-8, ROP E-14). While these lease stipulations and required operating procedures are generally protective for aquatic ecosystems, most allow exceptions for development infrastructure in certain situations, which may not in all instances provide adequate protection for certain fish and fish habitats.

Based upon available scientific information there are several potential options to strengthen the protection of important subsistence fishes in the Colville River Special Area. First, it will be important to add accurate information within the Special Area surface resource values description on the diversity of subsistence fish that use the Colville River Special Area and the significance of the watershed for spawning (Bendock 1979; Moulton and Carpenter 1985; Leppi et al. 2022a), rearing (Alt and Kogl

1973; Moulton and Carpenter 1985; Leppi et al. 2022b), foraging, and overwintering (Bendock 1979; Moulton and Carpenter 1985; Leppi et al. 2022b). In order to protect subsistence fish for the region, species that use the Colville River Special Area need to be described in better detail and important movement patterns, habitats, and populations should be described. In instances where limited information is known about an important fish species movement and ecology, new research should be completed to quantify and map important and limiting habitats such as spawning, rearing, foraging, and refugia habitat. Oil and gas discoveries within the Colville River Special Area (i.e., Harrier-1, Merlin-1, Umiat) posed an immediate and future threat to freshwater ecosystems and fish species. Second, due to the importance of Broad Whitefish for the region, it will be important to create and add a Colville River Special Area Broad Whitefish protection plan to K-1 lease stipulations to maintain important spawning, rearing, foraging, and overwintering habitat within the Special Area with the goal of providing durable and lasting protection. Broad Whitefish is an important subsistence fish that spawns and rears in the Colville River watershed that may support multiple subsistence fisheries. The plan should consider including specific stipulations to protect important fish habitats such as not allowing leasing, infrastructure, gravel removal, or winter water extraction within the floodplain (< 5 bankfull depths) throughout the Special area (Figure 3b.5). It should also consider prohibiting non-essential roads from being built in the Special Area and regulating that all essential roads are consolidated and cross at channel segments with low spawning habitat potential (Figure 3b.6) and low overwintering habitat potential (Figure 3b.7). This is important to minimize additional impacts on habitats used for reproduction and survival. It should also consider requiring that pipelines cross downstream of spawning habitats to mitigate the potential impacts of oil spills on larvae and juvenile fish. Last, to protect the variety of important fish habitats, the Broad Whitefish protection plan should consider requiring all allowed essential infrastructure within the watershed not alter the existing ecosystem-specific ecological integrity (Karr and Dudley 1981), water quality, or natural flow regimes (Poff et al. 1997) of the Colville River watershed. In most instances, new data will need to be collected and incorporated into models in order to quantify these important metrics across watersheds.

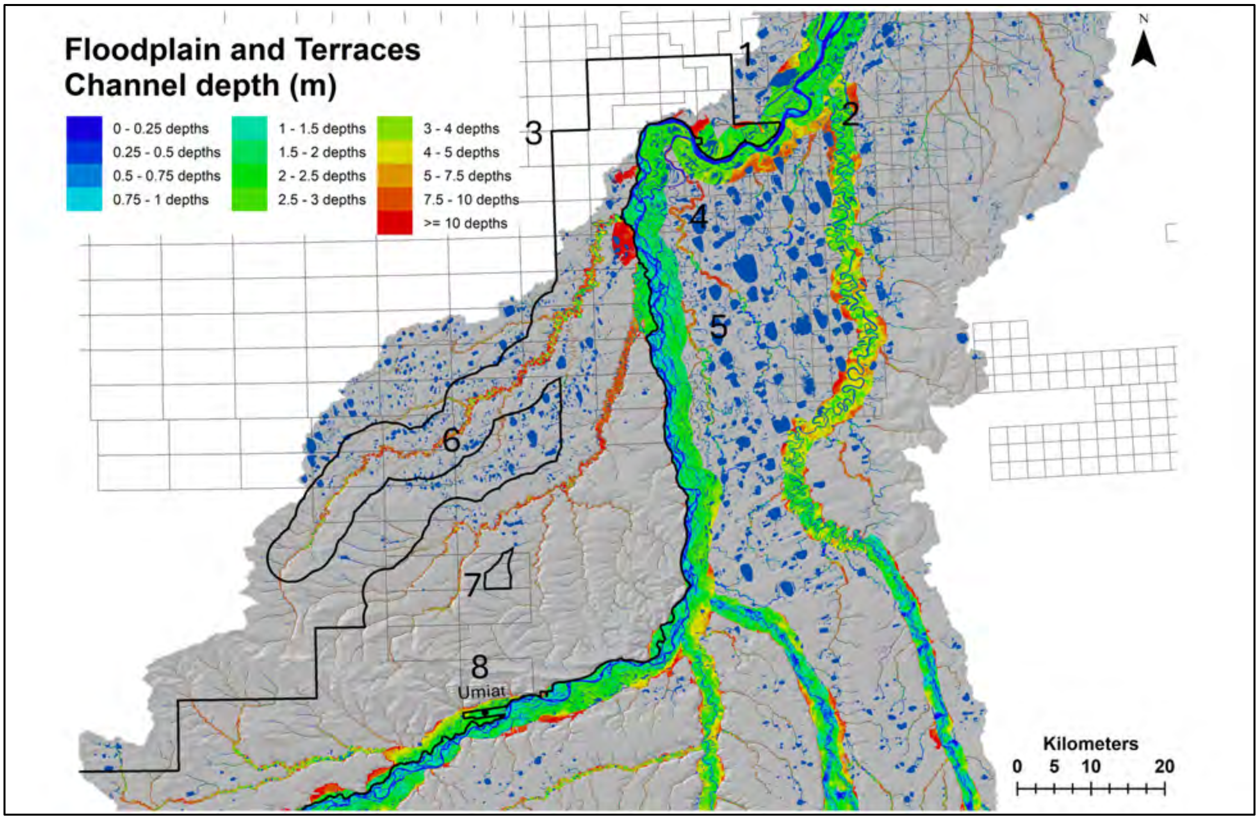

Figure 3b.5. Estimated floodplains and terraces for Colville River watershed within the Colville River Special Area between Umiat and Ocean Point. Floodplains and terraces are in increments of bankfull depths up to 3 km from the river channel centerline. Bankfull depths < 1 represent the active channel (Dark blue – light blue colors), bankfull depths 1—3 represent the active floodplain (turquoise— light green colors), bankfull depths 4 (yellow color) represent floodplains that are occasionally flooded, and bankfull depths > 4 represent terraces (Orange—red colors). Light grey rectangles represent oil leases near the Colville River watershed within the NPR-A and near surrounding lands and overlap with NPR-A Special Areas (thick black lines). Numbers shown on the map represent the general location of oil and gas discoveries in or near the Colville River Special area: 1 = Greater Mooses Tooth, 2 = Pika, 3 = Bear tooth, 4 = Horseshoe, 5 = Bear, 6 = Harrier-1, 7 = Merlin-1, 8 = Umiat. Please see Appendix B for a higher resolution version of this figure.

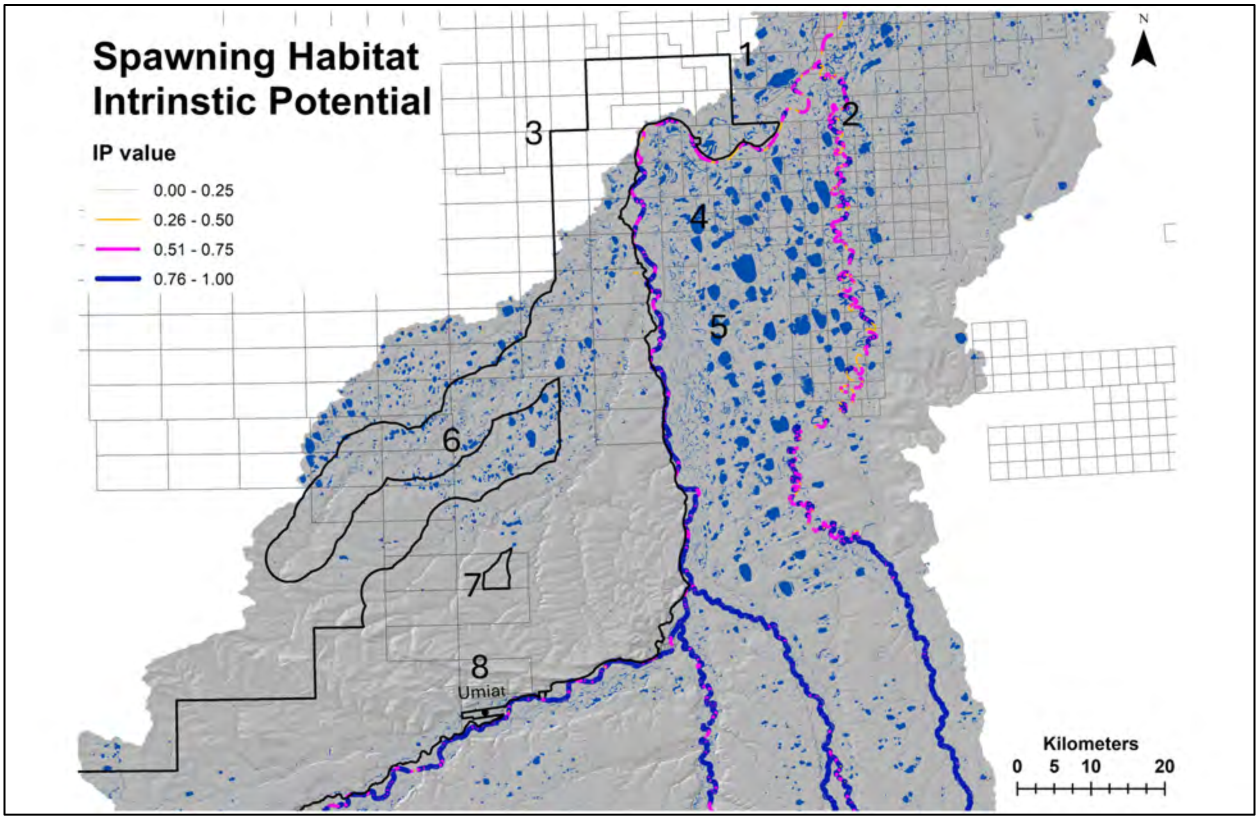

Figure 3b.6. Predicted intrinsic potential (IP) for Broad Whitefish spawning habitat within the Colville River Special Area. Channel segments with low IP values (light grey color), moderate IP values (yellow color), high IP values (pink color), and very high (dark blue color) are shown for the Colville River watershed. Light grey rectangles represent oil leases near the Colville River watershed within the NPR-A and near surrounding lands and overlap with NPR-A Special Areas (thick black lines). Numbers shown on the map represent the general location of oil and gas discoveries in or near the Colville River Special area: 1 = Greater Mooses Tooth, 2 = Pika, 3 = Bear tooth, 4 = Horseshoe, 5 = Bear, 6 = Harrier-1, 7 = Merlin-1, 8 = Umiat. Please see Appendix B for a higher resolution version of this figure.

To balance the impacts of future development on freshwater ecosystems and fish populations, it will be important to plan at the watershed scale. Watershed processes across space and time create a mosaic of habitat types (Resh et al. 1988), which provides a diversity of habitats for fish species and creates a variety of options available across changing environmental conditions (Stanford et al. 2005) — buffering populations from both climate and anthropogenic impacts (Schindler et al. 2015). Due to displaced resources, movement by anadromous and freshwater fish extensive; many fish species such as Broad Whitefish, Dolly Varden, and Arctic Cisco utilize large portions of watersheds from headwater streams to estuaries and move large distances between watersheds, to meet basic biological life requirements of reproduction, foraging, and survival (Zimmerman et al. 2013; Brown et al. 2019; Leppi et al. 2022b). Fragmentation of connected habitats or disruption of natural disturbance processes, from roads, culverts, bridges, and development pads, can if not designed correctly reduce habitat heterogeneity (Cott et al. 2015) and increase fish populations' vulnerability to long-term persistence (Penaluna et al. 2018). If significant enough, the homogenization and fragmentation of habitats can lead to the loss of local populations, and a reduction in local genetic and life-history diversity leading to less resilient populations (Duffy 2009; Schindler et al. 2010; Hellmair and Kinziger 2014; Meek et al. 2020).

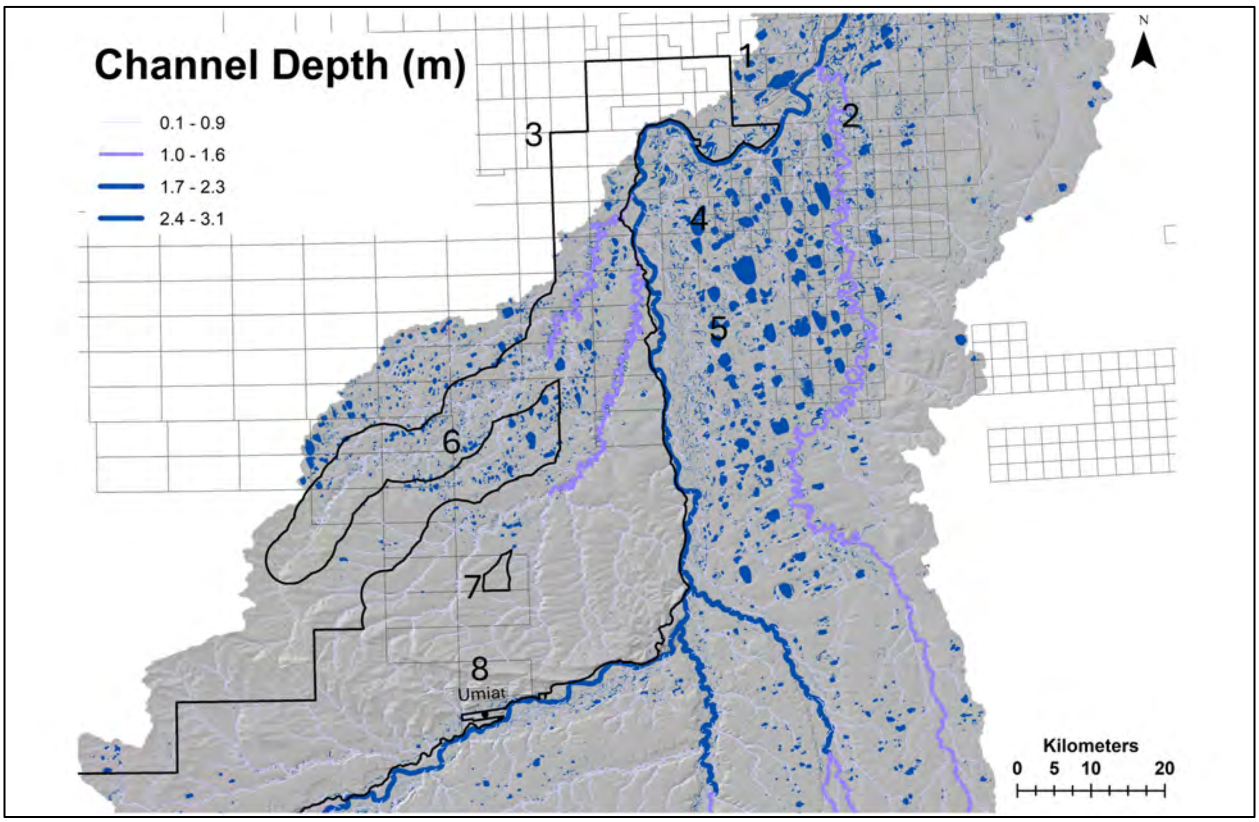

Figure 3b.7. Estimated channel depth for the Colville River watershed within the Colville River Special Area between Umiat and Ocean Point. Channel segments with higher channel depth segments are represented by darker colors (blues), while areas with lower depth are represented with lighter colors (purple, grey). Light grey rectangles represent oil leases near the Colville River watershed within the NPR-A and near surrounding lands and overlap with NPR-A Special Areas (thick black lines). Numbers shown on the map represent the general location of oil and gas discoveries in or near the Colville River Special area: 1 = Greater Mooses Tooth, 2 = Pika, 3 = Bear tooth, 4 = Horseshoe, 5 = Bear, 6 = Harrier-1, 7 = Merlin-1, 8 = Umiat. Please see Appendix B for a higher resolution version of this figure.

Another potential conservation measure to buffer fish populations from impacts of climate change and oil and gas development could include expanding the Colville Special Area boundary to include the entire watershed within the NPR-A. This could include expanding the western and southern boundary of the Colville River Special area to match the watershed boundary (HUC 08 codes = 19060301, 19060302, 19060304). Expanding the CRSA to include headwaters of subwatersheds would help buffer any future development impacts. Headwater streams and wetlands perform important ecological functions that support downstream habitats and fish species (Meyer et al. 2007; Colvin et al. 2019) and anthropogenic impacts upstream could impact sediment delivery, water flow, and nutrients to downstream waters. Last, designating the upper Colville River as a Wild and Scenic River (WSR) network should be considered as an additional conservation protection measure. The WSR Act has proven to be an effective conservation tool to protect native fishes (Rothlisberger et al. 2017) by protecting natural processes that maintain high-quality fish habitats. Numerous rivers, totaling hundreds of kilometers, within the upper Colville River watershed are eligible and suitable for Wild and Scenic River classification. Designating WSR classification for rivers in the upper Colville River that are completely within the NPR-A would ensure lasting protection for subsistence fish habitats in the upper watershed. The WSR Act protects rivers in five ways 1) it bans dams and harmful water development projects, 2) it ensures water quality is maintained and enhanced, 3) it protects outstanding resource values such as fish and wildlife habitats, 4) it creates a federally-reserved water right to maintain a rivers outstanding values, and 5) it requires the development of a Comprehensive River Management Plan to guide river corridor management. These durable protections would help maintain the ecological integrity and natural flow regime of the upper Colville River watershed to support species that use habitats lower in the watershed.

Arctic fish literature cited

ADFG. 2018. Data for Nuiqsut, Atqasuk, Utigavik, Point Lay, and Wainwright. Community Subsistence Information System (CSIS). Available from: https://www.adfg.alaska.gov/sb/CSIS/.

Alt, K. T., and D. R. Kogl. 1973. Notes on the whitefish of the Colville River, Alaska. Journal of the Fisheries Research Board of Canada 30(4):554–556. Available from: https://cdnsciencepub.com/doi/10.1139/f73-094.

Arp, C. D., J. E. Cherry, D. R. N. Brown, A. C. Bondurant, and K. L. Endres. 2020a. Observation-derived ice growth curves show patterns and trends in maximum ice thickness and safe travel duration of Alaskan lakes and rivers. The Cryosphere 14(11):3595–3609. Available from: https://tc.copernicus.org/articles/14/3595/2020/.

Arp, C. D., M. S. Whitman, R. Kemnitz, and S. L. Stuefer. 2020b. Evidence of hydrological intensification and regime change from northern Alaskan watershed runoff. Geophysical Research Letters 47(17). Available from: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020GL089186.

Bacon, J. J., T. R. Hepa, H. K. Brower Jr, M. Pederson, T. P. Olemaun, J. C. George, and B. G. Corrigan. 2009. Estimates of subsistence harvest for villages on the North Slope of Alaska, 1994-2003. Barrow, Alaska: North Slope Borough Department of Wildlife Management. Available from: https://catalog.northslopescience.org/is/dataset/2293.

Bacon, J. J., T. R. Hepa, H. K. Brower, M. Pederson, T. P. Olemaun, J. C. George, and B. G. Corrigan. 2011. Estimates of subsistence harvest for villages on the North Slope of Alaska, 1993–2004. Available from: https://www.north-slope.org/wp-content/uploads/2022/04/MASTER-SHDP-94-03-REPORT-FINAL-and-Errata-info-Sept-2012.pdf.

Balmer, J. E., H. Hung, Y. Yu, R. J. Letcher, and D. C. G. Muir. 2019. Sources and environmental fate of pyrogenic polycyclic aromatic hydrocarbons (PAHs) in the Arctic. Emerging Contaminants 5:128–142. Available from: https://www.sciencedirect.com/science/article/pii/S2405665018300684?via%3Dihub.

Baxter, C. V., and F. R. Hauer. 2000. Geomorphology, hyporheic exchange, and selection of spawning habitat by bull trout (Salvelinus confluentus). Canadian Journal of Fisheries and Aquatic Sciences 57(7):1470–1481. Available from: https://cdnsciencepub.com/doi/10.1139/f00-056.

Bean, J. R., A. C. Wilcox, W. W. Woessner, and C. C. Muhlfeld. 2015. Multiscale hydrogeomorphic influences on bull trout (*Salvelinus confluentus*) spawning habitat. Canadian Journal of Fisheries and Aquatic Sciences 72(4):514–526. Available from: https://cdnsciencepub.com/doi/abs/10.1139/cjfas-2013-0534.

Bendock, T. N. 1979. Inventory and cataloging of Arctic area waters. Alaska Department of Fish and Game (ADFG), 20. Available from: https://www.adfg.alaska.gov/fedaidpdfs/FREDF-9-11(20)G-I-I.PDF.

Berkes, F. 1990. Native Subsistence Fisheries: a synthesis of harvest studies in Canada. Arctic 43(1):35–42. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/64642.

Bersamin, A., S. Zidenberg-Cherr, J. S. Stern, and B. R. Luick. 2007. Nutrient intakes are associated with adherence to a traditional diet among Yup`ik Eskimos living in remote Alaska Native communities: the CANHR Study. International journal of circumpolar health 66(1):62–70. Available from: https://www.tandfonline.com/doi/abs/10.3402/ijch.v66i1.18228.

Bjornn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83–154 *in* W. R. Meehan, editor. Influences of Forest and Rangeland Management on Salmonid Fishes. Available from: https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626600.pdf

Bogdanov, V. D., and E. N. Bogdanova. 2012. Ecological aspects of larval drift in coregonids with long migration routes. Russian Journal of Ecology 43(4):315–322. Available from: https://link.springer.com/article/10.1134/S1067413612040042.

Bond, W. A., and R. N. Erickson. 1985. Life history studies of anadromous coregonid fishes in two freshwater lake systems on the Tuktoyaktuk Peninsula, Northwest Territories. Fisheries and Oceans, Canada. Available from: https://waves-vagues.dfo-mpo.gc.ca/Library/52067.pdf.

Bradley, P., W. Morris, and L. Moulton. 2016. Fish and aquatic habitat surveys in the Topagoruk, Chipp, and Meade Rivers 2012-2016. ADFG, Technical Report No. 16-07. Available from: https://www.adfg.alaska.gov/static/home/library/pdfs/habitat/16_07.pdf.

Brewster, K., C. George, M. Aiken, A. Brower, M. Itta, N. Itta, M. Lou Leavitt, O. Leavitt, and W. Matumeak. 2008. Iñupiat knowledge of selected subsistence fish near Barrow, Alaska. Report prepared for the Bureau of Land Management through an assistance agreement to the North Slope Borough Department of Wildlife Management. Available from: https://www.north-slope.org/wp-content/uploads/2022/04/Brewster_Fish-TEK-paper.pdf.

Brown, A. V., M. M. Lyttle, and K. B. Brown. 1998. Impacts of gravel mining on gravel bed streams. Transactions of the American Fisheries Society 127(6):979–994. Available from: https://afspubs.onlinelibrary.wiley.com/doi/abs/10.1577/1548-8659%281998%29127%3C0979%3AIOGMOG%3E2.0.CO%3B2.

Brown, C. L., N. M. Braem, M. L. Kostick, A. Trainor, L. J. Slayton, D. M. Runfola, E. H. Mikow, H. Ikuta, C. R. McDevitt, J. Park, and Others. 2016. Harvests and uses of wild resources in 4 interior Alaska communities and 3 Arctic Alaska communities. Technical Paper No. 426. Fairbanks: Alaska Department of Fish and Game Division of Subsistence. Available from: https://www.arlis.org/docs/vol1/M/972886420.pdf.

Brown, R. J., C. Brown, N. M. Braem, W. K. Carter III, N. Legere, and L. Slayton. 2012. Whitefish biology, distribution, and fisheries in the Yukon and Kuskokwim River drainages in Alaska: a synthesis of available information. US Fish and Wildlife Service, Alaska Fisheries Data Series 4. Available from: https://www.sciencebase.gov/catalog/item/5771b8ade4b07657d1a6cd82.

Brown, R. J., M. B. Courtney, and A. C. Seitz. 2019. New insights into the biology of anadromous Dolly Varden in the Canning River, Arctic National Wildlife Refuge, Alaska. Transactions of the American Fisheries Society 148(1):73–87. Available from: https://afspubs.onlinelibrary.wiley.com/doi/10.1002/tafs.10122.

Brown, R. J., M. B. Loewen, and T. L. Tanner. 2014. Overwintering Locations, Migrations, and Fidelity of Radio-Tagged Dolly Varden in the Hulahula River, Arctic National Wildlife Refuge, 2007–09. Arctic 67(2):149–158. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/67424.

Burkhead, N. M., and H. L. Jelks. 2001. Effects of suspended sediment on the reproductive success of the Tricolor Shiner, a crevice-spawning minnow. Transactions of the American Fisheries Society 130(5):959–968. Available from: https://afspubs.onlinelibrary.wiley.com/doi/abs/10.1577/1548-8659%282001%29130%3C0959%3AEOSSOT%3E2.0.CO%3B2.

Campana, S. E., J. M. Casselman, C. M. Jones, G. Black, O. Barker, M. Evans, M. M. Guzzo, R. Kilada, A. M. Muir, and R. Perry. 2020. Arctic freshwater fish productivity and colonization increase with climate warming. Nature Climate Change 10(5):428–433. Available from: https://www.nature.com/articles/s41558-020-0744-x.

Carls, M. G., and J. P. Meador. 2009. A perspective on the toxicity of petrogenic PAHs to developing fish embryos related to environmental chemistry. Human and Ecological Risk Assessment: An International Journal 15(6):1084–1098. Available from: https://www.tandfonline.com/doi/full/10.1080/10807030903304708.

Carls, M. G., S. D. Rice, and J. E. Hose. 1999. Sensitivity of fish embryos to weathered crude oil: part I. low-level exposure during incubation causes malformations, genetic damage, and mortality in larval pacific herring (*Clupea pallasi*). Environmental Toxicology and Chemistry 18(3):481–493. Available from: https://setac.onlinelibrary.wiley.com/doi/10.1002/etc.5620180317.

Carothers, C., T. L. Sformo, S. Cotton, J. C. George, and P. A. H. Westley. 2019. Pacific salmon in the rapidly changing Arctic: Exploring local knowledge and emerging fisheries in Utqiaġvik and Nuiqsut, Alaska. Arctic 72(3):273–288. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/68876.

Carter, W. K. 2010. Life history and spawning movements of broad whitefish in the middle Yukon River. University of Alaska Fairbanks. Available from: https://scholarworks.alaska.edu/handle/11122/12730.

Caulfield, R. A. 2002. Food security in arctic Alaska: A preliminary assessment. Pages 75–92 *in* G. Duhaime, editor. Sustainable food security in the Arctic: state of knowledge. Canadian Circumploar Institute Press, Edmonton, Alberta. Available from: https://chaireconditionautochtone.fss.ulaval.ca/doc/Publication/Chapitre-4-01.pdf.

Chapman, D. W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society 117(1):1–21. Available from: https://afspubs.onlinelibrary.wiley.com/doi/abs/10.1577/1548-8659%281988%29117%3C0001%3Acrovut%3E2.3.co%3B2.

Chapman, J. M., C. L. Proulx, M. A. N. Veilleux, C. Levert, S. Bliss, M.-È. André, N. W. R. Lapointe, and S. J. Cooke. 2014. Clear as mud: a meta-analysis on the effects of sedimentation on freshwater fish and the effectiveness of sediment-control measures. Water Research 56:190–202. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0043135414001754?via%3Dihub.

Colavecchia, M. V., S. M. Backus, P. V. Hodson, and J. L. Parrott. 2004. Toxicity of oil sands to early life stages of fathead minnows (*Pimephales promelas*). Environmental Toxicology and Chemistry 23(7):1709–1718. Available from: https://setac.onlinelibrary.wiley.com/doi/10.1897/03-412.

Collier, T. K., B. F. Anulacion, M. R. Arkoosh, J. P. Dietrich, J. P. Incardona, L. L. Johnson, G. M. Ylitalo, and M. S. Myers. 2013. 4 - Effects on fish of polycyclic aromatic hydrocarbons (PAHS) and naphthenic acid exposures. Pages 195–255 *in* K. B. Tierney, A. P. Farrell, and C. J. Brauner, editors. Fish Physiology. Academic Press. Available from: https://linkinghub.elsevier.com/retrieve/pii/B9780123982544000042.

Colvin, S. A. R., S. M. P. Sullivan, P. D. Shirey, R. W. Colvin, K. O. Winemiller, R. M. Hughes, K. D. Fausch, D. M. Infante, J. D. Olden, K. R. Bestgen, R. J. Danehy, and L. Eby. 2019. Headwater streams and wetlands are critical for sustaining fish, fisheries, and ecosystem services. Fisheries 44(2):73–91. https://afspubs.onlinelibrary.wiley.com/doi/10.1002/fsh.10229.

Comte, L., L. Buisson, M. Daufresne, and G. Grenouillet. 2013. Climate-induced changes in the distribution of freshwater fish: observed and predicted trends. Freshwater Biology 58(4):625–639. https://onlinelibrary.wiley.com/doi/10.1111/fwb.12081.

Cott, P. A., A. Schein, B. W. Hanna, T. A. Johnston, D. D. MacDonald, and J. M. Gunn. 2015. Implications of linear developments on northern fishes. Environmental Reviews 23(2):177–190. Available from: https://cdnsciencepub.com/doi/10.1139/er-2014-0075.

Craig, P. C. 1984. Fish use of coastal waters of the Alaskan Beaufort Sea: a review. Transactions of the American Fisheries Society 113(3):265–282. Available from: https://afspubs.onlinelibrary.wiley.com/doi/abs/10.1577/1548-8659%281984%29113%3C265%3AFUOCWO%3E2.0.CO%3B2.

Craig, P. C. 1989. Subsistence fisheries at coastal villages in the Alaskan Arctic, 1970–1986. Biological Paper of the University of Alaska 24:131–152. Available from: https://www.govinfo.gov/content/pkg/GOVPUB-I-a52f56b33abb4b5138c16654d3d72829/pdf/GOVPUB-I-a52f56b33abb4b5138c16654d3d72829.pdf.

Craig, P. C., and W. B. Griffiths. 1981. Passage of large fish around a causeway in Prudhoe Bay, Alaska. Arctic 34(4):314–317. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/download/65586/49500/.

Craig, P. C., W. B. Griffiths, L. Haldorson, and H. McElderry. 1985. Distributional patterns of fishes in an Alaskan Arctic Lagoon. Polar Biology 4(1):9–18. Available form: https://link.springer.com/article/10.1007/BF00286812.

Czuba, C. R., J. A. Czuba, C. S. Magirl, A. S. Gendaszek, and C. P. Konrad. 2018. Effect of river confinement on depth and spatial extent of bed disturbance affecting salmon redds. Journal of Ecohydraulics 3(1):4–17. Available from: https://www.tandfonline.com/doi/full/10.1080/24705357.2018.1457986.

De Luca, G., A. Furesi, G. Micera, A. Panzanelli, P. C. Piu, M. I. Pilo, N. Spano, and G. Sanna. 2005. Nature, distribution and origin of polycyclic aromatic hydrocarbons (PAHs) in the sediments of Olbia harbor (Northern Sardinia, Italy). Marine Pollution Bulletin 50(11):1223–1232. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0025326X05001657?via%3Dihub.

Duffy, J. E. 2009. Why biodiversity is important to the functioning of real-world ecosystems. Frontiers in ecology and the environment 7(8):437–444. https://esajournals.onlinelibrary.wiley.com/doi/10.1890/070195.

Etheridge, E. C., C. W. Bean, and C. E. Adams. 2011. An experimental approach to estimating vulnerability of European whitefish (lavaretus<i/>) ova to predation by invasive ruffe (*Gymnocephalus cernuus*). Ecology of Freshwater Fish 20(2):299–307. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1600-0633.2011.00496.x.

Fall, J. A. 2016. Regional patterns of fish and wildlife harvests in contemporary Alaska. Arctic 69(1):47–64. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/67588.

Fall, J. A., A. Godduhn, G. Halas, L. Hutchinson-Scarbrough, B. Jones, M. Kukkonen, D. Runfola, L. A. Sill, A. Trainor, and T. Lemons. 2017. Alaska subsistence and personal use salmon fisheries 2014 annual report. Alaska Department of Fish and Game, Technical Paper No. 427, Fairbanks.

Ficke, A. D., C. A. Myrick, and L. J. Hansen. 2007. Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries 17(4):581–613. Available from: https://link.springer.com/article/10.1007/s11160-007-9059-5#:~:text=The%20general%20effects%20of%20climate,the%20increased%20toxicity%20of%20pollutants.&text=Fish%20physiology%20is%20inextricably%20linked,hydrologic%20regimes%20and%20habitat%20niches.

Flowers, H. J., W. E. Pine III, A. C. Dutterer, K. G. Johnson, J. W. Ziewitz, M. S. Allen, and F. M. Parauka. 2009. Spawning site selection and potential implications of modified flow regimes on viability of Gulf Sturgeon populations. Transactions of the American Fisheries Society 138(6):1266–1284. Available from: https://afspubs.onlinelibrary.wiley.com/doi/10.1577/T08-144.1.

Gibson, R. J., R. L. Haedrich, and C. M. Wernerheim. 2005. Loss of Fish Habitat as a Consequence of Inappropriately Constructed Stream Crossings. Fisheries 30(1):10–17. Available from: https://afspubs.onlinelibrary.wiley.com/doi/abs/10.1577/1548-8446%282005%2930%5B10%3ALOFHAA%5D2.0.CO%3B2.

Goldsmit, J., P. Archambault, G. Chust, E. Villarino, G. Liu, J. V. Lukovich, D. G. Barber, and K. L. Howland. 2018. Projecting present and future habitat suitability of ship-mediated aquatic invasive species in the Canadian Arctic. Biological Invasions 20(2):501–517. Available from: https://link.springer.com/article/10.1007/s10530-017-1553-7.

Harlan, M. E., C. J. Gleason, J. A. Flores, T. M. Langhorst, and S. Roy. 2023. Mapping and characterizing Arctic beaded streams through high resolution satellite imagery. Remote Sensing of Environment 285:113378. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0034425722004849?via%3Dihub.

Harper, K. C., F. Harris, S. J. Miller, J. M. Thalhauser, and S. D. Ayers. 2012. Life History Traits of Adult Broad Whitefish and Humpback Whitefish. Journal of Fish and Wildlife Management 3(1):56–75. Available from: https://meridian.allenpress.com/jfwm/article/3/1/56/209528/Life-History-Traits-of-Adult-Broad-Whitefish-and.

Harris, L. N., E. B. Taylor, R. F. Tallman, and J. D. Reist. 2012. Gene flow and effective population size in two life-history types of Broad Whitefish *Coregonus nasus* from the Canadian Arctic. Journal of Fish Biology 81(1):288–307. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1095-8649.2012.03339.x.

Hauer, F. R., H. Locke, V. J. Dreitz, M. Hebblewhite, W. H. Lowe, C. C. Muhlfeld, and S. B. Rood. 2016. Gravel-bed river floodplains are the ecological nexus of glaciated mountain landscapes. Science Advances 2((6)):e1600026. Available from: https://www.science.org/doi/10.1126/sciadv.1600026.

Hayden, B., C. Harrod, S. M. Thomas, A. P. Eloranta, J.-P. Myllykangas, A. Siwertsson, K. Praebel, R. Knudsen, P.-A. Amundsen, and K. K. Kahilainen. 2019. From clear lakes to murky waters - tracing the functional response of high-latitude lake communities to concurrent “greening” and “browning.” Ecology Letters 22(5):807–816. Available from: https://onlinelibrary.wiley.com/doi/10.1111/ele.13238.

Hayden, B., J.-P. Myllykangas, R. J. Rolls, and K. K. Kahilainen. 2017. Climate and productivity shape fish and invertebrate community structure in subarctic lakes. Freshwater Biology 62(6):990–1003. Available from: https://onlinelibrary.wiley.com/doi/10.1111/fwb.12919.

Hellmair, M., and A. P. Kinziger. 2014. Increased extinction potential of insular fish populations with reduced life history variation and low genetic diversity. PloS one 9(11):e113139. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0113139.

Huser, B. J., M. N. Futter, D. Bogan, J. E. Brittain, J. M. Culp, W. Goedkoop, I. Gribovskaya, J. Karlsson, D. C. P. Lau, K. M. Rühland, A. K. Schartau, R. Shaftel, J. P. Smol, T. Vrede, and J. Lento. 2022. Spatial and temporal variation in Arctic freshwater chemistry—Reflecting climate-induced landscape alterations and a changing template for biodiversity. Freshwater biology 67(1):14–29. Available from: https://onlinelibrary.wiley.com/doi/10.1111/fwb.13645.

Inuit Circumpolar Council-Alaska. 2015. Alaskan Inuit food security conceptual framework: how to assess the Arctic from an Inuit perspective. Inuit Circumpolar Council. Available form: https://repository.oceanbestpractices.org/handle/11329/1828.

Irvine, J., L. Godbout, O. Canada, and R. Manitoba. 2009. Salmon in the arctic and how they avoid lethal low temperatures. North Pacific Anadromous Fish Commission (5):39–50. Available form: https://www.arlis.org/docs/vol1/B/594014227/npafc_bull_5_039-050(irvine).pdf.

Johaneman, T. M., C. D. Arp, M. S. Whitman, A. C. Bondurant, H. B. Hamann, and M. W. Kerwin. 2020. Classifying connectivity to guide aquatic habitat management in an Arctic coastal plain watershed experiencing land use and climate change. Arctic, Antarctic, and Alpine Research 52(1):476–490. Available from: https://www.tandfonline.com/doi/full/10.1080/15230430.2020.1805848.

Jones, L. A., E. R. Schoen, R. Shaftel, C. J. Cunningham, S. Mauger, D. J. Rinella, and A. St Saviour. 2020. Watershed-scale climate influences productivity of Chinook salmon populations across southcentral Alaska. Global Change Biology 26(9):4919–4936. Available from: https://onlinelibrary.wiley.com/doi/10.1111/gcb.15155.

de Jong, K., M. C. P. Amorim, P. J. Fonseca, C. J. Fox, and K. U. Heubel. 2018. Noise can affect acoustic communication and subsequent spawning success in fish. Environmental Pollution 237:814–823. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0269749117326064?via%3Dihub.

de Jong, K., T. N. Forland, M. C. P. Amorim, G. Rieucau, H. Slabbekoorn, and L. D. Sivle. 2020. Predicting the effects of anthropogenic noise on fish reproduction. Reviews in Fish Biology and Fisheries 30(2):245–268. Available from: https://link.springer.com/article/10.1007/s11160-020-09598-9.

Jorgenson, M. T., and J. Grunblatt. 2013. Landscape-level ecological mapping of northern Alaska and field site photography report. Arctic Landscape Conservation Cooperative. Available from: https://catalog.northslopescience.org/dataset/8e2d5a71-7808-4ea2-b60b-c2b615fceaa8/resource/7aead4d6-4fe9-4914-bc38-a1e072ff6030/download/n-alaska-landscape-mapping-and-field-site-photography-2013.pdf.

Karr, J. R., and D. R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 5(1):55–68. Available from: https://link.springer.com/article/10.1007/BF01866609.

Karr, J. R., E. R. Larson, and E. W. Chu. 2022. Ecological integrity is both real and valuable. Conservation Science and Practice 4(2). Available from: https://conbio.onlinelibrary.wiley.com/doi/10.1111/csp2.583.

Kime, D. E. 1995. The effects of pollution on reproduction in fish. Reviews in Fish Biology and Fisheries 5(1):52–95. Available from: https://link.springer.com/article/10.1007/BF01103366.

Kjelland, M. E., C. M. Woodley, T. M. Swannack, and D. L. Smith. 2015. A review of the potential effects of suspended sediment on fishes: potential dredging-related physiological, behavioral, and transgenerational implications. Environment Systems and Decisions 35(3):334–350. Available from: https://link.springer.com/article/10.1007/s10669-015-9557-2.

Kofinas, G. P., S. B. BurnSilver, J. S. Magdanz, R. Stotts, and M. M. Okada. 2016. Subsistence sharing networks and cooperation: Kaktovik, Wainwright, and Venetie, Alaska. US Department of the Interior, Bureau of Ocean Energy Management. , BOEM 2015-023. Available from: https://www.north-slope.org/wp-content/uploads/2022/04/subsistence_sharing_networks_BOEM-2015-23.pdf.

Kozhevnikov, A. Y., D. I. Falev, S. A. Sypalov, I. S. Kozhevnikova, and D. S. Kosyakov. 2021. Polycyclic aromatic hydrocarbons in the snow cover of the northern city agglomeration. Scientific Reports 11(1):19074. Available from: https://www.researchsquare.com/article/rs-148443/v1.

Kuhnlein, H. V., O. Receveur, R. Soueida, and G. M. Egeland. 2004. Arctic indigenous peoples experience the nutrition transition with changing dietary patterns and obesity. The Journal of Nutrition 134(6):1447–1453. Available from: https://www.sciencedirect.com/science/article/pii/S0022316623028195?via%3Dihub.

Lebedev, A. T., D. M. Mazur, O. V. Polyakova, and O. Hänninen. 2015. Snow samples as markers of air pollution in mass spectrometry analysis. Pages 515–541 *in* R. H. Armon and O. Hänninen, editors. Environmental Indicators. Springer Netherlands, Dordrecht. Available from: https://link.springer.com/chapter/10.1007/978-94-017-9499-2_31.

Leppi, J. C., J. A. Falke, D. J. Rinella, and M. S. Wipfli. 2022a. Landscape geomorphology and local-riverine features influence Broad Whitefish (*Coregonus nasus*) spawning habitat suitability in Arctic Alaska. Ecology of Freshwater Fish 31(4):622–639. Available from: https://onlinelibrary.wiley.com/doi/10.1111/eff.12657.

Leppi, J. C., D. J. Rinella, R. R. Wilson, and W. M. Loya. 2014. Linking climate change projections for an Alaskan watershed to future coho salmon production. Global Change Biology 20(6):1808–1820. Available from: https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.12492.

Leppi, J. C., D. J. Rinella, M. S. Wipfli, R. J. Brown, K. J. Spaleta, and M. S. Whitman. 2022b. Strontium isotopes reveal diverse life history variations, migration patterns, and habitat use for Broad Whitefish (*Coregonus nasus*) in Arctic, Alaska. PloS one 17(5):e0259921. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0259921.

Leppi, J. C., D. J. Rinella, M. S. Wipfli, and A. K. Liljedahl. 2023. Climate Change Risks to Freshwater Subsistence Fisheries in Arctic Alaska: Insights and Uncertainty from Broad Whitefish *Coregonus nasus*. Fisheries (48):295–306. Available from: https://afspubs.onlinelibrary.wiley.com/doi/10.1002/fsh.10918.

Leppi, J. C., D. J. Rinella, M. S. Wipfli, and M. S. Whitman. 2022c. Broad Whitefish (*Coregonus nasus*) isotopic niches: Stable isotopes reveal diverse foraging strategies and habitat use in Arctic Alaska. PloS one 17(7):e0270474. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0270474.

Lynch, A. J., B. J. E. Myers, C. Chu, L. A. Eby, J. A. Falke, R. P. Kovach, T. J. Krabbenhoft, T. J. Kwak, J. Lyons, C. P. Paukert, and J. E. Whitney. 2016. Climate Change Effects on North American Inland Fish Populations and Assemblages. Fisheries 41(7):346–361. Available from: https://afspubs.onlinelibrary.wiley.com/doi/10.1080/03632415.2016.1186016.

Lysenko, D., and S. Schott. 2019. Food security and wildlife management in Nunavut. Ecological economics: the journal of the International Society for Ecological Economics 156:360–374. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0921800918304051?via%3Dihub.

MacPherson, L. M., M. G. Sullivan, A. L. Foote, and C. E. Stevens. 2012. Effects of culverts on stream fish assemblages in the Alberta foothills. North American Journal of Fisheries Management 32(3):480–490. Available from: https://afspubs.onlinelibrary.wiley.com/doi/10.1080/02755947.2012.686004.

Maitland, B. M., M. Poesch, A. E. Anderson, and S. N. Pandit. 2016. Industrial road crossings drive changes in community structure and instream habitat for freshwater fishes in the boreal forest. Freshwater Biology 61(1):1–18. Available from: https://onlinelibrary.wiley.com/doi/10.1111/fwb.12671.

Meador, M. R., and A. O. Layher. 1998. Instream Sand and Gravel Mining: Environmental Issues and Regulatory Process in the United States. Fisheries 23(11):6–13. Available form: https://afspubs.onlinelibrary.wiley.com/doi/abs/10.1577/1548-8446%281998%29023%3C0006%3AISAGM%3E2.0.CO%3B2.

Meek, M. H., M. R. Stephens, and A. Goodbla. 2020. Identifying hidden biocomplexity and genomic diversity in Chinook salmon, an imperiled species with a history of anthropogenic influence. Canadian Journal of Fisheries and Aquatic Sciences. Available from: https://cdnsciencepub.com/doi/abs/10.1139/cjfas-2019-0171.

Meyer, J. L., D. L. Strayer, J. B. Wallace, S. L. Eggert, G. S. Helfman, and N. E. Leonard. 2007. The contribution of headwater streams to biodiversity in river networks[1]. Journal of the American Water Resources Association 43(1):86–103. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1752-1688.2007.00008.x.

Meyer, T., Y. D. Lei, and F. Wania. 2011. Transport of polycyclic aromatic hydrocarbons and pesticides during snowmelt within an urban watershed. Water Research 45(3):1147–1156. https://www.sciencedirect.com/science/article/abs/pii/S0043135410007669?via%3Dihub.

Mickle, M. F., and D. M. Higgs. 2018. Integrating techniques: a review of the effects of anthropogenic noise on freshwater fish. Canadian Journal of Fisheries and Aquatic Sciences 75(9):1534–1541. Available from: https://cdnsciencepub.com/doi/10.1139/cjfas-2017-0245.

Morris, W. 2003. Seasonal movements and habitat use of Arctic Grayling (*Thymallus arcticus*), Burbot (*Lota lota*), and Broad Whitefish (*Coregonus nasus*) within the Fish Creek drainage of the National Petroleum Reserve-Alaska, 2001-2002. Office of Habitat Management and Permitting Alaska Department of Natural Resources, 03–02. Available from: https://www.adfg.alaska.gov/static/home/library/pdfs/habitat/03_02.pdf.

Morris, W. A. 2000, May. Seasonal movements of broad whitefish (*Coregonus nasus*) in the freshwater systems of the Prudhoe Bay oil field. scholarworks.alaska.edu. Available form: https://scholarworks.alaska.edu/handle/11122/6783.

Morris, W. A., L. L. Moulton, J. Bacon, J. R. Rose, and M. S. Whitman. 2006. Seasonal Movements and Habitat Use by Broad Whitefish (*Coregonus Nasus*) in the Teshekpuk Lake Region of the National Petroleum Reserve-Alaska, 2003–2005. Alaska Department of Natural Resources, Office of Habitat Management and Permitting, 06–04. Available from: https://catalog.northslopescience.org/dataset/395.

Moulton, L. L., and T. A. Carpenter. 1985. Colville River fishes: a literature review. Pages 1–33 Colville River fish study. Annual report. Entrix, Inc, Anchorage, AK. Available from: https://northslopescience.org/wp-content/uploads/COLVILLE-RIVER-FISH-STUDY-1985-ANNUAL-REPORT.pdf.

Moulton, L. L., and F. Mueter. 2008. Feasibility study for estimating Broad Whitefish production in tapped lakes of the Colville Delta. ConocoPhillips, Alaska. Available from: https://northslopescience.org/wp-content/uploads/Broad-Whitefish-in-Tapped-Lakes.pdf.

Moulton, L. L., B. Seavey, and J. Pausanna. 2010. History of an Under-Ice Subsistence Fishery for Arctic Cisco and Least Cisco in the Colville River, Alaska. Arctic 63(4):381–390. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/66379.

Myers, B. J. E., A. J. Lynch, D. B. Bunnell, C. Chu, J. A. Falke, R. P. Kovach, T. J. Krabbenhoft, T. J. Kwak, and C. P. Paukert. 2017. Global synthesis of the documented and projected effects of climate change on inland fishes. Reviews in Fish Biology and Fisheries 27(2):339–361. Available from: https://link.springer.com/article/10.1007/s11160-017-9476-z.

Nielsen, J. L., G. T. Ruggerone, and C. E. Zimmerman. 2013. Adaptive strategies and life history characteristics in a warming climate: Salmon in the Arctic? Environmental Biology of Fishes 96(10):1187–1226. Available from: https://link.springer.com/article/10.1007/s10641-012-0082-6.

Packer, D., K. Griffin, and K. E. McGlynn. 2005. National Marine Fisheries Service national gravel extraction guidance : a review of the effects of in- and near-stream gravel extraction on anadromous fishes and their habitats, with recommendations for avoidance, minimization, and mitigation. U.S. Dep. Commerce, NOAA , Technical Memo. NMFS-F/SPO-70. Available from: https://spo.nmfs.noaa.gov/sites/default/files/tm70.pdf.

Penaluna, B. E., G. H. Reeves, Z. C. Barnett, P. A. Bisson, J. M. Buffington, C. A. Dolloff, R. L. Flitcroft, C. H. Luce, K. H. Nislow, J. D. Rothlisberger, and M. L. Warren Jr. 2018. Using natural disturbance and portfolio concepts to guide aquatic–riparian ecosystem management. Fisheries 43(9):406–422. Available from: https://afspubs.onlinelibrary.wiley.com/doi/10.1002/fsh.10097.

Peterson, B. J., R. M. Holmes, J. W. McClelland, C. J. Vörösmarty, R. B. Lammers, A. I. Shiklomanov, I. A. Shiklomanov, and S. Rahmstorf. 2002. Increasing river discharge to the Arctic Ocean. Science 298(5601):2171–2173. Available from: https://www.science.org/doi/10.1126/science.1077445.

Poesch, M. S., L. Chavarie, C. Chu, S. N. Pandit, and W. Tonn. 2016. Climate change impacts on freshwater fishes: a Canadian perspective. Fisheries 41(7):385–391. Available from: https://afspubs.onlinelibrary.wiley.com/doi/10.1080/03632415.2016.1180285.

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The Natural Flow Regime. Bioscience 47(11):769–784. Available from: https://academic.oup.com/bioscience/article/47/11/769/229917.

Popper, A. N., and A. D. Hawkins. 2019. An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. Journal of Fish Biology 94(5):692–713. Available from: https://onlinelibrary.wiley.com/doi/10.1111/jfb.13948.

Price, D. M., T. Quinn, and R. J. Barnard. 2010. Fish passage effectiveness of recently constructed road crossing culverts in the Puget Sound region of Washington state. North American Journal of Fisheries Management 30(5):1110–1125. Available from: https://afspubs.onlinelibrary.wiley.com/doi/10.1577/M10-004.1.

Raynolds, M. K., D. A. Walker, K. J. Ambrosius, J. Brown, K. R. Everett, M. Kanevskiy, G. P. Kofinas, V. E. Romanovsky, Y. Shur, and P. J. Webber. 2014. Cumulative geoecological effects of 62 years of infrastructure and climate change in ice-rich permafrost landscapes, Prudhoe Bay Oilfield, Alaska. Global Change Biology 20(4):1211–1224. Available from: https://onlinelibrary.wiley.com/doi/10.1111/gcb.12500.

Receveur, O., M. Boulay, and H. V. Kuhnlein. 1997. Decreasing traditional food use affects diet quality for adult Dene/Métis in 16 communities of the Canadian Northwest Territories. The Journal of Nutrition 127(11):2179–2186. Available from: https://www.sciencedirect.com/science/article/pii/S0022316623016358?via%3Dihub.

Reist, J. D., F. J. Wrona, T. D. Prowse, M. Power, J. B. Dempson, R. J. Beamish, J. R. King, T. J. Carmichael, and C. D. Sawatzky. 2006a. General effects of climate change on Arctic fishes and fish populations. Ambio 35(7):370–380. Available from: https://bioone.org/journals/ambio-a-journal-of-the-human-environment/volume-35/issue-7/0044-7447(2006)35%5b370%3aGEOCCO%5d2.0.CO%3b2/General-Effects-of-Climate-Change-on-Arctic-Fishes-and-Fish/10.1579/0044-7447(2006)35[370:GEOCCO]2.0.CO;2.short.

Reist, J. D., F. J. Wrona, T. D. Prowse, M. Power, J. B. Dempson, J. R. King, and R. J. Beamish. 2006b. An overview of effects of climate change on selected arctic freshwater and anadromous fishes. Ambio 35(7):381–387. Available from: https://bioone.org/journals/ambio-a-journal-of-the-human-environment/volume-35/issue-7/0044-7447(2006)35%5b381%3aAOOEOC%5d2.0.CO%3b2/An-Overview-of-Effects-of-Climate-Change-on-Selected-Arctic/10.1579/0044-7447(2006)35[381:AOOEOC]2.0.CO;2.short.

Resh, V. H., A. V. Brown, A. P. Covich, M. E. Gurtz, H. W. Li, G. W. Minshall, S. R. Reice, A. L. Sheldon, J. B. Wallace, and R. C. Wissmar. 1988. The role of disturbance in stream ecology. Journal of the North American Benthological Society 7(4):433–455. Available from: https://www.journals.uchicago.edu/doi/10.2307/1467300.

Rothlisberger, J., T. H. Scalley, and R. Thurow. 2017. The role of wild and scenic rivers in the conservation of aquatic biodiversity. International Journal of 23:49–63. Available from: https://www.fs.usda.gov/rm/pubs_journals/2017/rmrs_2017_rothlisberger_j001.pdf.

Schindler, D. E., J. B. Armstrong, and T. E. Reed. 2015. The portfolio concept in ecology and evolution. Frontiers in Ecology and the Environment 13(5):257–263. Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1890/140275.

Schindler, D. E., R. Hilborn, B. Chasco, C. P. Boatright, T. P. Quinn, L. A. Rogers, and M. S. Webster. 2010. Population diversity and the portfolio effect in an exploited species. Nature 465(7298):609–612. Available from: https://www.nature.com/articles/nature09060.

Schoen, E. R., M. S. Wipfli, E. J. Trammell, and D. J. Rinella. 2017. Future of Pacific salmon in the face of environmental change: lessons from one of the world's remaining productive salmon regions. Fisheries 42((10)):538–553. Available from: https://afspubs.onlinelibrary.wiley.com/doi/10.1080/03632415.2017.1374251.

Seigle, J. C., and J. M. Gottschalk. 2013. Fall 2012 subsistence fishery monitoring on the Colville River. ABR. Available form: https://northslopescience.org/wp-content/uploads/Fall-2012-Subsistence-Fishery-Monitoring-on-the-Colville-River.pdf.

Shiklomanov, A. I., R. B. Lammers, M. A. Rawlins, L. C. Smith, and T. M. Pavelsky. 2007. Temporal and spatial variations in maximum river discharge from a new Russian data set. Journal of Geophysical Research (112). Available from: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2006JG000352.

Smith, L. C., T. M. Pavelsky, G. M. MacDonald, A. I. Shiklomanov, and R. B. Lammers. 2007. Rising minimum daily flows in northern Eurasian rivers: A growing influence of groundwater in the high-latitude hydrologic cycle. Journal of Geophysical Research 112(G4). Available from: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2006JG000327.

Smith, R., E. Hitkolok, T. Loewen, A. Dumond, K. Kristensen, and H. Swanson. 2022. Overwintering ecology and movement of anadromous Arctic char (Salvelinus alpinus) in a large, ice-covered river in the Canadian Arctic. Journal of fish biology 100(6):1432–1446. Available from: https://onlinelibrary.wiley.com/doi/10.1111/jfb.15054.

Stanford, J. A., M. S. Lorang, and F. R. Hauer. 2005. The shifting habitat mosaic of river ecosystems. SIL Proceedings, 1922-2010 29(1):123–136. Available from: https://www.tandfonline.com/doi/abs/10.1080/03680770.2005.11901979.

Stuefer, S. L., C. D. Arp, and D. L. Kane. 2017. Recent extreme runoff observations from coastal Arctic watersheds in Alaska. Water Resources Research (53):9145–9163. Available from: https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2017WR020567.

Sutherland, A. B., and J. L. Meyer. 2007. Effects of increased suspended sediment on growth rate and gill condition of two southern Appalachian minnows. Environmental Biology of Fishes 80(4):389–403. Available from: https://link.springer.com/article/10.1007/s10641-006-9139-8.

Tallman, R. F., M. V. Abrahams, and D. H. Chudobiak. 2002. Migration and life history alternatives in a high latitude species, the broad whitefish, *Coregonus nasus* Pallas. Ecology of freshwater fish 11(2):101–111. Available from: https://onlinelibrary.wiley.com/doi/10.1034/j.1600-0633.2002.00001.x.

Tallman, R. F., and K. L. Howland. 2008. Seasonal migration patterns of lower Mackenzie River coregonids. Advances in Limnology 63:133–146.

Trombulak, S. C., and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14(1):18–30. Available from: https://conbio.onlinelibrary.wiley.com/doi/10.1046/j.1523-1739.2000.99084.x.

Viavant, T. 2005. Eastern North Slope Dolly Varden stock assessment. Alaska Department of Fish and game, Fishery Data Series No. 05-07. Available from: https://www.arlis.org/docs/vol1/C/58835909.pdf.

Viavant, T. 2009. Aerial monitoring of Dolly Varden overwintering abundance in the Anaktuvuk, Ivishak, Canning, and Hulahula Rivers, 2006-2008. Alaska Department of Fish and Game, Fishery Data Series 09-21. Available from: https://www.adfg.alaska.gov/FedAidPDFs/FDS09-21.pdf.

Walker, D. A., M. K. Raynolds, M. Z. Kanevskiy, Y. S. Shur, V. E. Romanovsky, B. M. Jones, M. Buchhorn, M. T. Jorgenson, J. Šibík, A. L. Breen, A. Kade, E. Watson-Cook, G. Matyshak, H. Bergstedt, A. K. Liljedahl, R. P. Daanen, B. Connor, D. Nicolsky, and J. L. Peirce. 2022. Cumulative impacts of a gravel road and climate change in an ice-wedge-polygon landscape, Prudhoe Bay, Alaska. Arctic Science. Available from: https://cdnsciencepub.com/doi/10.1139/as-2021-0014.

Walker, D. A., P. J. Webber, E. F. Binnian, K. R. Everett, N. D. Lederer, E. A. Nordstrand, and M. D. Walker. 1987. Cumulative impacts of oil fields on northern alaskan landscapes. Science 238(4828):757–761. Available from: https://www.science.org/doi/10.1126/science.238.4828.757.

Wang, R., S. Tao, B. Wang, Y. Yang, C. Lang, Y. Zhang, J. Hu, J. Ma, and H. Hung. 2010. Sources and pathways of polycyclic aromatic hydrocarbons transported to Alert, the Canadian High Arctic. Environmental Science & Technology 44(3):1017–1022. Available from: https://pubs.acs.org/doi/abs/10.1021/es902203w.

Weber, C., C. Nilsson, L. Lind, K. T. Alfredsen, and L. E. Polvi. 2013. Winter disturbances and riverine fish in temperate and cold regions. Bioscience 63(3):199–210. https://academic.oup.com/bioscience/article/63/3/199/228254?login=false.

West, R. L., M. W. Smith, W. E. Barber, J. B. Reynolds, and H. Hop. 1992. Autumn migration and overwintering of arctic Grayling in coastal streams of the arctic national wildlife refuge, Alaska. Transactions of the American Fisheries Society 121(6):709–715. Available from: https://afspubs.onlinelibrary.wiley.com/doi/abs/10.1577/1548-8659%281992%29121%3C0709%3AAMAOOA%3E2.3.CO%3B2.

Wetzel, D., and P. Mercurio. 2007. Petroleum hydrocarbons in fish and sediments of NPR-A: Teshekpuk lake and Colville and Ikpikpuk rivers. Mote Marine Laboratory, Technical Report 1128. Available from: https://www.north-slope.org/wp-content/uploads/2022/04/Tab_3_Wetzel_and_Mercurio_2007_PAHs_and_HCs.pdf.

Woodward, G., D. M. Perkins, and L. E. Brown. 2010. Climate change and freshwater ecosystems: impacts across multiple levels of organization. Philosophical Transactions of the Royal Society of London 365(1549):2093–2106. Available from: https://royalsocietypublishing.org/doi/10.1098/rstb.2010.0055.

Wrona, F. J., T. D. Prowse, J. D. Reist, J. E. Hobbie, L. M. J. Lévesque, and W. F. Vincent. 2006. Climate change effects on aquatic biota, ecosystem structure and function. Ambio 35(7):359–369. Available from: https://bioone.org/journals/ambio-a-journal-of-the-human-environment/volume-35/issue-7/0044-7447(2006)35%5b359%3aCCEOAB%5d2.0.CO%3b2/Climate-Change-Effects-on-Aquatic-Biota-Ecosystem-Structure-and-Function/10.1579/0044-7447(2006)35[359:CCEOAB]2.0.CO;2.short.

Zimmerman, C. E., A. M. Ramey, S. M. Turner, F. J. Mueter, S. M. Murphy, and J. L. Nielsen. 2013. Genetics, recruitment, and migration patterns of Arctic cisco (*Coregonus autumnalis*) in the Colville River, Alaska, and Mackenzie River, Canada. Polar Biology 36(11):1543–1555. Available from: https://link.springer.com/article/10.1007/s00300-013-1372-y.

3c: Yellow-billed Loon

Highlights:

- The entire yellow-billed loon breeding population within the United States occurs only in Alaska and the majority of the breeding population occurs in well-defined and already identified areas in the Teshekpuk Lake Special Area.
- The highest breeding densities occur primarily in the Special Area but high breeding densities also occur just outside the Special Area within the National Petroleum Reserve.
- Deep expansive lakes with well-defined characteristics including shoreline shape, presence of islands, seasonal connectivity to adjacent streams and rivers, adequate fish prey, and other qualities are the limiting agent on this species' breeding population in Alaska.
- The yellow-billed loon's reproductive success each year occurs within a tight window of time that can be disrupted leading to nest failure by a variety of stressors associated with weather, fluctuating water levels, nest predation, and the presence of human activity and oil field infrastructure including ice road disruption of hydrology, permanent roads, drill pads, vehicle traffic, operation of equipment, nest predator concentrations associated with infrastructure, helicopter and fixed wing air traffic, oil exploration, and human presence.
- Climate change has increased the presence of nest predators through range expansion. Negative impacts on nesting success also occurs through higher temperatures, higher insect densities, and altered hydrologic regimes. These stressors interact with and amplify the cumulative stressors associated with oil field and infrastructure impacts on nesting success.
- Climate change impacts on yellow-billed loon will continue to exert stressors through multiple mechanisms that are often exacerbated and amplified by a range of activities associated with oil field exploration, infrastructure development and use, oil extraction, and transportation to and from oil facilities.
- Adherence to best management practices and enhancement of best management practices related to established and potential nesting lakes associated with the timing and zoning requirements for the establishment of oil exploration, infrastructure, drill site operation, and the operation of machinery and transportation both on the ground and in the air is vital to maintenance of the breeding lake quality and reproductive success of the yellow-billed loon.

Distribution, Population Status, and Overview of Prospects Under Interacting Stressors

The yellow-billed loon (*Gavia adamsii*) is the largest of the world's five species of loon. Breeding populations of all five species occur in Alaska (Uher-Koch et al 2020). The yellow-billed loon breeds in Arctic tundra lakes as do the Pacific loon (*Gavia pacifica*) (Russell 2018), arctic loon (*Gavia arctica*) (Russell 2020), and red-throated loon (*Gavia stellata*) (Rizzolo 2020). The Pacific loon, a direct competitor with the yellow-billed loon on the same breeding lakes, is socially subordinate and typically displaced within large lakes to suboptimal habitat within the lake or to a wholly different tundra lake. The Pacific loon may also nest on forested lakes below latitudinal treeline, while the habitat requirements of the yellow-billed loon preclude this option. (Haynes et al 2014(a), Haynes et al 2014(b), Uher-Koch 2015, Uher-Koch 2020). The common loon (*Gavia immer*) (Paruk 2021), though closely related and sharing many behavioral traits with the yellow-billed loon, including interspecific aggression against other waterfowl species, exclusively uses forested lakes for breeding and therefore does not overlap in breeding lake selection with the yellow-billed loon.

Outside of Alaska, the yellow-billed loon breeds in Eurasian and Canadian Arctic tundra. The state of Alaska lists it as a species of Greatest Conservation need. National Audubon classifies the yellow-billed loon as a Red WatchList Species (Warnock 2017) and IUCN classifies it as "near-threatened" (IUCN 2018). The yellow-billed loon is the rarest loon species in Alaska and internationally with the lowest population numbers and most restricted range worldwide (Schmidt 2014). Its highest breeding densities in Alaska are in the Teshekpuk Special area in the National Petroleum Reserve – Alaska (NPR-A). Teshekpuk Lake is located with the North American Bird Conservation Initiative (NABCI) Bird Conservation Region 3 (BCR 3) and is identified by BirdLife International and U.S. partner, National Audubon, as an Important Bird Area (IBA) of Global Significance (National Audubon Society 2024). Breeding success and population viability of this species in Alaska is dependent upon the ecological integrity of this landscape and its preferred breeding lakes (North 1994, Earnst 2004, Earnst et al 2005, Earnst 2006, Schmutz et al 2014, Johnson et al 2019, Uher-Koch 2020, Parrett et al 2022, Parrett 2023).

The species' world population is estimated to be between 16,000 and 32,000 individuals (Uher-Koch 2020). More than 91 % of the breeding range of the yellow-billed loon in Alaska is located within the northern half of the NPR-A (Earnst 2005). More than 75 % of the approximately 1000 pairs breeding in the NPR-A occur along a broad coastal band of tundra lakes and rivers from Point Lay to the Colville River extending inland to encompass Teshekpuk Lake and the Teshekpuk Lake Special Area (Mallek et al. 2006, Uher-Koch 2020, Parrett 2023). The highest breeding densities (see Figure 3c.1, Yellow-billed Loon Breeding Density for Teshekpuk Lake Special Area) for yellow-billed loon in the Teshekpuk Lake Special Area occur west and southwest of the lake and east of Atqasuk including areas just outside the Teshekpuk Lake Special Area; south of the lake and extending outside the boundary of the Special Area; and southeast and east of the lake and west of Nuiksut up to and beyond the eastern boundary of the NPR-A (Earnst 2004, Earnst et al 2005, Earnst et al. 2006). This latter area is neither in the

Teshekpuk Special Area nor Colville River Special Area but still within the NPR-A. This preferred landscape is such a high density nesting area due to the regular occurrence of its preferred breeding lakes, the integrity of the hydrologic systems connecting the lakes, and lack of high predator densities associated with high densities of human settlement and or industrial development. The availability of these preferred lakes and this landscape are likely limiting this species' population numbers and are therefore of the utmost importance to the population viability of the yellow-billed loon in Alaska (Earnst 2004, Earnst et al 2005, Earnst 2006, Schmutz et al 2014, Johnson et al 2019, Uher-Koch 2020, Parrett et al. 2023(a), Parrett et al. 2023(b))

Climate change stressors such as heat and altered hydrology are already exerting negative impacts on the species' breeding success in Alaska (Parrett 2023(a), Parrett et al 2023(b)). While climate change impacts are underway and predicted to worsen (Arp 2019) there are activities associated with the Petroleum industry that interact and magnify these climate change effects. These include direct human disturbance, direct anthropogenic effects (on top of climate change) on the landscape's hydrology, and human refuse driven subsidization of nest predator populations (on top of climate change induced range expansions), all demonstrably linked to reduced nesting success in a population that cannot afford another additive and cumulative challenge (Earnst et al 2005, Earnst 2006) Parrett et al. 2023(a), Parrett et al. 2023(b)).

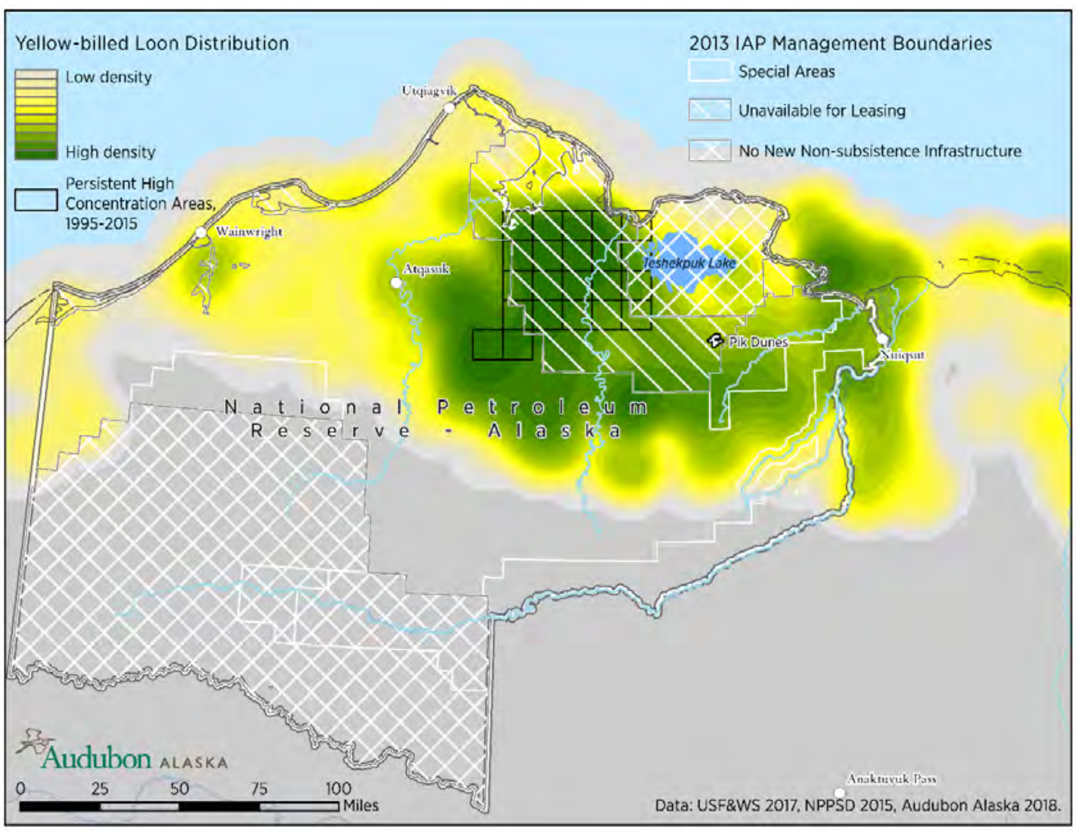

Figure 3c.1. Yellow-billed Loon breeding density within the Teshekpuk Lake Special Area.

Breeding Ecology

Mature breeding pairs of yellow-billed loon arrive in northern Alaska on the NPR-A in the vicinity of Teshekpuk Lake Special Area and the Colville River in late May to early June while the nonbreeding population primarily consisting of unpaired loons aged less than three years arrive approximately two weeks later (Earnst 200, Schmutz 2014, Johnson 2019, Uher-Koch 2020). The early arriving territory holding breeding adults make up approximately 80% of the total population, the balance being those individuals in their first several years after hatch year. Members of a breeding pair typically return to the previous year's territory thereby returning to the same mate as well. Arrival usually precedes formation of an ice free moat along the lake margin thus they use neighboring streams and rivers until their chosen lake opens up which they determine through repeated monitoring flights from their temporary base of available open water on the nearby riparian system. As these neighboring streams and rivers are also important to fish prey stock replenishment of the breeding lakes, it is important to think of high density breeding areas in terms of a landscape mosaic of lakes, rivers, and tundra centered on the larger, preferred breeding and brooding lakes.

Nests are constructed and incubation initiated by mid to late June. Both parents take turns incubating such that eggs are covered by an adult approximately 95 % of the time. Incubation lasts approximately 30 days leading to hatching in the middle of July. Young leave the nest within several days of hatching and remain dependent upon adult food provisioning past 45 days. Young are capable of swimming upon leaving the nest. If the nest is not on a preferred nesting lake that can meet food provisioning needs the adults will lead the young across tundra vegetation to the adjacent feeding lake or lakes; both young and adult skidding on their breast and propelling themselves with their legs. Adults do not bring food to young from a different water body, therefore, all feeding occurs on the brood lake whether that lake was also the nesting lake (the preferred condition) or a separate brooding lake accessed post hatching. Both parents feed the young at rates as high as 0.3 to 1 food items per minute per chick (Parrett 2023(a)). Young are capable of flying at 8 to 12 weeks after hatching, or approximately mid to late September (North and Ryan 1988, North 1994, Earnst 2004). A pair produces 1 to 2 eggs (North and Ryan 1988) and are not likely to have a second clutch even in the event of a failed first attempt as limited available time does not permit a second attempt.

Preferred Habitat Attributes

The focal feature of their territory is preferentially a single large and deep lake, large being defined as 65 -750 ha and deep as greater than 4 m (Earnst 2006). Earnst (2006), reports that lakes greater than 4 meters deep were 13 times more likely to have a breeding pair of yellow-billed loon than shallow lakes (<1.6 m), while lakes defined as medium depth (1.6 m to 4 m) were 4.7 times more likely to have a mated pair of territory holders than shallow lakes. The largest lakes (up to 6 x larger than lakes with a single pair) may have several territorial pairs, with one lake in a study in the Colville Delta supporting 4 territorial pairs for three years (Johnson et al 2019). One study documented the importance of Alaska blackfish and whitefish on the breeding territory and three-spined stickleback on coastal staging areas and also reported 8 other fish species; arctic flounder, arctic grayling, burbot, least cisco, ninespine stickleback, northern pike, rainbow smelt, and slimy sculpin, and two invertebrate groups (amphipods and fairy shrimp) (Haynes 2015). Small lakes (defined as less than 60 ha) with hydrological connectivity (defined as a stream within 100 meters) were reported to be 1.7 to 4.8 times likely to have a mated pair of territory holding yellow-billed loons than small hydrologically isolated lakes due to the potential for streams to restock the lake with fish prey periodically under flood conditions outside of the breeding season (Earnst 2006). Persistent tapping of a lake by a channel that permits chronic water fluctuation, however, is not desirable. It is important for the water level around the nest site to remain constant so as not to inundate the nest with high water nor strand it by receding lake levels (Johnson et al 2019).

Other preferred lake characteristics include highly convoluted shoreline, peninsulas with vegetation cover, and islands with open views (North and Ryan 1989, North 1994, Earnst 2006). Islands and peninsulas are favored for nest sites as they afford good visibility of approaching predators and are more easily defended and indeed have higher nesting success (Bergman and Derksen 1977, Petersen 1979, North and Ryan 1989, Earnst 2006). Other preferred characteristics of territorial breeding lakes include limited exposure to long open fetches of prevailing wind and waves and broken ice fetch as both can destroy active nests and prevent reproductive success that year as second replacement clutches are highly unlikely (North and Ryan 1989, Earnst 2006, Haynes 2014, Johnson et al 2019).

Yellow-billed loon pairs are territorial and defend territories vigorously against not only conspecifics but a closely related and competing species, the Pacific loon (Haynes et al 2014, Uher-Koch 2019, Uher-Koch 2020). Interspecific and intraspecific competition is vocal and physical, and possibly fatal as is reported for the closely related common loon (Piper 2008). In any case, these frequent territorial contests are a naturally occurring stressor on the nest attendance and brood caring time budget that are further evidence for the limiting nature of the preferred habitat. Interspecific competition with the Pacific loon may begin earlier than the intraspecific with young, unpaired yellow-billed loons. It typically results in displacement of the socially subordinate Pacific loon either to another lake altogether or to a suboptimal and uncontested surplus region of the larger lakes. Interspecific and intraspecific competition may recur throughout the breeding season and is understood to be one of several sources of nest site disturbance and potential reproductive failure along with predation, heat, insects, and fluctuating water levels (Uher-Koch 2020, Uher-Koch 2019, Parrett et al. 2023, Haynes et al 2014). The median radius for territory size of the breeding lake and in some cases adjacent brooding lake and closely associated stream system in the NPR-A is 0.69 km (Schmutz et al 2014). This may include the entirety of a larger lake or just part of larger lakes, both preferred over using separate lakes for nesting and brooding (Johnson et al 2019).

Managing Risk of Unavoidable and Avoidable Interacting Stressors on Habitat and Reproductive Output

Available nesting habitat for the yellow-billed loon is likely limiting the breeding population in Alaska resulting in recruitment balancing mortality (Earnst 2004, Earnst et al. 2005, Schmutz 2014). The quality of its breeding habitat is already suffering the effects of climate change and impacts are likely to intensify. Relatively low population numbers in Alaska and worldwide relative to the other four species of loon make this animal vulnerable to extinction. A credible risk of extinction calls for exercising precaution regarding those activities that can be mitigated such as those associated with petroleum extraction. The major impediment to reproductive success is reduced attendance at the nest by incubating adults leading to compromised egg viability, outright abandonment, and predation (Parrett et al 2023). A combination of climate change and anthropogenic development stressors can interact and reduce nest attendance.

Climate change has expanded the range of nest predators such as the red fox, a predator capable of flushing adults from the nest unlike the native arctic fox which can only depredate an unguarded nest as they are not capable of flushing an adult (Parrett 2023(b)). The red fox is additionally expanding its range due to subsidization by human settlement including oil field development facilities (Johnson et al 2019, McGuire et al 2023, Parrett 2023(b)). Another nest predator whose subsidization by human development including oil field development is the Glaucous Gull. The Glaucous Gull is not capable of flushing an adult but like the arctic fox or parasitic jaeger, will take advantage of an unguarded nest. (Parrett et al 2023a, Parrett et al 2023b). Increasing intensity and frequency of warm days and biting insects also can contribute to lowered nest attendance thus creating an opportunity for those smaller predators to depredate an unguarded nest (Parrett et al 2023a, Parrett et al 2023b). Lower nest attendance also facilitates nest failure through greater direct exposure to heat, cold, and precipitation.

Over the last 35 years evaporation has been exceeding precipitation at an increasing rate leading to more rapid decrease in water levels of lakes over summer due to climate change (Earnst 2004, Arp et al 2011, Arp 2019). Dropping water levels may lead to nest inaccessibility while heavier precipitation events may cause nest flooding (Haynes 2014). In either case, more extreme and unpredictable climate change induced episodes of flooding and evaporation (Arp 2019) are yet another stressor on yellow-billed loon breeding ecology that can lead to reproductive failure through nest abandonment or failure to establish the nest in formerly preferred locations. These unpredictable events and stressors are unavoidable, yet similar negative effects on nest site availability associated with water drawdown for hydrological fracturing and construction of ice roads and delayed ice road melting are avoidable. Delayed ice road melting can lead to nest site flooding and nest failure (Earnst 2004, Arp 2011, Arp 2023). Delayed ice road melt off on a breeding lake can also delay lake availability. Even short delays to loon nest establishment could mean reproductive failure that year. Recalling that breeding pairs time their arrival such that they are on their territory before there is even an open moat of ice on their focal lake and that successful fledging of young if it does occur is not until mid-September, it is apparent that weeks and even days matter. It is no trivial concern then that delayed melting of ice roads or delayed nest site availability from melt water flooding could be significant to the overall timing of the tight breeding season (Earnst 2004). Moreover, delayed melting and flooding could occur after nest initiation leading to direct loss of eggs.

A range of management guidelines may be undertaken to mitigate petroleum development stressors on yellow-billed loon reproductive success. These guidelines can be broadly classified according to the timing and location of various activities associated with exploration, development of infrastructure, actual extraction, and transportation of people and materials by land and air across the tundra and lakes. Since the breeding season spans May through September, the remaining months are preferable for conducting disruptive activities such as seismic exploration and gravel road and drill pad construction that are particularly disruptive to the behavior and breeding success of yellow-billed loons. In contrast to restrictions on the timing of disruptive industrial activity, the permanent development of infrastructure, drill sites, and living quarters leave a fixed footprint that must be mitigated by spatial separation zones. Other infrastructure such as ice roads leave a temporary but potentially consequential footprint as well. This footprint includes the water drawn down to build pads and roads and the delayed melting of the pads and roads (Earnst 2004, Arp 2019). Water removal from shallow lakes can impact the winter survivorship of fish prey. At the onset of the breeding season delayed melting of the ice roads and pads can lead to pulses of water that may impact nest site establishment or cause abandonment through flooding (Earnst 2004, Arp 2019).

Management Recommendations

Prudent risk management (Aplet and McKinley 2017) given the limited population size of the yellow-billed loon, limited preferred habitat, highly uncertain interacting effects from a changing climate and pressures from petroleum field development warrant strict adherence and improvement to all recommended BLM best management practices regarding yellow-billed loon nesting lakes and the greater landscape. There is a strong case to simply take the Teshekpuk Lake special area out of the pool of available lands for petroleum lease or subject to any temporary or permanent infrastructure development for the continued viability of this breeding population.

Established best management practices mandate that permanent facilities must be located > 1.6 km from nest sites and > 500 m from the shorelines of nesting lake (Earnst 2004). Earnst (2004) reports loons will leave their nests when humans approach at approximately 1.6 km which suggests that this distance is inadequate as the stressors leading to flushing of an animal typically occur prior to the actual flushing event. The management objective should be to avoid stressors, not simply the flushing behavior. While Johnson et al (2019) suggest that though this distance may have been sufficient to ensure territory occupancy of the limited population they observed in their particular study they acknowledge the high uncertainty around the efficacy of this prescription regarding incubation behavior and nesting and fledging success (Johnson et al 2019). They further suggest that these breeding behaviors and breeding success may very well be more sensitive than territory occupancy to aircraft flight, traffic, and construction and operation of facilities. Caron and Robinson (1994) observed common loons on lakes with more human activity spending more time off their nests and Titus and Vandruff (1981) observed lower productivity of common loons associated with increased human activity and development. Behavioral stressors on birds can be cumulative and additive and taken in sum lead to more frequent incubation interruptions to incubation, brooding, and feeding or increase duration of time away from the nest and thus increase the probably of predation (Parrett 2023(a)).

Established best management practices also require at least 3 years of aerial surveys with 2 surveys per year searching for nests and broods on lakes thought to be unoccupied that are greater than 10 ha in size and less than or equal to 1.6 km from the construction of a new permanent facility. As established in this report, 10 ha is on the smaller side when considering preferred lakes. Under future climate change scenarios, however, small lakes may increase in areal extent and depth (Haynes et al 2014) thus increasing or improving yellow-billed loon habitat in some cases. It is worth considering longer periods of prohibited construction for new permanent facilities on lakes currently under 10 ha to allow evaluation for breeding activity on these smaller as yet unoccupied lakes that might become higher quality habitat in the coming years.

Taking a precautionary approach, the existing requirement that heavy construction of gravel roads, pads, pipelines, and oil exploration occur outside of the breeding season is an important bmp to follow. The buffer zone of 1.6 km for permanent facilities is not likely adequate to prevent the disturbance of yellow-billed loon nesting sites from nest predators such as the glaucous gull and red fox drawn to facilities as these predators search much larger areas during their foraging bouts. The buffer of 500 m for the location of permanent facilities with respect to the shore of a nesting lake is inadequate as foraging adults and fledged young could be anywhere on the lake and therefore within the established 1.6 km zone of identified as a threshold distance associated with stress. The bmp regarding minimum aircraft flight elevations of 305 m (with the exception of wildlife survey flights) is the minimum advisable standard given that human activity is deemed adversely significant at distances < 1.6 km. Similarly the bmp for the establishment of a permanent road should require that it not pass within 1.6 km of a nest site or nesting lake similar to the bmp for drill pads based on this rationale.

The effects of delayed ice melting from ice roads deserves more attention from best management practices. Establishing buffer zones for ice roads with respect to entire lake shores could help to mitigate the impacts of delayed melting and prolonged flooding of nest sites. It is incumbent on the industry and collaborators to model the trajectory of these effects according to different scenarios of ice road proximity and water volumes used. Water volume removed is of course an additional concern and regulated for the sake of the fish prey communities needed by the yellow-billed loon.

Another creative strategy might be to develop an index that relates reproductive success to various lake parameters to use as a guideline for more precautionary bmp zones for high quality lakes, whether occupied or unoccupied. In such a system higher scoring lakes would qualify for more conservative bmps. A still more cautious approach would be to make the highest density nesting landscape areas including lake, river, and tundra systems that incorporates multiple yellow-billed loon territories completely off limits to petroleum development of any kind.   It is the only reliable manner by which we can mitigate the many interacting, cumulative, and additive impacts on yellow-billed loon reproductive success.

Loon literature cited

Aplet, G.A., P.S. McKinley 2017. A portfolio approach to managing ecological risks of global change. Ecosystem health and sustainability. Volume 3 Issue 2, February. E01261. Available from: https://spj.science.org/doi/10.1002/ehs2.1261.

Arp, C.D., B. M. Jones, F.E. Urban and G. Grosse 2011. Hydrogeomorphic processes of themokarst lakes with grounded-ice and floating-ice regimes on the Arctic Coastal Plain, Alaska. Hydrological Processes 25: 2422-2238. Available from: https://onlinelibrary.wiley.com/doi/10.1002/hyp.8019.

Arp C.D., M.S. Whitman, B. M. Jones, D.A. Nigro, V.A. Alexeev, A. Gadeke, S. Fritz, R. Daanen, A.K. Liljedahl, F.J. Adams, B. V. Gagliotie, G. Grosse, K. C. Heim, J. R. Beaver, L. Cai, M. Engram, H. R. Uher-Koch 2019. Ice roads through lake-rich Arctic watersheds: integrating climate uncertainty and freshwater habitat responses in to adaptive management. Arctic, Antarctic, and Alpine Research, 51:1, 0-23, DOI 10.1080/15230430.2018.1560839. Available from: https://www.tandfonline.com/doi/full/10.1080/15230430.2018.1560839.

Bergman, R.D. and D.V. Derksen 1977. Observations on Arctic and Red-throated loons at Stokersen Point, Alaska. Arctic 30:41-51. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/65734.

BirdLife International. 2018. *Gavia adamsii*. *The IUCN Red List of Threatened Species* 2018: e.T22697847A132607949. Available form: https://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T22697847A132607949.en Accessed on 05 August 2024.

Carron, J. A. Jr., and W.L. Robinson. 1994. Responses of breeding common loons to human activity in upper Michigan. Hydrobiologia 279/280:431-438.

Earnst, S.I. 2004. Status Assessment and conservation plan for the yellow-billed loon (*Gavia adamsii*) U.S. Geological Survey, Scientific Investigations Report 2004-5258, 42 p. Available from: https://pubs.usgs.gov/publication/sir20045258.

Earnst, S.I. R.A. Stehn, R. M. Platte, W. W. Larned, E. J. Mallek 2005. Population size and trend of yellow-billed loons in northern Alaska. Condor 107:289-384. The Cooper Ornithological Society. Available from: https://academic.oup.com/condor/article/107/2/289/5563707?login=false.

Earnst, S.I., R. Platte, L. Bond 2006. A landscape-scale model of yellow-billed loon (*Gavia adamsii*) habitat preferences in northern Alaska. Hydrobiologia 567:227-236. A.R. Hanson, J. J. Kerekes (eds.) Limnology and aquatic birds. DOI 10.1007/s10750-006-0042-2. Available from: https://link.springer.com/article/10.1007/s10750-006-0042-2.

Haynes, T. B., J.A. Schmutz, M.S. Lindbergh, A.E. Rosenberger 2014(a). Risk of predation and weather events affect nest site selection by sympatric Pacific (*Gavia pacifica*) loons and yellow-billed (*Gavia adamsii*) loons in Arctic habitats. Waterbirds 37 (Special Publication 1): 16-25. Available from: https://bioone.org/journals/waterbirds/volume-37/issue-sp1/063.037.sp104/Risk-of-Predation-and-Weather-Events-Affect-Nest-Site-Selection/10.1675/063.037.sp104.short.

Haynes, T.B., A. Schmutz, M.S. Lindbergh, K.G. Wright, B.D. Uher-Kock, A.E. Rosenberger 2014(b). Occupancy of yellow-billed and Pacific loons: evidence for interspecific competition and habitat mediated co-occurrence. Journal of Avian Biology 45.001-009, March. Available from: https://nsojournals.onlinelibrary.wiley.com/doi/epdf/10.1111/jav.00394.

Haynes, T.B., J.A. Schmutz, J.F. Bromaghin, S.J. Iverson, V.M. Padula, A.E. Rosenberger 2015. Diet of yellow-billed loons (*Gavia* adamsii) in Arctic lakes during the nesting season inferred from fatty acid analysis. Polar Biology DOI 10.1007/s00300-015-1690-3. Available from: https://link.springer.com/article/10.1007/s00300-015-1690-3.

Johnson, D.B., A.M. Wildman, A.K. Prichard, C.L. Rea 2019. Territory occupancy by breeding yellow-billed loons near oil development. The journal of wildlife management 83(2):410-425; DOI : 10.1002/jwmg.21592. Available from: https://wildlife.onlinelibrary.wiley.com/doi/10.1002/jwmg.21592.

McGuire, Rebecca., L., Martin Robards, and Joseph R. Liebezeit. 2023. Patterns in avian reproduction in the Prudhoe Bay Oilfield, Alaska, 2003-2019. Journal of avian biology. eo3o75. Available from: https://nsojournals.onlinelibrary.wiley.com/doi/10.1111/jav.03075.

National Audubon Society. 2024. Important Bird Areas Database, Boundary Digital Data Set. Available from: https://gis.audubon.org/portal/apps/sites/?_gl=1*y46er7*_gcl_au*MTk2ODQ1ODM0MS4xNzIzODI0NjUx*_ga*MTQzNjgwNjMyNy4xNzIzODI0NjUy*_ga_X2XNL2MWTT*MTcyMzgyNDY1MS4xLjAuMTcyMzgyNDY1MS42MC4wLjA.#/nas-hub-site.

North, M.R., M.R. Ryan 1988. Yellow-billed loons, (*Gavia adamsii*) breeding chronology and reproductive success in arctic Alaska. Canadian field-naturalist 102:485-490.

North, M.R., M.R. Ryan 1989. Characteristics of lakes and nest sites used by yellow-billed loons (*Gavia adamsii*) in arctic Alaska. Journal of field ornithology 60:296-304. Available from: https://www.jstor.org/stable/4513443.

Parrett, J. P. A. K. Prichard, C. B. Johnson, and B. R. Lawhead 2023(a). An ongoing shift in mammalian nest predators of yellow-billed loons in arctic Alaska. Arctic. Vol. 79. No. 1 (March 2023) P. 14-25. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/76945.

Parrett, J. P., C. B. Johnson, A. E. Gall, A.K. Prichard 2023(b). Factors influencing incubation behavior and nesting success of yellow-billed loons in arctic Alaska. The journal of wildlife management. 2023:e22406. DOI 10.1002/jwmg.22406. Available from: https://wildlife.onlinelibrary.wiley.com/doi/10.1002/jwmg.22406.

Paruk, J. D., D. C. Evers, J. W. McIntyre, J. F. Barr, J. Mager, and W. H. Piper (2021). Common Loon (*Gavia immer*), version 2.0. In Birds of the World (P. G. Rodewald and B. K. Keeney, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. Available from: https://doi.org/10.2173/bow.comloo.02

Piper, W.C., W.J. Mager, F. Spilker 2008. Fatal battles in common loons: a preliminary analysis, Animal behavior. 75:1109-1115 Available from: https://www.sciencedirect.com/science/article/abs/pii/S0003347207005969?via%3Dihub.

Rizzolo, D. J., C. E. Gray, J. A. Schmutz, J. F. Barr, C. Eberl, and J. W. McIntyre (2020). Red-throated Loon (*Gavia stellata*), version 2.0. In Birds of the World (P. G. Rodewald and B. K. Keeney, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. Available from: https://doi.org/10.2173/bow.retloo.02.

Russell, R. W. (2020). Arctic Loon (*Gavia arctica*), version 1.0. In Birds of the World (S. M. Billerman, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. Available from: https://doi.org/10.2173/bow.arcloo.01

Russell, R. W. (2020). Pacific Loon (*Gavia pacifica*), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. Available from: https://doi.org/10.2173/bow.pacloo.01

Schmidt, J. H., M.J. Flamme, J. Walker 2014. Habitat use and population status of yellow-billed and Pacific loons in western Alaska, USA. Condor, Ornithological applications Volume 116, pp. 483-492 DOI: 10.1650/condor-14-28.1. Available from: https://academic.oup.com/condor/article/116/3/483/5153150?login=false.

Schmutz, J. A., K. G. Wright, C. R. DeSorbo, J. Fair, D.D. Evers, B.D. Uher-Koch, and D.M. Mulcahy. 2014. Size and retention of breeding territories of yellow-billed loons (Gavia adamsii) in Alaska and Canada. Waterbirds 37 (sp 1); 53-63. Available from: https://bioone.org/journals/waterbirds/volume-37/issue-sp1/063.037.sp108/Size-and-Retention-of-Breeding-Territories-of-Yellow-Billed-Loons/10.1675/063.037.sp108.short.

Titus, J. R., and L.W. VanDruff. 1981. Response of the common loon to the recreational pressure int eh Boundary Waters Canoe Area, northeastern Minnesota. Wildlife Mongraphs No. 79. Available from: https://www.proquest.com/docview/302980098.

Uher-Koch, B. D., M. R. North, and J. A. Schmutz (2020). Yellow-billed Loon (*Gavia adamsii*), version 1.0. In Birds of the World (S. M. Billerman, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. Available from: https://doi.org/10.2173/bow.yebloo.01

Uher-Koch, B. D., J.A. Schmutz, K. G. Wright 2015. Nest visits and capture events affect breeding success of yellow-billed and Pacific loons. Condor, ornithological applications Volume 117, pp. 121-129. DOI 10.1650/condor-14-102.1. Available from: https://academic.oup.com/condor/article/117/1/121/5153158.

Uher-Koch, B. D., K. G. Wright, J. A. Schmutz 2019. The influence of chick production on territory retention in Arctic-breeding Pacific and Yellow-billed loons. Condor 121, pp.1-11. DOI: 10.1093/condor/duy/021. Available from: https://bioone.org/journals/the-condor/volume-121/issue-1/duy021/The-influence-of-chick-production-on-territory-retention-in-Arctic/10.1093/condor/duy021.short.

Uher-Koch, B. D., K.G. Wright, H. R. Uher-Koch, J.A. Schmutz 2020. Effects of fish populations on Pacific loon (*Gavia pacifica*) and yellow-billed loon (*Gavia adamsii*) lake occupancy and chick production in northern Alaska. Arctic. Volume. 73, No. 4 (December) P. 450-460. DOI: 10.14430.arctic71533. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/71533.

Warnock N. 2017. The Alaska WatchList 2017. Audubon Alaska, Anchorage, AK. Available from: https://ak.audubon.org/sites/default/files/watchlist_2017_-_technical_report.pdf.

3d: Shorebirds

Highlights:

- North American shorebirds are declining, including almost all of the species that breed in the NPR-A.
- The NPR-A is of worldwide importance to breeding shorebirds with some of the highest densities and diversity of breeding shorebirds in the circumpolar Arctic.
- Within the NPR-A, the Teshekpuk Lake Special Area supports the highest diversity and density of shorebirds.
- The area, including BLM's Qupałuk EAAFP Flyway Network Site, is particularly important to Dunlin (*Calidris alpina arcticola)*.
- Up to 19% of the global population of *C. a. arcticola* breed within the Teshekpuk Lake Special Area.
- *C. a. arcticola* is a declining species that has long been noted as being sensitive to disturbance and structures (roads and facilities) within the Prudhoe Bay area.
- Roadless development should be required within areas important to Dunlin and other shorebirds (see areas in blue, Figure 3d.1).
- Development should avoid lower elevation moist to wet meadow habitats due to their importance to breeding shorebirds.
- Potential shorebird predators should be minimized including restricting trash to centralized, covered locations and minimizing structures used by predators, particularly Arctic Fox.

Global status of North American shorebirds

Worldwide, challenges to shorebird populations are increasing (Munro 2017, Pearce-Higgins et al. 2017, Warnock et al. 2021), with negative population consequences throughout the flyways (Bart et al. 2007, Gratto-Trevor et al. 2011, Simmons et al. 2015, Clemens et al. 2016, Smith et al. 2023). In a summary of trends of North American breeding birds from 1970 through about 2018 (Rosenberg et al. 2019), total numbers of shorebirds as a group declined by 37%, with local and regional declines of North American wintering populations of shorebirds reaching as high as 66% (Warnock et al. 2021). In a more recent analysis of shorebird migration monitoring data from across North America covering 1980 to 2019, it was found that 26 of 28 (93%) shorebird species declined, and declines appear to be accelerating in recent years (Smith et al. 2023).

Importance of shorebirds for Arctic Communities

There is an indigenous harvest of thousands of shorebirds per year in Alaska but on the North Slope of Alaska harvest numbers of shorebirds and their eggs is in the low hundreds (Naves et al. 2019). Preferred species are small shorebirds and their eggs and small numbers of Black-bellied/Golden plovers (Naves et al. 2019).

Importance of Alaska and Arctic Coastal Plain to North American shorebirds

Alaska as a state had a disproportionate responsibility for global flyway populations as it is at the northern ends of 5 major bird flyways, the East Asian Australasian Flyway, the Central Pacific Flyway, the Pacific Americas Flyway, the Central America Flyway, and the Atlantic Americas Flyway from which shorebirds come to breed in the millions of birds. Of over 200 shorebird species in the world, over 70 species have been detected in Alaska, and 29 species breed in the Arctic Coastal Plain and mountains (BCR region 3) (Alaska Shorebird Group 2019). Between 7 to 12 million shorebirds occur in Alaska, roughly 50% of all the shorebirds that occur in North America (https://www.fws.gov/office/alaska-migratory-birds/shorebirds-alaska). Alaska's Arctic Coastal Plain, which encompasses the NPR-A has been known as an important breeding region for shorebirds, and especially waterfowl, for a long time (e.g. see references in Pitelka 1974, Johnson and Herter 1989). However, shorebirds are more difficult to count from aerial surveys than waterfowl and generally require ground surveys to get accurate species counts (Andres et al. 2012). The most recent and complete attempts to systematically estimate the distribution and abundance of Alaska's Arctic Coastal Plain including the NPR-A occurred between 1992-2005 through a combination of ground and aerial efforts (summarized in Bart et al. 2012). Perhaps half of Alaska's shorebirds breed on the Arctic Coastal Plain of Alaska, where an estimated 6.3 million shorebirds nest (Bart et al. 2013).

SAALFELD ET AL.

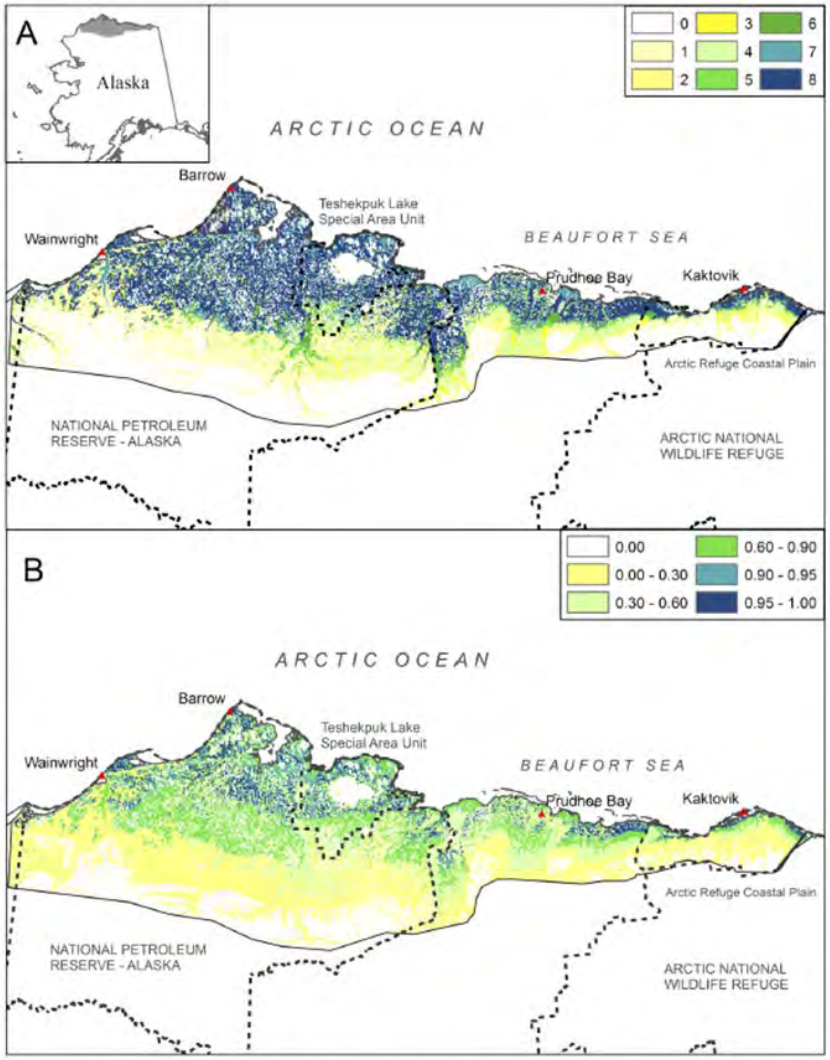

Fig. 2. (A) predicted species richness (i.e., number of shorebird species exceeding selected threshold values) and (B) mean habitat suitability index for eight shorebird species (i.e., Black-bellied Plover [*Pluvialis squatarola*], American Golden-Plover [*Pluvialis dominica*], Semipalmated Sandpiper [*Calidris pusilla*], Pectoral Sandpiper [*Calidris melanotos*], Dunlin [*Calidris alpina*], Long-billed Dowitcher [*Limnodromus scolopaceus*], Red-necked Phalarope [*Phalaropus lobatus*], and Red Phalarope [*Phalaropus fulicarius*]) in relation to administrative boundaries (dashed lines) and study area (solid line) in the Arctic Coastal Plain of Alaska, USA, 1998–2008.

Figure 3d.1. Predicted bird species richness (From Saalfeld et al. 2013a. Data source: https://www.sciencebase.gov/catalog/item/5a300b8ee4b08e6a89d57d1c).

Importance of the NPR-A to breeding shorebirds

Of Arctic Coastal Plain breeding shorebirds, an estimated 72% of them nest in the NPR-A (over 4.5 million birds) (Bart et al. 2012, Bart et al. 2013). Alongside Alaska's Yukon-Kuskokwim Delta (Lyons et al. 2024), this is one of the greatest concentrations of breeding shorebirds and other aquatic birds in the circumpolar Arctic (Bart et al. 2012, Bart et al. 2013). Numerically dominant species that breed in the NPR-A include Semipalmated Sandpiper, Pectoral Sandpiper, Long-billed Dowitcher, Red and Red-necked Phalarope, and Dunlin (Bart et al. 2012) (Table 3d.1).

Within the NPR-A, the distribution of shorebirds is not uniform (King 1979, Andres et al. 2012, Bart et al. 2012, Bart et al. 2013, Saalfeld et al. 2013a). There is an east to west density gradient, with higher overall densities of shorebirds occurring westward, and a south to north density gradient with higher overall shorebird densities closer to the coast (King 1979, Andres et al. 2012, Bart et al. 2012, Bart et al. 2013, Saalfeld et al. 2013a). Within the NPR-A, some of the highest predicted shorebird species richness values and mean habitat suitability indexes occur around Teshekpuk Lake and west and north from there over to Wainwright (See Figure 3d.1).

Table 3d.1. Most common shorebirds in the National Petroleum Reserve – Alaska (from Bart et al. 2012) and in the Teshekpuk Lake Special Area (from Andres et al. 2012) with population estimates and rank in abundance.

	NPR-A	Rank	Teshekpuk Lake	Rank
Semipalmated Sandpiper	902819	1	149889	1
Pectoral Sandpiper	745179	2	68732	5
Long-billed Dowitcher	499030	3	32678	6
Red Phalarope	427952	4	102026	2
Red-necked Phalarope	402491	5	69103	4
Dunlin	376370	6	95245	3
Western Sandpiper	320451	7	-	-
Black-bellied Plover	142288	8	26623	7
American Golden Plover	131827	9	18113	8
Stilt Sandpiper	72130	10	5394	9
Bar-tailed Godwit	62494	11	998	13
Buff-breasted Sandpiper	21788	12	1258	11
Whimbrel	13520	13	-	-
Ruddy Turnstone	2240	14	2016	10

Current data on the status and trends of shorebirds suggest that almost all of the species that use the NPR-A are declining in at least parts of their distribution, and declines may be accelerating (Piersma et al. 2016, Ruthrauff et al. 2021, Warnock et al. 2021, Smith et al. 2023). Of particular concern has been severe declines in the race of Dunlin that breed in northern Alaska, *Calidris alpina arcticola* (Weiser at al. 2020). While causes for the decline are thought to mainly be due to habitat loss at its East Asian non-breeding sites (Weiser et al. 2020), it is also a species thought to be especially sensitive to effects of oil development (Meehan 1986 in Troy and Wickliffe 1990).

Special Areas

***Teshekpuk Lake Special Area* –** The Teshekpuk Lake Special Area was designated as a special area in part because of its importance to breeding shorebirds. Andres et al. (2012) first surveyed the special area for shorebirds, following Bart et al.'s shorebird surveys of shorebirds across the entire Arctic Coastal Plain of Alaska (Bart et al. 2012 Arctic Shorebirds in North America), and recognized the area, particularly the Outer Coastal Plain region including Teshekpuk Lake, as being one of the most important breeding areas for shorebirds across the Arctic based on the high breeding shorebird densities within the area. Up to 19% of the global race of Dunlin, *Calidris alpina arcticola*, a declining species, may breed here (Figure 3d.1) , as well as 10% of Black-bellied Plover of the race *Pluvialis squatarola squatarola*, 10% of the western population of Semipalmated Sandpipers, and 16% and 12% of the northern Alaska population of Red and Red-necked Phalaropes, respectively (Andres et al. 2012, see also Table 3d.1).

In the Teshekpuk Lake Special Area, increased wetness of the landscape was associated with increased importance to breeding shorebirds (Andres et al. 2012). Densities of shorebirds in the Outer Coastal Plain were 42% higher in areas with ≥14% aquatic cover type vs areas with ≤14% cover type; in the Inner Coastal Plain, areas with wetlands covering >43% of the area had 3.7 x the densities of areas with wetlands covering ≤43% of the area (Andres et al. 2012). Some of the highest densities of shorebirds occurred along the eastern, southern, and south-eastern corner of Teshekpuk Lake (Fig. 2 in Andres et al. 2012). Mirroring Andres et al.'s (2012) findings, Saalfeld et al (2013a) found that lower elevation areas with moist to wet habitat held the highest numbers and densities of shorebirds in the Teshekpuk Lake Special Area.

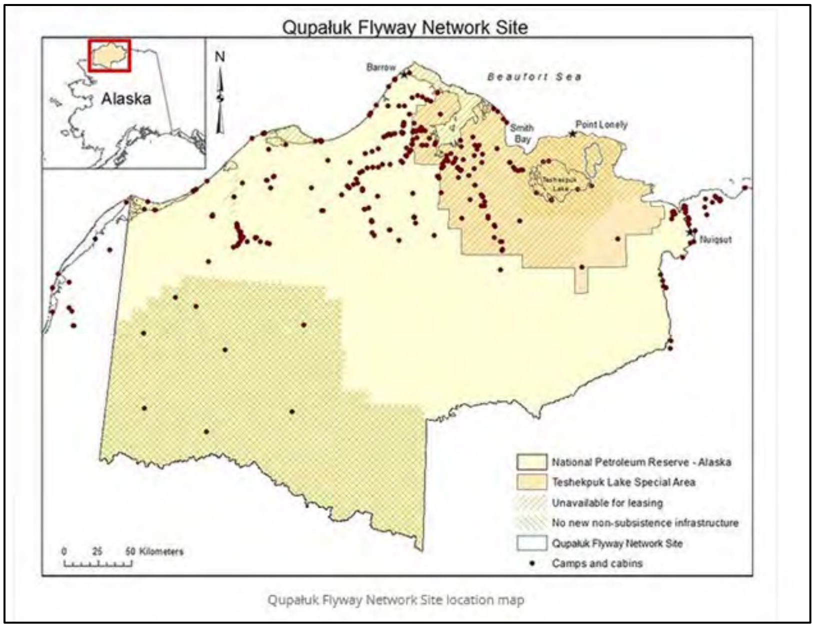

Figure 3d.2. Map of the Teshekpuk Lake Special Area showing the location of the Qupałuk EAAFP Flyway Network Site (From https://eaaflyway.net/qupaluk-flyway-network-site-eaaf133-east-asian-australasian-flyway-partnership/).

***Qupałuk EAAFP Flyway Network Site* –** In 2016 in recognition of how important this area is for breeding shorebirds the BLM, with support from USFWS, nominated a 21,000 ha area within this Special Area to the north and just east of Teshekpuk Lake to be recognized as an East Asian-Australasian Flyway Partnership (EAAFP) Flyway Network Site due its global importance for a variety of waterbird species, particularly Dunlin, *Calidris alpina articola* (see Figure 3d.2 below).

The Qupałuk EAAFP Flyway Network Site, was formally accepted into the Network in 2017, and is only the second EAAFP Flyway Network Site in the United States and the first on BLM-managed lands to be nominated and accepted (https://eaaflyway.net/qupaluk-flyway-network-site-eaaf133-east-asian-australasian-flyway-partnership/).

***Kasegaluk Lagoon Special Area* –** The Kasegaluk Lagoon Special Area is particularly important to shorebirds during the fall post-breeding period (Johnson et al. 1993), as they stage (sensu Warnock 2010) before migrating, although numbers using this area vary among years (Taylor et al. 2011). Up to 19 species of shorebirds may use the site (Alaska Shorebird Group 2019). Fall staging by post-breeding shorebirds occurs from the end of July through August, peaking throughout August, depending on year (Powell et al. 2010, Taylor et al. 2011). Depending on year and time, the site is especially important to fall staging Red and Red-necked phalaropes, Semipalmated Sandpipers, Dunlin, and Western Sandpipers (Johnson et al. 1993, Taylor et al. 2010).

Peard Bay Special Area – The Peard Bay Special Area was established in part because of its significant use by staging shorebirds (BLM, NPR–A IAP ROD 4 (Feb. 2013). The site is particularly important to thousands of Red Phalaropes that use the site in the summer and fall, in part because of its beach habitat and gravel spit (Connors et al. 1981, Taylor et al. 2011, Alaska Shorebird Group 2019).

Colville River Special Area – Specific estimates of the numbers of shorebirds using this special area are lacking although habitat along the river is used by breeding and migrant shorebirds with densities increasing the farther north one gets (Saalfeld et al. 2013a). Common species include Semipalmated Plover, American Golden-Plover, Pectoral Sandpiper, Semipalmated Sandpiper, and both phalaropes (Kessel and Cade 1958).

Utukok Upland Special Area – Rigorous surveys for shorebirds in the Utukok Uplands Special Area are lacking. The Alaska Shorebird Conservation Plan (Alaska Shorebird Group 2019) states that "Developments in the interior of NPR–A would have less impact on shorebirds than coastal developments due to the lower diversity and abundance of birds, but some Interior species would potentially be affected (Johnson et al. 2007; Bart et al. 2013; Saalfeld et al. 2013b)." Some of the species of the highland dry tundra include American Golden-Plover, Semipalmated Sandpiper, Long-billed Dowitcher, and Bar-tailed Godwit (e.g. Kessel and Cade 1958, Maher 1959). The plan also points out that the effects of mining on shorebirds have been poorly studied.

Other important shorebird sites within the NPR-A

The Western Hemisphere Shorebird Reserve Network (WHSRN) recognizes important shorebird sites across the Western Hemisphere, and ranks them from regional to hemispheric importance, largely based on shorebird numbers using the site (see https://whsrn.org/). Along the Alaska Coastal Plain, a number of sites are recognized as meeting the criteria as being important sites, including the Teshekpuk-Dease Inlet area, Kasegaluk Lagoon, and Peard Bay (see Harrington and Perry 1995, Alaska Shorebird Group 2008, 2019).

Other sites recognized as meeting WHRN criteria (from Alaska Shorebird Group 2019) include:

Elson Lagoon – Recognized as a potential site of Regional Importance for few tens of thousands of Red Phalaropes that use the site in the fall.

Meade River (from Alaska Shorebird Group 2019) **–** Recognized as a potential site of Regional Importance for tens of thousands of Semipalmated Sandpipers, Long-billed Dowitchers, and Red-necked Phalaropes that use the site in the summer.
Barrow and Admiralty Bay – Recognized as a potential site of International Importance for hundreds of thousands of Semipalmated Sandpipers, Pectoral Sandpipers, Dunlin, Long-billed Dowitchers and Red Phalaropes that use the site in the summer.

***Ikpikpuk River* –** Recognized as a potential site of Regional Importance for tens of thousands of American Golden Plover, Black-bellied Plover, Bar-tailed Godwit, Semipalmated Sandpiper, Stilt Sandpiper, and Long-billed Dowitcher that use the site in the summer.

***Ikpikpuk River Delta* –** Recognized as a potential site of Regional Importance for tens of thousands of Black-bellied Plover, Ruddy Turnstone, Semipalmated Sandpiper, Pectoral Sandpiper, Dunlin, and Red Phalarope that use the site in the summer.

***Cape Halkett* –** Recognized as a potential site of Regional Importance for tens of thousands of Pectoral Sandpiper, Dunlin, Long-billed Dowitcher, and Red Phalarope that use the site in the summer.

***Kogru River Delta* –** Recognized as a potential site of Regional Importance for thousands of Pectoral Sandpiper, Dunlin, and Red Phalarope that use the site in the summer.

***Colville River Delta* –** Recognized as a potential site of Regional Importance for tens of thousands of Dunlin, Semipalmated Sandpiper, and Red-necked Phalarope that use the site in the summer and fall.

All of these sites would benefit from additional protection against oil development activities.

Impacts of oil development on shorebirds

In the 1970s, during studies to better understand the potential impacts of offshore oil development on Arctic shorebirds in Alaska, Connors et al. (1981) listed four potential effects of oil development on shorebirds:

1) Habitat change
    a. Loss of habitat
    b. Change in quality of habitat
    c. Construction of new habitat
2) Activity disturbance
3) Changes in prey resource
4) Direct oil spill effects

These all remain valid concerns for both offshore and onshore oil development and have been the focus of various studies in and around the oil producing regions of Arctic Alaska (see review in National Research Council 2003). The Alaska Shorebird Conservation Plan (Alaska Shorebird Group 2019) concludes that the primary negative effects of oil development in the Prudhoe Bay-NPR-A region are from the effects of disturbance and increased predators on shorebird nest success as well as direct habitat loss and fragmentation of habitat. Referencing the National Research Council (2003), the plan lists additional effects including: alteration of habitat due to changes in drainage patterns, dust from roads, thermokarst, physical and noise pollution, industrial pollution and collisions with human structures (Alaska Shorebird Group 2019).

Building roads and facilities and other structures associated with oil development can directly cover and decrease habitat available for breeding birds (e.g. Troy and Carpenter 1990 p. 29), and oil spills have obvious consequences for shorebird populations, especially for the fall-staging shorebirds that concentrate in large numbers along the coast, but other potential effects like disturbance are more difficult to quantify. Studies have also been conducted on the impacts of increased predator populations on breeding shorebirds due to oil development activities (e.g. Liebezeit et al. 2009, McGuire et al. 2023).

Roads and facilities

A fair amount of research has centered around disturbance of shorebirds from facilities, roads, and other oil development related activities (for early studies see summary in Meehan and Nickles 2002). In Prudhoe Bay, nest densities of American Golden Plover and Baird's Sandpiper decreased closer to facilities while Red-necked Phalarope nest densities increased (TERA 1994). In some years post breeding shorebirds in Prudhoe Bay including Dunlin, Red Phalarope, and American Golden-Plover showed an avoidance of oil development facilities (TERA 1994).

In the most robust study to date, McGuire et al. (2023) looked at nest survival of birds in the Prudhoe Bay field from 2003-2019 in relationship to proximity to facilities and roads and found that birds that nested closer to high-use facilities had significantly lower nest survival than those farther away (shorebirds accounted for 1265 of the 1874 nests examined). Additionally, they had evidence that where nests were near more concentrated facilities and where nests were closer to roads, nest survival decreased, although results were not significant (McGuire et al. 2023). In a shorter study with smaller sample sizes (1257 nests) in and around the Prudhoe Bay oil field, Liebezeit et al. (2009) failed to detect a relationship between shorebird nest survival (as a group) and proximity to infrastructure although a finer scale analysis found evidence that nests of Red and Red-necked phalaropes (species combined) had lower survival closer to facilities where more predators were found.

A number of breeding season shorebird species in Prudhoe Bay were found to avoid roads, including Dunlin, Semipalmated Sandpiper, Stilt Sandpiper, and Pectoral Sandpiper (TERA 1993). Dust from roads cause snow to melt earlier next to roads than in other areas and this may attract shorebirds as well as other birds early in the season (Walker and Everett 1987). Within Prudhoe Bay it has also been shown that road dust affects the composition of plants next to the road, especially small forbs, mosses, and lichens, and habitat types around the area (Walker et al. 2022). In addition, roads and other gravel structures like drilling pads can cause water to impound, thermokarsting, and other environmental changes resulting in significant habitat changes for breeding birds (Meehan and Nickles 2002, Raynolds et al. 2014, Bergstedt et al. 2023).

Predators

Nest predation has been cited as the most significant cause of nest failure for shorebirds in the Prudhoe Bay area (Liebezeit and Zack 2009) and Arctic Fox may be the most impactful of the nest predators (Troy and Carpenter 1990, Troy 1996 Inter Wader Studies, Alaska Shorebird Group 2019). Studies have shown that certain shorebird nest predators, including Glaucous Gulls, Common Ravens, and Arctic Fox are more concentrated in oil development areas due to subsidized food and favorable breeding habitat on structures associated with oil development (Liebezeit et al. 2009, Saalfeld et al. 2013b; see also Coates et al. 2014 and review in Alaska Shorebird Conservation Plan (Alaska Shorebird Group 2019)), and that these subsidized predator populations have increased (in Prudhoe Bay) (Ballard et al. 2000, McGuire et al. 2023).

Changes in prey resource

Few studies (if any) have looked at the impact of oil development on shorebird prey populations. It has been suggested that invertebrate populations that shorebirds eat might be affected by contaminants from oil reserve pits although this practice has been discontinued (National Research Council 2003). Dust from roads likely affects invertebrate populations in habitat closest to the roads (NW pers. obs.).

Climate change impacts

Further removal and burning of petroleum products currently stored in the NPR-A will further increase global temperatures, especially in Arctic regions. Two immediate negative consequences for shorebirds in the NPR-A include the potential loss of low elevation breeding and staging habitat to sea level rise (Alaska Shorebird Group 2019) and phenological mismatches between shorebirds and their prey (Kwon et al. 2019, Saalfeld et al. 2019).

Rehabilitated sites

Bentzen et al. (2018) found that on the North Slope of Alaska oil field habitat rehabilitated after disturbance (gravel removal) did not offer the same shorebird (and other birds) breeding habitat values that it did prior to disturbance, and the effects were observed 10 years post rehabilitation in some areas. Shorebirds that were noted nesting in the rehabilitated sites included Semipalmated Plover and American Golden-Plover, both species often associated with sparsely vegetated habitat, and one Semipalmated Sandpiper. Authors noted that this paper was "The first primary literature publication to systematically evaluate bird use of rehabilitation sites on Alaska's Arctic coastal plain." (p. 423).

Shorebird literature cited

Alaska Shorebird Group 2019. Alaska Shorebird Conservation Plan. Version III. Alaska Shorebird Group, Anchorage, AK. Available from: https://www.shorebirdplan.org/wp-content/uploads/2019/05/AlaskaPlan2019.pdf.

Ballard, W.B., Cronin, M.A., Rodrigues, R., Skoog, R.O., and Pollard, R.H. 2000. Arctic fox, *Alopex lagopus*, den densities in the Prudhoe Bay oil field, Alaska. Canadian Field-Naturalist 114:453 – 456. Available from: https://www.biodiversitylibrary.org/part/363997.

Bart, J., S. C. Brown, B. A. Harrington, and R. I. G. Morrison. 2007. Survey trends of North American shorebirds: Population declines or shifting distributions? Journal of Avian Biology 38:73-82. Available from: https://nsojournals.onlinelibrary.wiley.com/doi/epdf/10.1111/j.2007.0908-8857.03698.x.

Bart, J. R., and V. H. Johnston. 2012. Eds. Arctic shorebirds in North America: a decade of monitoring. No. 44. Univ of California Press. Available from: https://www.ucpress.edu/books/arctic-shorebirds-in-north-america/hardcover.

Bart, J., R. M. Platte, B. Andres, S. Brown, J. A. Johnson, and W. Larned. 2013. Importance of the National Petroleum Reserve–Alaska for aquatic birds. Conservation Biology 27: 1304-1312. Available from: https://conbio.onlinelibrary.wiley.com/doi/10.1111/cobi.12133.

Bentzen, R., Dinsmore, S., Liebezeit, J., Robards, M., Streever, B. and Zack, S. 2017. Assessing development impacts on Arctic nesting birds using real and artificial nests. Polar Biology 40:1527-1536. Available from: https://link.springer.com/article/10.1007/s00300-017-2074-7.

Bergstedt, H., Jones, B.M., Walker, D., Peirce, J., Bartsch, A., Pointner, G., Kanevskiy, M., Raynolds, M. and Buchhorn, M. 2022. The spatial and temporal influence of infrastructure and road dust on seasonal snowmelt, vegetation productivity, and early season surface water cover in the Prudhoe Bay Oilfield. Arctic Science, 9:243-259. Available from: https://cdnsciencepub.com/doi/10.1139/as-2022-0013.

Clemens, R., D. I. Rogers, B. D. Hansen, K. Gosbell, C. D. Minton, P. Straw, M. Bamford, E. J. Woehler, D. A. Milton, M. A. Weston, and B. Venables. 2016. Continental-scale decreases in shorebird populations in Australia. Emu-Austral Ornithology 116:119-135. Available from: https://www.tandfonline.com/doi/abs/10.1071/MU15056.

Coates, P.S., Howe, K.B., Casazza, M.L. and Delehanty, D.J., 2014. Common raven occurrence in relation to energy transmission line corridors transiting human-altered sagebrush steppe. Journal of Arid Environments, 111, pp.68-78. Available from: https://www.sciencedirect.com/science/article/pii/S014019631400175X?via%3Dihub.

Connors, P.G., Connors, C.S., and Smith, K. G. 1981. Shorebird littoral zone ecology of the Alaska Beaufort Coast. Anchorage: Bureau of Land Management/National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program. Final reports of Principal Investigators 23:295 – 396. Available at the Alaska resources library and information Services. http://www.arlis.org Available from: https://espis.boem.gov/final%20reports/287.pdf.

Gratto-Trevor, C., R. I. G. Morrison, B. Collins, J. Rausch, M. Drever, and V. Johnston. 2011. Trends in Canadian shorebirds. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 13. Canadian Councils of Resource Ministers. Ottawa, ON. iv + 32 p. Available from: https://publications.gc.ca/collections/collection_2011/ec/En14-26-2010-eng.pdf.

Harrington, B.A. and E. Perry. 1995 Important shorebird staging sites meeting Western Hemisphere Shorebird Reserve Network criteria in the United States. Report to U.S. Fish and Wildlife Service, Washington, DC. Available from: https://babel.hathitrust.org/cgi/pt?id=umn.31951d01464144b&seq=1.

Johnson, J.A., Lanctot, R.B., Andres, B.A., Bart, J.R., Brown, S.C., Kendall, S.J. and Payer, D.C. 2007. Distribution of breeding shorebirds on the Arctic Coastal Plain of Alaska. Arctic, 60:277-293. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/63282.

Johnson, S.R., and Herter, D.R. 1989. The birds of the Beaufort Sea. Anchorage: British Petroleum Exploration (Alaska), Inc. Available from: https://www.amazon.com/The-Birds-Beaufort-Stephen-Johnson/dp/B0006ES4UI.

Kessel, B. and Cade, T.J. 1958. Birds of the Colville River, northern Alaska. University of Alaska. Institute of Arctic Biology. https://scholarworks.alaska.edu/handle/11122/1421.

King, R. J. 1979. Results of aerial surveys of migratory birds on NPR-A in 1977 and 1978. Pages 187–226 in P. C. Lent, editor. Studies of selected wildlife and fish and their use of habitats on and adjacent to NPR-A 1977–1978. Volume 1. Field Study 3. National Petroleum Reserve in Alaska, 105(c) Land Use Study. U.S. Department of the Interior, Anchorage, Alaska, USA.

Kwon, E., Weiser, E.L., Lanctot, R.B., Brown, S.C., Gates, H.R., Gilchrist, G., Kendall, S.J., Lank, D.B., Liebezeit, J.R., McKinnon, L. and Nol, E., 2019. Geographic variation in the intensity of warming and phenological mismatch between Arctic shorebirds and invertebrates. Ecological Monographs, 89(4), p.e01383. Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1002/ecm.1383.

Liebezeit, J.R., Kendall, S.J., Brown, S., Johnson, C.B., Martin, P., McDonald, T.L., Payer, D.C., Rea, C.L., Streever, B., Wildman, A.M. and Zack, S. 2009. Influence of human development and predators on nest survival of tundra birds, Arctic Coastal Plain, Alaska. Ecological Applications, 19:1628-1644. Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1890/08-1661.1.

Liebezeit J.R. and S. Zack. 2009. Nesting success and nest predators of tundra-nesting birds in the Prudhoe Bay Oilfield – Long-term monitoring. Report prepared by of the Wildlife Conservation Society for The U.S. Fish and Wildlife Service (Arctic NWR), BP Exploration (Alaska), Inc., & other interested parties/stakeholders. December 2009. Available from: https://catalog.northslopescience.org/dataset/39e6dd80-b89c-42d1-aeed-5c235ea9dd03/resource/e47c7353-0277-4118-8586-c77e37ce46e0/download/2009prudhoebayreport.pdf.

Lyons, J.E., Brown, S.C., Saalfeld, S.T., Johnson, J.A., Andres, B.A., Sowl, K.M., Gill Jr, R.E., McCaffery, B.J., Kidd, L.R., McGarvey, M. and Winn, B., 2024. Alaska's climate sensitive Yukon–Kuskokwim Delta supports seven million Arctic-breeding shorebirds, including the majority of six North American populations. Ornithological Applications 126: p.duad066. Available from: https://academic.oup.com/condor/article/126/2/duad066/7491465.

Maher WJ. 1959. Habitat distribution of birds breeding along the upper Kaolak River, northern Alaska. The Condor 61:351-68. Available from: https://academic.oup.com/condor/article/61/5/351/5230419.

McGuire, R.L., Robards, M. and Liebezeit, J.R., 2023. Patterns in avian reproduction in the Prudhoe Bay Oilfield, Alaska, 2003–2019. Journal of Avian Biology 23: p.e03075. Available from: https://nsojournals.onlinelibrary.wiley.com/doi/10.1111/jav.03075.

Meehan R, Nickles J. 2002 Oil development in northern Alaska: a guide to the effects of gravel placement on wetlands and waterbirds. U.S. Fish and Wildlife Service Alaska Investigations, Environmental Research Laboratory, U.S. EPA. Available from: https://www.osti.gov/biblio/6975002.

Meehan, R. H. 1986. Impacts of oil development on shorebirds, Prudhoe Bay, Alaska. PhD dissertation, University of Colorado, Boulder.

Meehan, R. and J. Nickles. 2002. Oil development in northern Alaska: a guide to the effects of gravel placement on wetlands and waterbirds. U.S. Environmental Protection Agency, Washington, D.C., EPA/600/3-88/024. Available from: https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=ORD&dirEntryID=36950.

Munro, M. 2017. What's killing the world's shorebirds. Nature 541:16-20. Available from: https://www.nature.com/articles/541016a.

National Research Council. 2003. Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope. Washington, DC: The National Academies Press. https://doi.org/10.17226/10639). Available from: https://nap.nationalacademies.org/catalog/10639/cumulative-environmental-effects-of-oil-and-gas-activities-on-alaskas-north-slope.

Naves, L.C., Keating, J.M., Tibbitts, T.L. and Ruthrauff, D.R., 2019. Shorebird subsistence harvest and indigenous knowledge in Alaska: Informing harvest management and engaging users in shorebird conservation. The Condor 121:p.duz023. Available from: https://academic.oup.com/condor/article/121/2/duz023/5523065?login=false.

Pearce-Higgins, J.W., D. J. Brown, D.J. Douglas, J. A. Alves, M. Bellio, P. Bocher, G. M. Buchanan, R. P. Clay, J. Conklin, N. Crockford, and P. Dann. 2017. A global threats overview for Numeniini populations: Synthesising expert knowledge for a group of declining migratory birds. Bird Conservation International 27:6-34. Available from: https://www.cambridge.org/core/journals/bird-conservation-international/article/global-threats-overview-for-numeniini-populations-synthesising-expert-knowledge-for-a-group-of-declining-migratory-birds/88F5B93483C8250D5DDB72172360F2D6.

Piersma, T., T. Lok, Y. Chen, C. J. Hassell, H. Y. Yang, A. Boyle, M. Slaymaker, Y. C. Chan, D. S. Melville, Z. W. Zhang, and Z. Ma. 2016. Simultaneous declines in summer survival of three shorebird species signals a flyway at risk. Journal of Applied Ecology 53:479–490. Available from: https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2664.12582.

Pitelka, F. A. 1974. An Avifaunal Review for the Barrow Region and North Slope of Arctic Alaska, Arctic and Alpine Research, 6:2, 161-184, DOI: 10.1080/00040851.1974.12003772. Available from: https://www.tandfonline.com/doi/pdf/10.1080/00040851.1974.12003772.

Powell, A.N., Taylor, A.R. and Lanctot, R.B., 2010. Pre-migratory ecology and physiology of shorebirds staging on Alaska's North Slope. Coastal Marine Institute, University of Alaska Fairbanks. Available from: https://espis.boem.gov/final%20reports/5051.PDF.

Raynolds, M.K., Walker, D.A., Ambrosius, K.J., Brown, J., Everett, K.R., Kanevskiy, M., Kofinas, G.P., Romanovsky, V.E., Shur, Y. and Webber, P.J. 2014. Cumulative geoecological effects of 62 years of infrastructure and climate change in ice-rich permafrost landscapes, Prudhoe Bay Oilfield, Alaska. Global Change Biology 20:1211-1224. Available from: https://onlinelibrary.wiley.com/doi/10.1111/gcb.12500.

Rosenberg, K. V., A. M. Dokter, P. J. Blancher, J. R. Sauer, A. C. Smith, P. A. Smith, J. C. Stanton, A. Panjabi, L. Helft, M. Parr, and P. P. Marra. 2019. Decline of the North American avifauna. Science 366:120-124. Available from: https://www.science.org/doi/10.1126/science.aaw1313.

Ruthrauff, D.R., Pohlen, Z.M., Wilson, H.M. and Johnson, J.A., 2021. Bar-tailed Godwits *Limosa lapponica* in Alaska: revisiting population estimates from the staging grounds. Wader Study 128:255-264. Available from: https://www.waderstudygroup.org/article/15741/.

Saalfeld, S.T., Lanctot, R.B., Brown, S. 2012. Development of shorebird distribution maps for the North Slope of Alaska using geospatial habitat modeling: The first step in assessing effects of climate change. Arctic LCC project summary, submitted 24 Sep 2012. https://www.sciencebase.gov/catalog/item/5a300b75e4b08e6a89d57cec.

Saalfeld, S.T., Lanctot, R.B., Brown, S.C., Saalfeld, D.T., Johnson, J.A., Andres, B.A. and Bart, J.R., 2013a. Predicting breeding shorebird distributions on the Arctic Coastal Plain of Alaska. Ecosphere 4:1-17. Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1890/ES12-00292.1.

Saalfeld, S.T., Hill, B.L. and Lanctot, R.B. 2013b. Shorebird responses to construction and operation of a landfill on the Arctic Coastal Plain. The Condor 115:816-829. Available from: https://bioone.org/journals/the-condor/volume-115/issue-4/cond.2013.120169/Shorebird-Responses-to-Construction-and-Operation-of-a-Landfill-on/10.1525/cond.2013.120169.short.

Saalfeld, S.T., McEwen, D.C., Kesler, D.C., Butler, M.G., Cunningham, J.A., Doll, A.C., English, W.B., Gerik, D.E., Grond, K., Herzog, P. and Hill, B.L., 2019. Phenological mismatch in Arctic-breeding shorebirds: Impact of snowmelt and unpredictable weather conditions on food availability and chick growth. Ecology and Evolution 9:6693-6707. Available from: https://onlinelibrary.wiley.com/doi/10.1002/ece3.5248.

Simmons, R.E., H. Kolberg, R. Braby, and B. Erni. 2015. Declines in migrant shorebird populations from a winter-quarter perspective. Conservation Biology 29:877-887. Available from: https://conbio.onlinelibrary.wiley.com/doi/10.1111/cobi.12493.

Smith, P.A., Smith, A.C., Andres, B., Francis, C.M., Harrington, B., Friis, C., Morrison, R.G., Paquet, J., Winn, B. and Brown, S., 2023. Accelerating declines of North America's shorebirds signal the need for urgent conservation action. Ornithological Applications 125:p.duad003. Available from: https://academic.oup.com/condor/article/125/2/duad003/7031074.

Taylor, A.R., Lanctot, R.B., Powell, A.N., Huettmann, F., Nigro, D.A. and Kendall, S.J. 2010. Distribution and community characteristics of staging shorebirds on the northern coast of Alaska. Arctic 63:451-467. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/66385.

Taylor, A.R., Lanctot, R.B., Powell, A.N., Kendall, S.J. and Nigro, D.A., 2011. Residence time and movements of postbreeding shorebirds on the northern coast of Alaska. The Condor 113:779-794. Available from: https://academic.oup.com/condor/article/113/4/779/5153061?login=false.

TERA. 1993. Population dynamics of birds in the Pt. McIntyre Reference Area 1981-1992. Report by Troy Ecological Research Associates for BP Exploration (Alaska) Inc., Anchorage, AK.

TERA. 1994. Bird use of coastal tundra at Prudhoe Bay, Alaska: 1991-1992. Report by Troy Ecological Research Associates for BP Exploration (Alaska) Inc., Anchorage, AK.

Troy, D.M., 1996. Population dynamics of breeding shorebirds in Arctic Alaska. International Wader Studies 8:15-27. Available from: https://sora.unm.edu/sites/default/files/journals/iws/n008/p00015-p00027.pdf.

Troy, D. M. and T. A. Carpenter. 1990. The fate of birds displaced by P-Pad, Prudhoe Bay, Alaska: the distribution of nesting birds before and after pad construction. Report by Troy Ecological Research Associates for BP Exploration (Alaska) Inc., Anchorage, AK. Available from: https://www.arlis.org/docs/vol2/point_thomson/1014/1014_Fate%20of%20birds%20Prudhoe%20dec%2010%201990.pdf.

Troy, D.M. and J. K. Wickliffe. 1990. Trends in bird use of the Pt. McIntyre Reference Area, 1981-1989. Report by Troy Ecological Research Associates for BP Exploration (Alaska) Inc.

Walker, D. A. & K. R. Everett. 1987. Road dust and its environmental impact on Alaskan taiga and tundra. Arctic and Alpine Research 19:479-489, DOI: 10.1080/00040851.1987.12002630. Available from: https://www.tandfonline.com/doi/pdf/10.1080/00040851.1987.12002630.

Walker, D.A., Raynolds, M.K., Kanevskiy, M.Z., Shur, Y.S., Romanovsky, V.E., Jones, B.M., Buchhorn, M., Jorgenson, M.T., Šibík, J., Breen, A.L. and Kade, A. 2022. Cumulative impacts of a gravel road and climate change in an ice-wedge-polygon landscape, Prudhoe Bay, Alaska. Arctic Science 8:1040-1066. Available from: https://cdnsciencepub.com/doi/10.1139/as-2021-0014.

Warnock, N., 2010. Stopping vs. staging: the difference between a hop and a jump. Journal of Avian Biology 41:621-626. Available from: https://nsojournals.onlinelibrary.wiley.com/doi/epdf/10.1111/j.1600-048X.2010.05155.x.

Warnock, N., Jennings, S., Kelly, J.P., Condeso, T.E. and Lumpkin, D., 2021. Declining wintering shorebird populations at a temperate estuary in California: A 30-year perspective. Ornithological Apps 123:p.duaa060. Available from: https://academic.oup.com/condor/article/123/1/duaa060/6132586?login=false.

Weiser, E.L., Lanctot, R.B., Brown, S.C., Gates, H.R., Bêty, J., Boldenow, M.L., Brook, R.W., Brown, G.S., English, W.B., Flemming, S.A. and Franks, S.E. 2020. Annual adult survival drives trends in Arctic-breeding shorebirds but knowledge gaps in other vital rates remain. The Condor 122:p.duaa026. Available from: https://academic.oup.com/condor/article/122/3/duaa026/5857122.

3e: Wolverine

Highlights:

- A cryptic species with low tolerance to human presence. Development projects can limit wolverine passage between areas of suitable habitat
- Compared to the other northern large carnivores, wolverines are considered to be the most sensitive species with regard to habitat changes and human disturbance
- When studied in a similar environment to the NPR-A in Scandinavia, wolverine distribution was positively correlated with reindeer (*Rangifer tarandus*) distribution and experienced indirect losses of habitat related to changes in reindeer populations caused by avoidance of human development
- With less topographic diversity for den sites, refugia, and opportunities for hunting compared to studies in the lower 48 and Scandinavia, wolverines in the NPR-A may be especially sensitive to the effects of development projects fragmenting their habitat
- Wolverine relative densities in the NPR-A are highest in the area directly south of Teshekpuk Lake and outside the Special Area in the southern half of the NPR-A between the Teshekpuk Lake Special Area and the Colville River Special Area.
- Maintaining connectivity between Teshekpuk Lake Special Area and the southern half of the Special Area in the NPR-A would serve the highest benefit for wolverine populations through protection of denning and foraging habitat allowing travel and dispersal corridors. Wolverine follow caribou north after denning in the mountains to the south.
- Last November 2023, the U.S. Fish and Wildlife Service designated wolverines in the lower 48 as a threatened species, “due primarily to the ongoing and increasing impacts of climate change and associated habitat degradation and fragmentation (Federal Register 2023).”
- While unlisted, the Alaskan population of wolverines is increasingly threatened by the same challenges as in the lower 48. The NPR-A is undergoing much faster warming than the contiguous US with warming increases four times that of the global average

Wolverines (*Gulo gulo*) are a snow dependent species that require large expanses of habitat in rugged montane or tundra landscapes. Their habitat selection is strongly influenced by availability of food resources like ungulates and smaller game, as well as reducing human disturbance within occupied habitat (Lofroth and Krebs 2007). They are snow specialists with large, paddle-like paws that have evolved to disperse weight for fast and efficient travel over deep snow.

These animals are valued as a fur resource important to Alaska Native communities' subsistence and culture. Due in part to their low densities and low reproductive output, hunters and trappers in Alaska harvest an average of only 545 wolverines each year (Alaska Department of Fish and Game, Wolverine). As such, each wolverine can be deeply important to subsistence users. In rural areas, households use most of the wolverine pelts harvested locally for wind guards and fur ruffs, as imported materials are considered inferior (Wolfe 1991). Many furs are distributed among kinship networks by sharing. Furs often flow between households and families across communities (Wolfe 1991).

Wolverines are a solitary species with large home range sizes. Male home ranges average 500 - 675 km sq (200 - 260 mi sq) and female home ranges average 300 km sq (115 mi sq). Resident females with juveniles maintain much smaller home ranges during summer rearing (Landa et al. 1998). Generally during the mating season males show territoriality, otherwise they remain a solitary species that avoid other wolverines. Wolverines' home range structure reflects their polygynous territoriality, where multiple females mate with one male. As such wolverines manage their home ranges to abut those of a neighboring adult same-sex home range, but do not overlap. Female wolverines exhibit fidelity to denning areas and territories across years and generations. Male home ranges usually encompass several adjacent female home ranges, and are correspondingly larger in size. In this way, home range size is closely, though not directly, related to population density (Glass and Robards 2024).

All maternal wolverine dens are located in areas that retain snow through the spring, and there is no evidence, either currently or historically, that wolverine populations can persist in areas without a sustained spring snowpack (Magoun and Copeland 1998). While literature is sparse on the projected changes to Alaskan wolverine habitat, warming temperatures are expected to shrink the mountain snowpack wolverines rely on for hunting and denning in the Lower 48: "By the late 21st century, dispersal modeling indicates that habitat isolation at or above levels associated with genetic isolation of wolverine populations becomes widespread. Overall, we expect wolverine habitat to persist throughout the species range at least for the first half of the 21st century, but populations will likely become smaller and more isolated" (McKelvey et al. 2011). In light of the climate challenges that face this snow-dependent species, habitat connectivity is more critical now than ever.

No studies have been conducted on the sub-lethal impacts of human disturbance (including from casual winter recreation) on wolverine denning, because such studies are viewed as unethical due to the conservation status of wolverines globally. However, it is worth noting that numerous wolverine researchers have documented wolverine relocating their den sites upon researcher arrival, seemingly in response to researchers approaching them, suggesting there is low tolerance to human presence, let alone larger-scale development or seismic activity (Hausleitner et al. 2024). Additionally, human disturbance is the main reason for den abandonment in other carnivores (Reshamwala et al. 2021, Ciarniello et al. 2004). According to the Guidelines for Winter Recreation near Wolverine Dens in Montane Western North America, "wolverines are sensitive to disturbance at a very low intensity of use and are at greatest risk when disturbances are dispersed and unpredictable. The risks of human presence near den sites are that female wolverine may shift den sites or indirectly lose access to habitat, thereby compromising reproductive output. High risk occurs during den selection, parturition, and natal development from January to mid-May. Moderate risk occurs May to July while the family is using rendezvous sites. Low risk occurs July through December when kits are mobile and nutritionally independent (Hausleitner et al. 2024)." Development projects can limit wolverine passage between areas of suitable snow habitat. Compared to the other northern large carnivores, wolverines are considered to be the most sensitive species with regard to habitat changes and human disturbance (May et al. 2006). Leading hypotheses suggest that dens keeping females and young reliably sheltered from disturbance (e.g., predation, weather, people), thermally insulated, and with adequate access to food are most likely to successfully reproduce (Jokinen et al. 2019).

Last November 2023, the U.S. Fish and Wildlife Service designated wolverines in the lower 48 as a threatened species, "due primarily to the ongoing and increasing impacts of climate change and associated habitat degradation and fragmentation (Federal Register 2023)." While unlisted, the Alaskan population of wolverines is increasingly threatened by the same challenges. The NPR-A is undergoing much faster warming than the contiguous US with warming increases four times that of the global average (Rantanen et al. 2022). As islands of habitable alpine and tundra communities begin to experience reduced snowpacks, wolverines will require passage to pockets of isolated snow found at higher elevation and/or in deep snowy areas adequate for denning and hunting with a sustained spring snowpack.

Nearly all documented wolverine dens in the world have been associated with deep snow and persistent spring snow cover. The denning period occurs in late winter and kits are born between February and March. Ultimately, females are present at dens between mid-January and mid-May (Hausleitner et al. 2024). The Wolverine Foundation (2014) provides a comprehensive literature review and summation of wolverine dens characteristics:

> “Magoun and Copeland (1998) described two types of reproductive dens, natal dens where young are born and maternal dens where the mother may move the kits if conditions are no longer suitable at the natal den. In tundra and alpine areas where wind-hardened snowdrifts are used as natal dens, the dens have a complex structure involving branching snow tunnels about 30-40 cm in width that are up to 60 m in total length and contain a number of enlarged beds 40-90 cm wide that are used as lairs for the kits, food storage, and latrine depots (Myrberget 1968, Serebryakov 1984, Magoun 1985). The floor of the tunnel system where the kits are kept can be as much as 3-5 m under the surface of the snowdrift or a little as 1 m. Kits often rest directly on the snow surface or on bare ground if the tunnels go all the way to the ground. Sometimes there is vegetation on the floor of the bed where kits are kept, although it is not clear if the female purposefully places vegetation in the bed or if the vegetation on the floor of the bed results from the female chewing off shrubby vegetation contained within the snow layer while constructing the bed. If boulders or rocky cliffs are present at the den site, the snow tunnels will often run along the edge of the boulders or cliffs where snow has accumulated in deep drifts and the boulders and rocky shelves of the cliffs may be used to shelter the kits. If rocky areas are extensive enough, the kits may be located well within the rocks where they are inaccessible to larger predators…Sites used for maternal dens are often close to the natal den and have similar structure, although the distance between the natal den and maternal den can be 3-4 km away (Magoun and Copeland 1998) and as much as 6 km (Myrberget 1968). The length of the tunnel systems in maternal dens can be considerably shorter than at the natal den site, especially if the female moved her kits to the maternal den as a result of disturbance at the natal den (Myrberget 1968).”

Unlike the high montane habitats of wolverines in the contiguous US, the NPR-A is a largely treeless area with vegetation characterized by tussock tundra, dry upland meadows, river flood plains, and talus hills. With less topologic diversity for den sites, refugia, and opportunities for hunting, wolverines in the NPR-A may be especially sensitive to the effects of development projects fragmenting their habitat (Glass et al. 2022).

When studied in a similar environment to the NPR-A in Scandinavia, wolverine distribution had a sympatric, positively correlated distribution with reindeer (*Rangifer tarandus*) and experienced indirect losses of habitat related to changes in reindeer populations caused by avoidance of human development (May et al. 2006). Given the similarities of this system to the NPR-A it is likely that wolverines would respond similarly in the NPR-A to the Scandinavian study, and that fewer caribou would negatively affect wolverines as reproduction output is tightly linked to food availability, and human development would force both caribou and wolverines from their preferred habitat. Wolverine distributions may be influenced by direct disturbance and human-caused mortality associated with infrastructure. Increased development and human activity in otherwise remote areas may thus reduce the ability of wolverines to achieve their necessary daily activities, making the habitat less optimal, or causing wolverines to avoid the disturbed area (Mat et al. 2006).

Wolverines are a cryptic species that are under studied in Arctic Alaska, but one study has used flight data to model wolverine occupancy across the NPR-A. Wolverine tracks were common in the southern half of the region and in the area directly south of Teshekpuk Lake (Poley et al. 2018). In areas not currently designated as Special Area, the land between the Teshekpuk Lake Special Area and the Colville River Special Area has the highest likelihood of occupancy (81-100%) by wolverines in the NPR-A. The study reported that hunters in the area linked wolverine dispersal in these areas with caribou occurrence, stating that wolverines followed the caribou north after denning in the mountains to the south.

Maintaining connectivity between those two areas would serve the highest benefit for wolverine populations and increase protection for the species. Protections in this area would allow denning and foraging habitat to persist and also include travel and dispersal corridors between these habitats to avoid fragmenting populations.

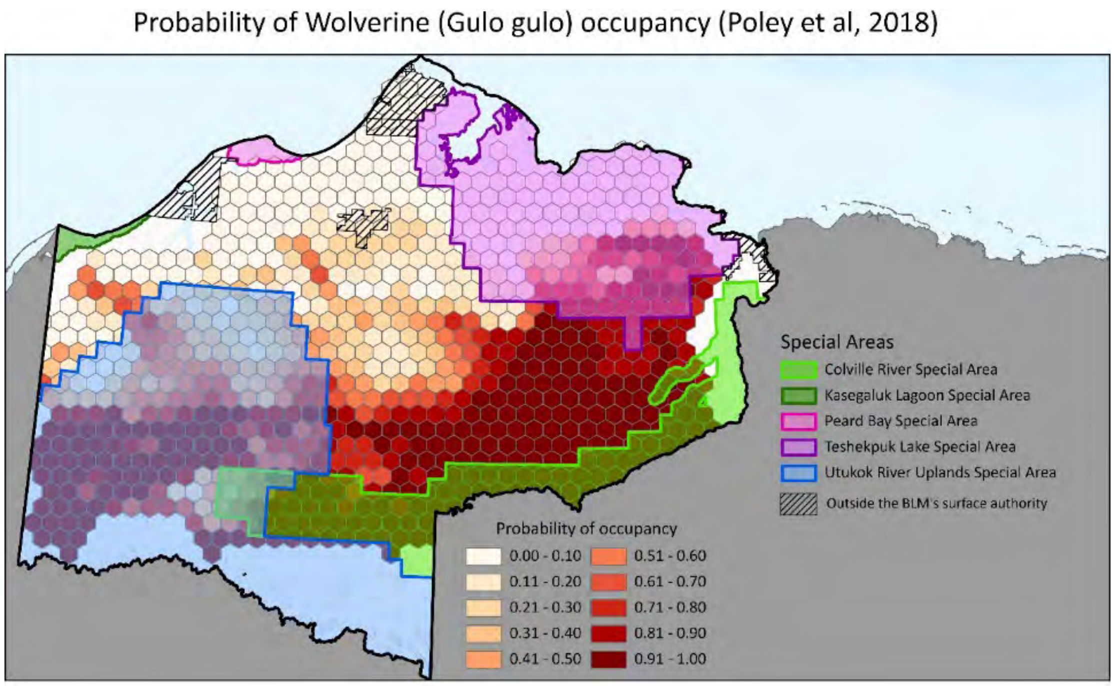

Figure 3e.1. Spatial pattern of the probability of wolverine occupancy within each hexagonal survey unit across the National Petroleum Reserve Alaska, Alaska, USA. Study area based on data collected during aerial track surveys in March 2014 and March–April 2015 and detection and habitat covariates retained in the best-fitting model to the data (Poley et al. 2018). Current NPR-A Special Area designations are marked in colored polygons.

Wolverine literature cited

Alaska Department of Fish and Game. *Wolverine (Gulo Gulo)*, www.adfg.alaska.gov/index.cfm?adfg=wolverine.uses Accessed 6 Aug. 2024.

Ciarniello, L.M., Boyce, M.S., Heard, D.C. and Seip, D.R., 2005. Denning behavior and den site selection of grizzly bears along the Parsnip River, British Columbia, Canada. *Ursus*, *16*(1), pp.47-58. https://doi.org/10.2192/1537-6176(2005)016[0047:DBADSS]2.0.CO;2.

Federal Register. 2023. Endangered and Threatened Wildlife and Plants; Threatened Species Status With Section 4(d) Rule for North American Wolverine 50 CFR Part 17. https://www.federalregister.gov/documents/2023/11/30/2023-26206/endangered-and-threatened-wildlife-and-plants-threatened-species-status-with-section-4d-rule-for.

Glass, T.W. and Robards, M.D., 2024. Wolverine population density and home range size in Arctic Alaska. *The Journal of Wildlife Management*, p.e22600. https://wildlife.onlinelibrary.wiley.com/doi/abs/10.1002/jwmg.22600.

Glass, T.W., Magoun, A.J., Robards, M.D. and Kielland, K., 2022. Wolverines (Gulo gulo) in the Arctic: Revisiting distribution and identifying research and conservation priorities amid rapid environmental change. *Polar Biology*, *45*(9), pp.1465-1482. https://link.springer.com/article/10.1007/s00300-022-03079-4.

Hausleitner, D., Kortello, A., Barrueto, M., Harrower, W. and Krebs, J., 2024. Guidelines for Winter Recreation near Wolverine Dens in Montane Western North America. Journal of Ecosystems & Management, 24(1), pp.1-20. https://arcabc.ca/islandora/object/sc%3A6628.

Jokinen, M.E., Webb, S.M., Manzer, D.L. and Anderson, R.B., 2019. Characteristics of Wolverine (*Gulo gulo*) dens in the lowland boreal forest of north-central Alberta. The Canadian Field-Naturalist. https://www.canadianfieldnaturalist.ca/index.php/cfn/article/view/2083.

Landa, A., Strand, O., Linnell, J.D. and Skogland, T., 1998. Home-range sizes and altitude selection for arctic foxes and wolverines in an alpine environment. Canadian Journal of Zoology, 76(3), pp.448-457. https://cdnsciencepub.com/doi/10.1139/z97-209.

Lofroth, E.C. and Krebs, J., 2007. The abundance and distribution of wolverines in British Columbia, Canada. The Journal of Wildlife Management, 71(7), pp.2159-2169. https://wildlife.onlinelibrary.wiley.com/doi/10.2193/2007-094.

Magoun, A.J. and Copeland, J.P., 1998. Characteristics of wolverine reproductive den sites. *The Journal of wildlife management*, pp.1313-1320. https://www.jstor.org/stable/3801996?origin=crossref.

May, R., Landa, A., van Dijk, J., Linnell, J.D. and Andersen, R., 2006. Impact of infrastructure on habitat selection of wolverines (*Gulo gulo)*. *Wildlife Biology*, *12*(3), pp.285-295. https://bioone.org/journals/wildlife-biology/volume-12/issue-3/0909-6396_2006_12_285_IOIOHS_2.0.CO_2/Impact-of-infrastructure-on-habitat-selection-of-wolverines-Gulo-gulo/10.2981/0909-6396(2006)12[285:IOIOHS]2.0.CO;2.full.

McKelvey, K.S., Copeland, J.P., Schwartz, M.K., Littell, J.S., Aubry, K.B., Squires, J.R., Parks, S.A., Elsner, M.M. and Mauger, G.S., 2011. Climate change predicted to shift wolverine distributions, connectivity, and dispersal corridors. *Ecological Applications*, *21*(8), pp.2882-2897. https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/10-2206.1.

Poley, L.G., Magoun, A.J., Robards, M.D. and Klimstra, R.L., 2018. Distribution and occupancy of wolverines on tundra, northwestern Alaska. The Journal of Wildlife Management, 82(5), pp.991-1002. https://wildlife.onlinelibrary.wiley.com/doi/10.1002/jwmg.21439.

Rantanen, M., Karpechko, A.Y., Lipponen, A., Nordling, K., Hyvärinen, O., Ruosteenoja, K., Vihma, T. and Laaksonen, A., 2022. The Arctic has warmed nearly four times faster than the globe since 1979. Communications earth & environment, 3(1), p.168. https://www.nature.com/articles/s43247-022-00498-3.

Reshamwala, H.S., N. Mahar, R. Dirzo, R. & B. Habib. 2021 Successful neighbor: Interaction of generalist carnivore red fox with dogs, wolves and humans for continued survival in dynamic anthropogenic landscapes. Glob. Ecol. Conserv. 25. doi:10.1016/j.gecco.2020.e01446. https://www.sciencedirect.com/science/article/pii/S2351989420309884?via%3Dihub

The Wolverine Foundation. "The Wolverine Foundation. Promoting Science-Based Management of Wolverines Across Their Global Range." The Wolverine Foundation, 21 Feb. 2014, www.wolverinefoundation.org/denning.

Wolfe, R.J., 1991. *Trapping in Alaska communities with mixed, subsistence-cash economies*. Division of Subsistence, Alaska Department of Fish and Game. https://www.adfg.alaska.gov/techpap/tp217.pdf.

3f: Moose

Moose *(Alces alces)* are the largest member of the Cervidae family and inhabit a diversity of north temperate ecosystems, including Alaska. They are mainly associated with early-successional, recently disturbed habitats and prioritize browsing on fresh riparian shrubs, particularly willow (*Salix spp*). In the summer they supplement this browse with large amounts of aquatic vegetation and riparian grasses and sedges. In one study, moose on Alaska's North Slope spent 80–90% of their tracked distance during winter in tall shrub habitats (over 1m), with the remainder on frozen riverbeds between vegetation pockets (Tape et al. 2016). Longer winters with shorter shrubs nearer the coast help explain the current habitat unsuitability of the NPR-A (Mould 1979).

Historically moose have inhabited the Arctic, migrating into the region around the same time as humans after the last ice age (Mann et al. 2013). Moose bones from thawing permafrost have been found north of the Colville River that span 3000 years ago to present, including several bones that date to the Little Ice Age. Archaeologists conclude that moose have been present in the region during the last three millennia. Indigenous peoples and early explorers do not document an absence of moose until the latter half of the 19th and early 20th century in tundra areas of Alaska (Mann et al. 2013). Moose are among the most widely distributed species in the state, with a coarse population estimate of up to 200,000 animals statewide (ADFG Moose). Though abundant in the state, the northern and western limits of their range end near the Colville River in the NPR-A. Moose occur near the Arctic coast north of the village of Nuiqsut and follow the Colville River drainage south past the village of Umiat (Zhou et al. 2022). They do not populate the remainder of the NPR-A at present and are restricted to thickets of willow along the Colville River (Zhou et al. 2022).

The NPR-A falls in the Alaska Depart of Fish and Game's Management Unit 26A. The ADFG report reads: "Population assessments indicate that moose numbers increased in the area between the early 1970s (about 1,220) and the early 1990s (to about 1,535); then declined to about 760 in 1995 and to about 325 in 1999. The decline appeared to be a combination of malnourishment, disease, mineral deficiency, predation, weather, and competition with hares (relative newcomers to the area). 50 moose were captured, examined and radio collared in 1996-97, providing insights. The population began increasing in the late 1990s and the count was 576 moose in 2002 and 1,058 in 2005 (this includes moose counted on the border of 26B to the east). Reasons for the increase may include improved browse conditions, reduced predation, favorable weather and reduced disease prevalence."

The increasing permafrost thaw and wildfire occurrence associated with warming in the boreal forest have likely created more deciduous moose habitat. As noted by the changes in populations on the Colville River, the Arctic is experiencing, and expected to continue experiencing, increased shrub encroachment on the tundra, displacing lichens and increasing potential moose habitat. The combination of longer growing seasons and increasing shrub habitat have allowed moose to colonize tundra regions of Alaska. Increases in shrubs and earlier snowmelt have occurred across most of the Arctic, notably along the northern edge of moose distribution, so increases in abundance and extended northward and westward distribution of moose should be anticipated in the NPR-A branching from their current range on the Colville River (Brown et al. 2010, Tape et al. 2017). Vegetation types have been projected based on the NCAR CCSM4 climate model under a mid-range RCP 8.5 emission scenario and indicate that shrub tundra, which is viable moose habitat, is expected to reach Teshekpuk Lake by 2099 (Scenarios Network 2023, Mann et al. 2012).

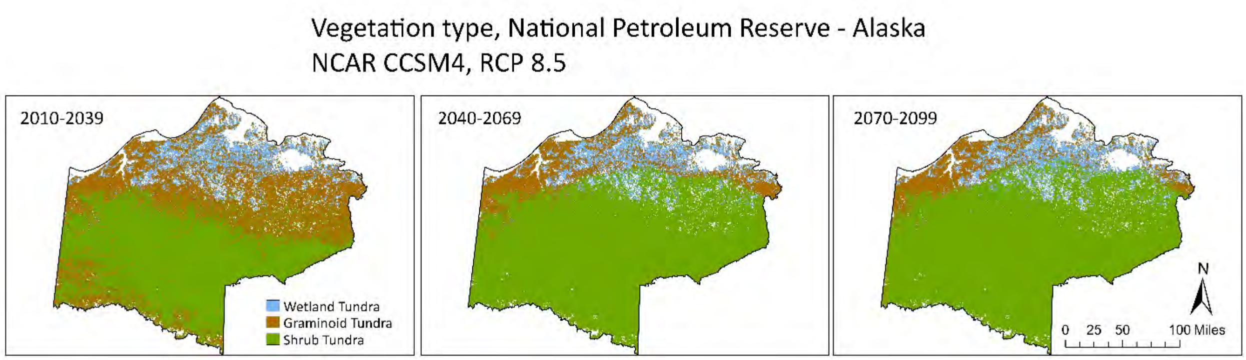

Figure 3f.1. Projected vegetation type based on NCAR CCSM4 climate model under Representative Concentration Pathway (RCP) 8.5 emission scenario. Current and projected vegetation types in the National Petroleum Reserve – Alaska from 2010 through 2099 divided in classification types of wetland tundra, graminoid tundra, and shrub tundra (Johnstone et al. 2011).

Moose literature cited

ADFG Species Profile: https://www.adfg.alaska.gov/index.cfm?adfg=moose.printerfriendly#:~:text=About%20175%2C000%20to%20200%2C000%20moose,various%20regions%20in%20the%20state. Accessed 7 July 2024.

Brown R., Derksen C, Wang L (2010) A multi-data set analysis of variability and change in Arctic spring snow cover extent, 1967–2008. Journal of Geophysical Research: Atmospheres (1984–2012) 115. https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2010JD013975.

Johnstone, J. F., Rupp, T. S., Olson, M, Verbyla, D. (2011). Modeling impacts of fire severity on successional trajectories and future fire behavior in Alaskan boreal forests. *Landscape Ecology, 26*, 487–500. https://doi.org/10.1007/s10980-011-9574-6.

Mann, D.H., Groves, P., Kunz, M.L., Reanier, R.E. and Gaglioti, B.V., 2013. Ice-age megafauna in Arctic Alaska: extinction, invasion, survival. Quaternary Science Reviews, 70, pp.91-108. https://www.sciencedirect.com/science/article/abs/pii/S0277379113001200?via%3Dihub.

Mann, D.H., Rupp, T.S., Olson, M.A. and Duffy, P.A., 2012. Is Alaska's boreal forest now crossing a major ecological threshold?. *Arctic, Antarctic, and Alpine Research*, *44*(3), pp.319-331. https://www.tandfonline.com/doi/full/10.1657/1938-4246-44.3.319.

Mould, E., 1979. Seasonal movement related to habitat of moose along the Colville River, Alaska. *The Murrelet*, *60*(1), pp.6-11. https://www.jstor.org/stable/3534458?origin=crossref.

Scenarios Network for Alaska and Arctic Planning. 2023. ALFRESCO model outputs - vegetation type. http://data.snap.uaf.edu/data/IEM/Outputs/ALF/Gen_1a/alfresco_relative_spatial_outputs/vegetation_type.

Tape, K.D., Gustine, D.D., Ruess, R.W., Adams, L.G. and Clark, J.A., 2016. Range expansion of moose in Arctic Alaska linked to warming and increased shrub habitat. PloS one, 11(4), p.e0152636. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0152636.

Zhou, J., Kofinas, G.P., Kielland, K., Boone, R.B., Prugh, L. and Tape, K.D., 2022. Climate change, moose, and subsistence harvest: social-ecological assessment of Nuiqsut, Alaska. Ecology and Society, 27(3). https://ecologyandsociety.org/vol27/iss3/art29/.

3g: Tundra

Introduction

Tundra is commonly defined as the low-stature vegetation growing beyond the cold limit of tree growth, both at high elevations (alpine tundra) and at high latitudes (arctic tundra). Tundra vegetation is composed of herbaceous plants, shrubs, mosses, liverworts and lichens. Arctic tundra covers 7.02 x 10^6 km^2, mostly north of the Arctic Circle, including the approximately 94,000 km^2 of the National Petroleum Reserve – Alaska (NPR-A) on the North Slope of Alaska.

The Alaska tundra is the home of the Iñupiat people, who have lived there for millennia, subsisting on the resources of the sea and land. The people living in the NPR-A area, most of whom reside in the communities of Utqiaġvik, Wainwright, Atqasuk and Nuiqsut, rely on the intact ecosystems that surround them to provide their food.

Arctic tundra is underlain by permafrost, which results in cold, saturated soils not suitable for agriculture. As a result, arctic tundra has remained mostly undisturbed, forming some of the last intact ecosystems on Earth. The NPR-A and surrounding areas provide habitat for large numbers of migrating animals such as caribou and birds, and smaller numbers of year-round resident animals such as lemmings, arctic foxes, and ravens. The waters are largely unpolluted (except for atmospheric fallout) and provide habitat to waterfowl and fish. The land holds carbon sequestered in the permafrost. All of these attributes rely on the intact, functioning layer of tundra vegetation on the surface, which insulates the permafrost and provides food for the animals (and thus the people).

Description of NPR-A tundra vegetation

The NPR-A includes 3 major landscape types, or ecosections: the Beaufort Coastal Plain, the Brooks Range Foothills, and the Brooks Range itself (Figure 3g.1). The Beaufort Coastal Plain is mostly flat tundra with wet vegetation and many lakes. The Brooks Range Foothills are rolling hills and drainages, often with tussock tundra on the hills and shrub tundra along the drainages. The Brooks Range in the NPR-A includes mountains that reach to around 1000 m, with alpine vegetation.

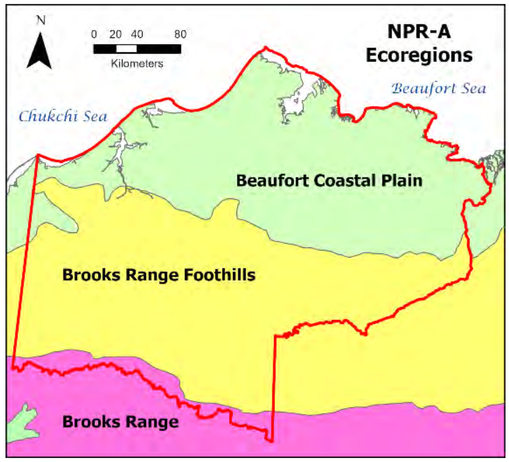

Figure 3g.1. Ecoregions of the National Petroleum Reserve – Alaska (following Nowacki et al. 2001).

Wet, graminoid-dominated vegetation is common close to the coast, with Wet Sedge tundra covering 12% of the NPR-A, Freshwater Marsh 8%, and Open Water 10% (Figure 3g.2, Table 3g.1). Moist graminoid types, such as Tussock Tundra (22%), become more common as distance from the coast and elevation increase. Erect dwarf shrubs (willow and birch) are common in the foothills, forming Shrub Tussock Tundra on the hillsides (33% of the NPR-A), and Low-Tall Willow in the drainages (4%). The Low-Tall Willow vegetation type, though it doesn't cover much area, is very important in providing habitat diversity in the large areas of Shrub Tussock Tundra in the foothills. Similarly, patches of alder vegetation provide important habitat along larger rivers, such as the Colville, covering 186 km^2 in the NPR-A (0.2%). In the southwest portion of the NPR-A, prostrate dwarf shrubs are common in the Utukok Hills and alpine areas of the Brooks Range, forming Dwarf Shrub - Dryas (on carbonate substrates) and Dwarf Shrub – Other (non-carbonate areas).

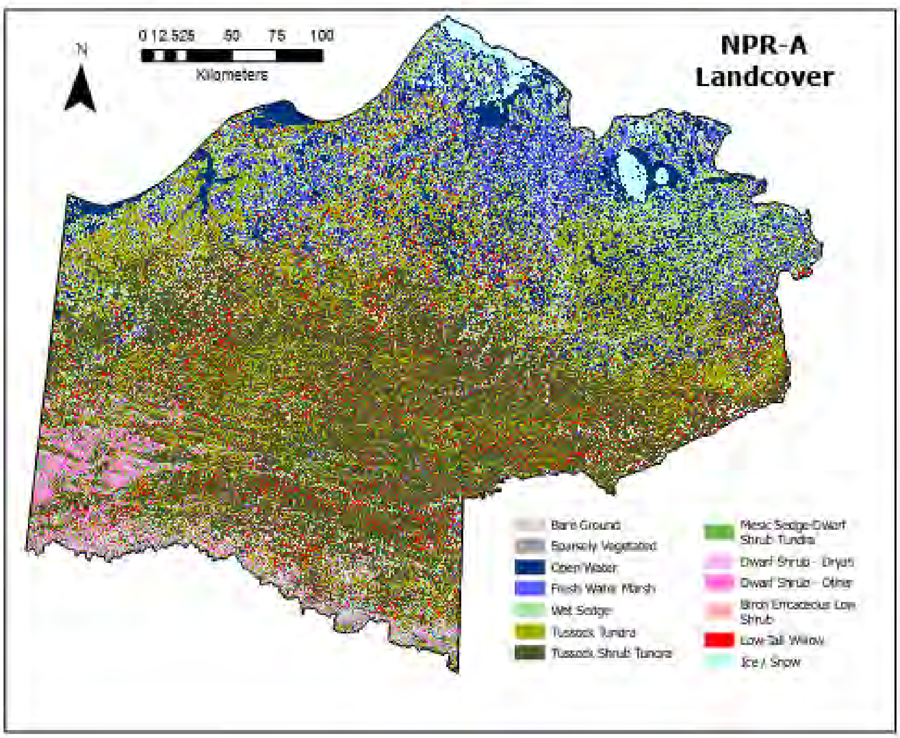

Figure 3g.2. Land cover types of the National Petroleum Reserve – Alaska. Produced for the North Slope Science Initiative (NSSI) by Ducks Unlimited (2013).

Table 3g.1. Area of different land cover types in the National Petroleum Reserve – Alaska (Ducks Unlimited 2013) and their sensitivity to winter vehicle traffic (Jorgenson et al. 2010). See Section Definitions for description of vegetation types.

Vegetation type	Area (km^2)	Percent	Sensitivity to winter vehicle traffic
Bare Ground	1,248	1%	low
Sparsely Vegetated	1,024	1%	low
Open Water	9,538	10%	low
Fresh Water Marsh	7,484	8%	low
Wet Sedge	11,094	12%	low
Tussock Tundra	20,270	22%	medium
Tussock Shrub Tundra	30,693	33%	medium
Mesic Sedge-Dwarf Shrub Tundra	2,150	2%	high
Dwarf Shrub - Dryas	954	1%	medium
Dwarf Shrub - Other	2,882	3%	medium
Birch Ericaceous Low Shrub	925	1%	medium
Low-Tall Willow	3,866	4%	medium
Ice / Snow	1,117	1%	low

Vulnerability/Resilience of vegetation types

The vulnerability of tundra to various types of disturbance is related to both the characteristics of the vegetation and of the underlying substrate and permafrost. Taller shrubs, especially those that are taller than the snowpack, are vulnerable to breakage from any kind of vehicle traffic. However, these shrubs also regrow quickly, in a matter of years (Jorgenson et al. 2010). Most tundra vegetation is short enough to be under the snowpack for most of the winter, where it is protected from the desiccation and abrasion that occur above the snow due to wind and ice. This lower-stature vegetation is also more protected from various types of winter traffic. However, vegetation types that form hummocks, such as Tussock Tundra, Tussock Shrub Tundra and Mesic Sedge-Dwarf Shrub Tundra may have very little protective snow cover on the tops of the mounds or tussocks, which may even be exposed after winter wind events. This makes them vulnerable not only to natural disturbance, but also various kinds of human activities (Jorgenson et al. 2010).

The other factor besides lack of snow cover which makes tundra vulnerable is its relationship with permafrost. Vegetation, especially mosses, insulate the underlying soil from warm summer temperatures. If the vegetation is compressed or removed, it loses that insulative value and the permafrost will thaw in response (Kade and Walker 2008). Areas with completely saturated soils, such as Freshwater Marsh and Wet Sedge freeze with enough water around and above the vegetation to protect them from most types of winter vehicle traffic. Some areas with gravel substrates are thaw stable, so when the permafrost thaws, there is no change in the surface elevation, making it more resistant to disturbance. However, most places in the NPR-A have finer-textured soils that hold excess ice in the permafrost. When the vegetation is disturbed, it exposes the dark organic soil under the live vegetation. This dark soil absorbs sunlight, heating the soil and thawing the permafrost. Mesic Sedge-Dwarf Shrub Tundra is especially ice-rich, which makes it especially vulnerable to disturbance (Jorgenson et al. 2010).

When permafrost thaws, the ice melts and any excess water flows away, resulting in surface subsidence. A study of excess ice along the Beaufort coast, from Pt. Barrow in the west to the Canadian border in the east, found an average of 11% volume of ice in the upper permafrost (Kanevskiy et al. 2013). Even more ground ice can occur in areas of “yedoma”, which are ice-rich silt and organic deposits of Pleistocene age. Yedoma areas have thick organic deposits with large quantities of sequestered carbon, and can also accumulate tremendous amounts of ice (Figure 3g.3). While this is not typical of tundra in the NPR-A, it does demonstrate the potential to accumulate massive ice in permafrost. To date, the only example of oil exploration on yedoma was the exploratory drilling during the 1940s to 1950s in the Naval Petroleum Reserve Number 4 (now the

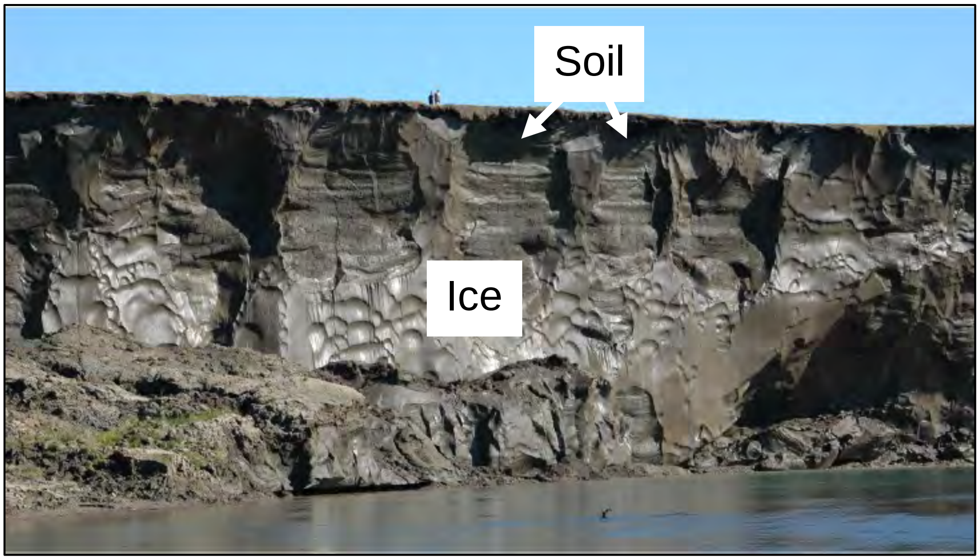

Figure 3g.3. A bluff along the Itkillik River in the NPR-A, showing the massive ice below the yedoma deposit. All the shiny material is melting ice. Pockets of dark organic soil can be seen near the surface. For scale, note people standing at top of the bluff (Kanevskiy et al. 2011).

NPR-A), where very severe subsidence was noted at several wells during cleanup operations in the 1980s (Lawson 1982).

The resilience of tundra vegetation to climate change is also related to permafrost and ground ice. Dramatic changes in surface topography, such as slumps and slides disrupt tundra vegetation. These features are increasing across the Arctic, and have been mapped throughout the foothills of the NPR-A (Makopoulou et al. 2024). Much of the southern and southwestern NPR-A was mapped as “Medium to Very High” susceptibility for retrogressive thaw slump occurrence (Makopoulou et al. 2024), but these features do not cover a large area. In areas with polygonal ice wedges, which occur throughout most of the NPR-A, thawing permafrost results in a polygonal pattern of depressions, which form drainage networks. This drainage and the increased depth of the annual active layer due to warmer air temperatures both lead to drying of the landscape, with resulting changes in vegetation (Liljedahl et al. 2016). The centers of the polygons become drier and the ice-wedge troughs become wetter, with corresponding changes in vegetation. Climate change also increases the potential for fires. Tundra fires in Alaska are expected to increase, but are not common (French et al. 2015).

Some tundra vegetation is relatively resilient to climate change. If the substrate is stable, changes in vegetation related to temperature are slow, because of delays in the arrival and establishment of new species (Crawford 1997). Studies on experimentally warmed tundra found changes over decades in the height and proportion of species, but not changes in vegetation type (Elmendorf et al. 2012).

Status of tundra in the NPR-A

The tundra of the NPR-A was first used by humans who migrated from Siberia around 5000 years ago. Today there are around 6,000 people living in the NPR-A in four communities: Atqasuk (~300), Nuiqsut (~550), Wainwright (~650), and Utqiaġvik (~4,500). The land occupied by these communities and adjacent areas are outside of BLM's authority. The people who live in these communities hunt throughout a large land area, using snow mobiles, 4-wheelers, river boats and other all-terrain vehicles. Some of the communities are connected in winter by Community Winter Access Trails, which are improved snow trails with signs and safety shelters scattered along the routes. These trails and the extensive travel in the NPR-A for subsistence hunting are regulated by the BLM.

The history of exploration for oil in the NPR-A began in the 1880s, with the first wells drilled in the 1940s. Between 1944 and 1982, the U.S. Navy and the U.S. Geological Survey drilled 136 wells in the NPR-A that are now abandoned (U.S. Bureau of Land Management 2023a). These oil wells do not cover a large area, but some included extensive camps and series of wells (e.g. Simpson, Oumalik, Umiat). Plugging these wells and site clean-up continue today (U.S. Bureau of Land Management 2023a). Bulldozed trails made to access these well sites are now shrubby ditches in the tundra, contrasting in elevation and vegetation with the surrounding tundra and changing the surrounding hydrology (Orians et al. 2003).

Recent oil development has extended westward from Prudhoe Bay, crossing the Colville River into the NPR-A. As of October 2023, there were 290 leases covering over 10,000 km^2 in the northeastern NPR-A. There are over 35 km of gravel road in the eastern NPR-A supporting oil and gas exploration and development. The first 3 km of the approximately 35 km of additional gravel road permitted for the Willow project was built in 2023 (U.S. Bureau of Land Management 2023a). When completed, that road will extend into the Teshekpuk Lake Special Area.

While tundra travel used to occur in the summer, creating some of the trails described above, by the 1970s people recognized that crossing the tundra in the summer with any but the lightest of vehicles damaged the tundra and underlying permafrost, making future travel on the same trail impossible. Since that time, travel has been restricted to winter conditions, with various regulations determining the beginning of the winter travel season. The Alaska Dept. of Natural Resources (AKDNR) monitors snow depth and soil temperature at a series of sites along the road system to determine the dates to open and close the tundra to winter vehicle travel (Raynolds et al. 2020). The BLM stopped using the AKDNR system and instead uses a “performance-based” system whereby the operator decides when there is enough snow to begin winter travel (U.S. Bureau of Land Management 2013).

Seismic exploration is the cause of the most extensive surface disturbance to the NPR-A tundra. Seismic exploration involves driving large tracked vehicles that shake the ground in a grid pattern (Figure 3g.4) and recording the return of those vibrations to understand the subsurface geology. Though the programs are conducted only in winter, when the ground is frozen and snow depths are deemed adequate, permanent impacts to the tundra do occur to a small percentage of the trails (Raynolds et al. 2020).

Figure 3g.4. Trails left by the 3D Icewine seismic survey, seen the following spring of 2018, approximately 40 km south of the Prudhoe Bay oilfield and 20 km west of the Dalton Highway. The survey consisted of seismic lines spaced 37.5 m to 150 m apart and covered approximately 518 km^2 (Alaska Department of Natural Resources 2018, Photo: H. Buelow).

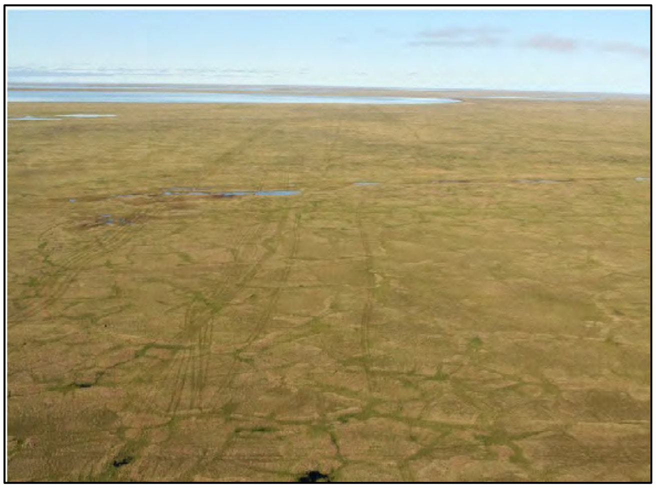

Figure 3g.5. Flat coastal plain of the NPR-A (Cape Halkett area), with tracks from winter vehicle travel. Note green trails going from lower left side towards lake in distance Even single tracks are visible the following summer (photo: M. T. Jorgenson).

Trails from seismic vehicles are visible the following year, usually as green swaths where the standing dead vegetation has been crushed (Figure 3g.5). Most of these green trails recover and are no longer visible in a year or two. In moist areas, or in areas where the vegetation has been scuffed and where permafrost is ice-rich, this disturbance can change a site from moist to wet. Where this occurs, the soil warms in summer due to heat absorption by the water and exposed soil, thawing the permafrost, which usually results in subsidence of the trail and a permanent change in vegetation (Raynolds et al. 2020).

The seismic programs are carried out far from any accommodations, so workers are housed in mobile camps, which include fuel and water carriers as well as bulldozers to pull the camp units. Camps and camp-move trails are made by vehicles with higher ground pressure than those used on the seismic lines, and therefore cause more initial damage and have slower recovery (Figure 3g.6, Jorgenson et al. 2010; U.S. Bureau of Land Management 2012).

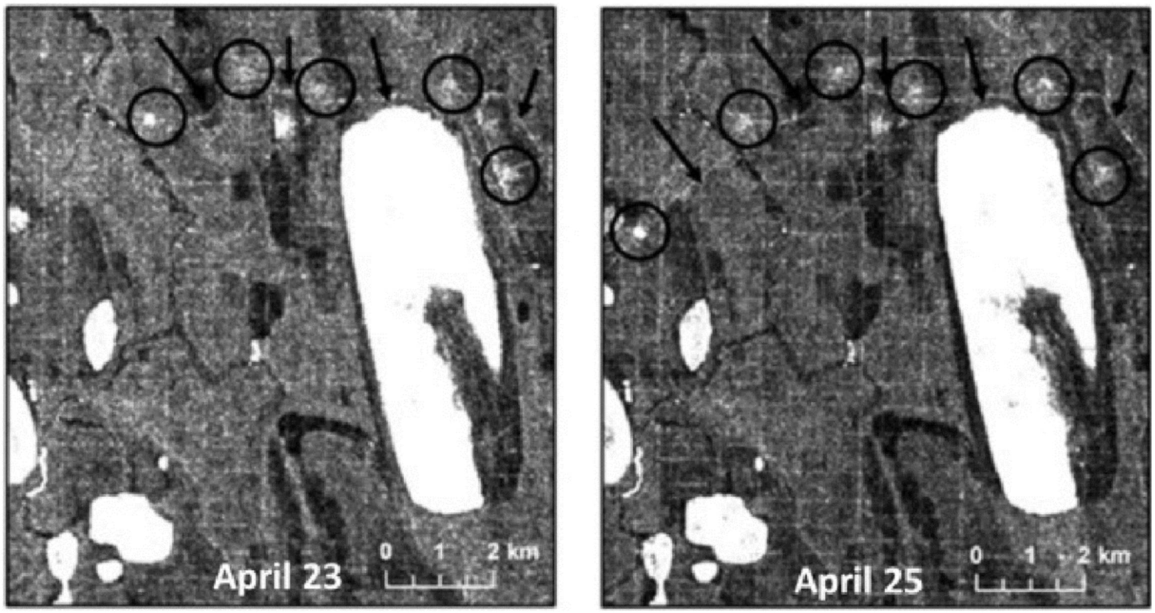

Figure 3g.6. Radarsat-1 Synthetic Aperture Radar (SAR) images from 23 April and 25 April 2006, showing a faint grid of 3-D seismic lines spaced at approximately 400 m, and a progression of camp moves (black circles), south of the Lonely DEW Line Station in the NPR-A. A new campsite was added between 23 and 25 April, visible on the left side of the right photo. Note the more intense radar signal associated with the camps (circles) and camp move trails (black arrows), which corresponds to the generally more intense disturbance caused by these activities (Jones et al. 2008).

Studies of winter offroad traffic show that despite efforts to reduce impacts, such as requiring minimum snow cover and freeze depth, impacts continue to occur, resulting in some areas with permanent changes to landscape and vegetation (Bader 2006; Jorgenson et al. 2010; Orians et al. 2003; U.S. Bureau of Land Management 2008). For example, a study of disturbance from 1998 3D-seismic exploration in the flat coastal plain of the NPR-A found that 4% of seismic lines were still disturbed after six years and 2% after 15 years In addition, 63% of the camp-move trails were still disturbed after six years and 20% after 15 years (Yokel and Ver Hoef 2014). Although the disturbance is relatively minor in most areas, the cumulative effects of the minor disturbance can result in long-term changes to species composition of vegetation communities over very large areas, such as throughout the Prudhoe Bay area (Raynolds et al. 2014b).

Oil in the leased areas is accessed by directional drilling, in an attempt to minimize the surface footprint of the oil infrastructure, including gravel roads. Disturbances from these roads include their gravel footprint and the much larger area impacted by indirect effects, such as dust and flooding (Raynolds et al 2014a). Many facilities are connected in the winter with ice roads, constructed by pumping water on the tundra. Traffic on these roads includes heavy equipment, with impacts similar to seismic exploration camp moves (Yokel and Ver Hoef 2014).

The main direct impacts to tundra in the NPR-A are summarized in Table 2. Seismic trails by far affect the largest area. Though the programs are conducted only in winter, when the ground is frozen and snow depths are deemed adequate, permanent impacts to the tundra do occur to a small percentage of the trails (Raynolds et al. 2020). And this table lists only one year's operation. The cumulative area impacted by seismic trails is much larger, with additional impacts outpacing recovery. It takes decades for vegetation to stabilize after disturbance by winter vehicle traffic (Jorgenson et al. 2010; Yokel and Ver Hoef 2014) and additional impacted areas are added every year that seismic exploration is permitted. The example of Prudhoe Bay shows that seismic operations are often also conducted repeatedly in the same areas, by different operators, using different technologies, and tracking changes in oil reservoirs. This results in significant changes in vegetation, particularly loss of the tundra microrelief which supports species diversity, and reduced cover of lichens (Raynolds et al. 2014b), which are important to caribou.

Table 3g.2. Direct impacts to tundra in NPR-A due to human activities. Area impacted values reflect the amount affected in one year of activity, see text for details.

Impact	**Area directly impacted**	**Severity of impact**
Footprint of communities	< 15 km^2	Mostly gravel, no longer tundra
Modern oil facilities	~ 1 km^2	Mostly gravel, no longer tundra
Old oil wells & roads	~ 1 km^2	Changed tundra vegetation – wetter, shrubbier, some gravel
Community Winter Access Trails	~ 2 km^2	Likely changed vegetation due to compaction and thawing of permafrost along portions of trail
Travel for subsistence hunting & gathering	Large area	Minimal impact except in close proximity to communities, where many trails overlap
Oil industry ice roads just in 2024*	< 1 km^2	Minor impacts in most areas after 5 years, some proportion (< 5%) with changed vegetation
Seismic exploration just in 2024*	~ 75 km^2 if spaced at 200 x 200 m	Minor impacts in most areas after 5 years, some proportion (< 5%) with changed vegetation

*(U.S. Bureau of Land Management 2023a)

Figure 3g.7. Strings of sled-mounted trailers (Cat trains) being moved during 3-D seismic exploration in foothills terrain near Kavik, west of the Arctic NWR, 2001. The Cat trains in the background apparently required two tractors per train to travel in this hilly terrain (one D7 to assist the lighter tractor), while the two trains in the foreground were waiting for tractors to return for them. Photo courtesy U.S. Fish & Wildlife Service.

Claims have been made that current 3-D seismic methods cause insignificant impacts to the tundra compared to the 2-D surveys in the Arctic National Wildlife Refuge (NWR) of the 1980s. However, although methods did change between the first and second year of those surveys, when the energy source changed from explosions in drilled holes to vibrating vehicles, vibrating vehicles have been used in the 40 years since then. While there have been improvements in reducing the ground pressure of some vehicles used for winter travel on tundra, the types of vehicles used for the seismic work continue to be the same types that were used in the Arctic NWR, including the vehicles that cause the most damage - heavy sleds and tractors for the camps (Figure 3g.7, Table 3g.1, Raynolds et al. 2020).

What has changed, is that instead of widely spaced 2-D seismic lines (5 x 20 km in the Arctic NWR in the 1980s (Felix and Raynolds 1989a), current data processing allows 3-D interpretation of much more closely spaced seismic lines (37.5 x 150 m in Figure 3g.4). Fleet sizes for 3-D seismic exploration continue to grow (Raynolds et al. 2020). Although the seismic trails cause less damage than the camp move trails, their close spacing results in impacts to very large areas. A study of repeated 2-D exploration in the flat Colville River delta in 1992, 1993, and 1995 and from 3-D work in 1996 found high levels of disturbance persisted on 1% of the sites surveyed (Jorgenson and Roth 1996). The same study noted the much higher density of trails associated with the 3-D operations. A BLM Environmental Assessment stated that “seismic exploration may vary from having no observable effects in some situations to damaging vegetation to the extent that it may take years or even decades to heal. These impacts occur despite existing stipulations on operations, and cannot be further mitigated, given the types of equipment currently used.” (U.S. Bureau of Land Management 2008). Another EA from this past winter found that disturbance from repeated heavy traffic, such as “the changes in soil thermal regime and mechanical damage to vegetation, including the crushing of tussocks and dwarf shrubs, can result in community successional changes in vegetation, potentially reducing or changing habitat value for foraging species such as caribou.” (U.S. Bureau of Land Management 2023b).

In addition to impacts to vegetation on the ground, trails on the tundra create a visual impact to observers from the air. For example, the contrast is striking between the east and west sides of the Canning River, between the heavily explored Alaska State land to the west and the relatively protected Arctic National Wildlife Refuge to the east. The human eye notices linear trails, and any impression of intact wilderness is quickly dispelled by the evidence of trails across the tundra.

NPR-A Special Areas

The NPR-A Special Areas include, listed by size: the Utukok River Uplands (28,577 km^2), Teshekpuk Lake (14,740 km^2), Colville River (9,879 km^2), Peard Bay (430 km^2), and Kasegaluk Lagoon (390 km^2). There is some overlap, as the Colville River Special Area extends into the Utukok River Uplands Special Area.

The Utukok River Uplands Special Area is in the southwest part of the NPR-A, in the Foothills ecoregion. Its outstanding attribute is the habitat it provides for the Western Arctic Caribou Herd. Almost two-thirds of the area is Tussock Tundra and Tussock Shrub Tundra (Table 3g.3). It also has more Dwarf-Shrub vegetation than the other special areas, especially on carbonate substrates, has more Low-Tall Willow than the other areas, and has most of the Mesic-Sedge Dwarf Shrub in the NPR-A. This area would be particularly sensitive to disturbance from winter seismic exploration due to its hilly terrain, which leads to low snow cover on ridges and requires heavier vehicles to be able to work on slopes. The Mesic-Sedge Dwarf Shrub vegetation is particularly sensitive to disturbance as it is usually found on ice-rich permafrost.

The Teshekpuk Lake Special Area, in the NE part of the NPR-A is in the Coastal Plain ecoregion. It is famous for its bird habitat, as well as supporting the Teshekpuk Caribou

Herd. Over one quarter of this area is water, including not only the large Teshekpuk Lake, but also thousands of small ponds. Almost half of the area is Fresh Water Marsh and Wet Sedge. The most common moist vegetation is Tussock Tundra, providing habitat diversity, often related to small differences in elevation in this relatively flat area (Figure 3g.8). This vegetation is sensitive to disturbance by winter vehicle traffic, as the tussocks often have little snow cover, which makes them susceptible to scuffing and compression.

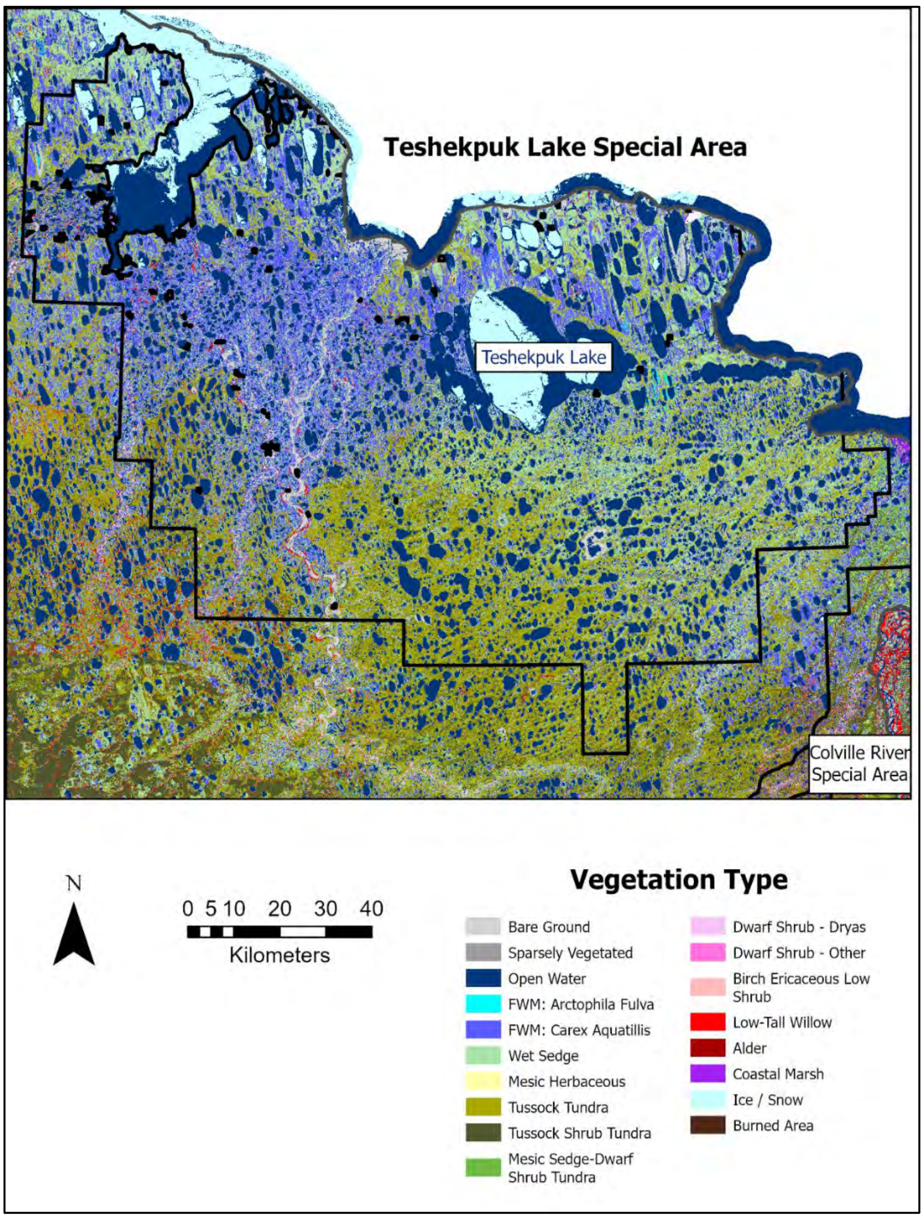

Figure 3g.8. Close-up of land cover types in the Teshekpuk Lake Special Area (following Ducks Unlimited 2013).

Table 3g.3. Cover of different land cover types in the Special Areas of the National Petroleum Reserve – Alaska, as defined in the 2022 IAP-ROD (U.S. Bureau of Land Management 2022). Land cover types according to Ducks Unlimited (2013). See Section Definitions for description of land cover types.

	Utukok		**Teshekpuk**		**Colville**		**Peard**		**Kasegaluk**	
Bare Ground	563	2%	369	3%	54	1%	9	2%	18	5%
Sparsely Vegetated	788	3%	101	1%	48	<1%	<1	<1%	<1	<1%
Open Water	183	1%	3,854	26%	142	1%	321	75%	234	60%
Fresh Water Marsh *Arctophila fulva*	8	<1%	73	<1%	2	<1%	1	0%	1	<1%
Fresh Water Marsh *Carex aquatillis*	155	1%	3,085	21%	196	2%	18	4%	26	7%
Wet Sedge	2,020	7%	3,327	23%	458	5%	22	5%	50	13%
Mesic Herbaceous	98	<1%	2	<1%	42	<1%	0	0%	<1	<1%
Tussock Tundra	5,153	18%	2,847	19%	1,560	16%	42	10%	49	13%
Tussock Shrub Tundra	13,009	46%	322	2%	5,751	58%	10	2%	4	1%
Mesic Sedge-Dwarf Shrub Tundra	1,417	5%	15	<1%	312	3%	<1	<1%	3	1%
Dwarf Shrub - Dryas	715	3%	67	<1%	83	1%	<1	<1%	<1	<1%
Dwarf Shrub - Other	2,621	9%	2	<1%	106	1%	<1	<1%	2	1%
Birch Ericaceous Low Shrub	482	2%	10	<1%	167	2%	<1	<1%	0	0%
Low-Tall Willow	1,360	5%	151	1%	812	8%	5	1%	1	<1%
Alder	<1	<1%	0	0%	143	1%	0	0%	0	0%
Ice / Snow	1	<1%	507	3%	3	<1%	0	0%	0	0%
TOTAL	28,577		14,740		9,879		430		390	

The Colville River Special Area follows the eastern and southern boundaries of the NPR-A. The Colville is the largest river in the NPR-A and hosts numerous fish and wildlife species, including raptors, that rely on its unique riparian habitats. The most common vegetation type in this Special Area is Tussock Shrub Tundra, but it also includes almost 10% cover of Low to Tall Willow and almost all of the Alder area in the NPR-A. These taller shrubs are unique in the NPR-A and provide habitat for nesting passerine birds and browse for caribou and ptarmigan. They grow along the river corridor, and cannot be crossed without damage to the vegetation. Deep snow cover and low-ground pressure vehicles are necessary to minimize damage.

The area between the Teshekpuk Lake Special Area and the Colville River Special Area includes coastal marsh on the west side of the Colville River, a rare vegetation type in the NPR-A, providing unique habitat for shorebirds and other waterfowl. Like the Teshekpuk Lake Special Area, the Coastal Plain portion of this in-between area is mostly water, Fresh Water Marsh and Wet Sedge. Farther south, in the Foothills area, Tussock Tundra is the dominant vegetation type.

The Peard Bay and Kasegaluk Lagoon Special Areas are mostly water, and are known for their marine and coastal habitat.

Existing regulations in 2022 ROD relating to tundra travel

The Bureau of Land Management (BLM), in its 2022 Record of Decision (U.S. Bureau of Land Management 2022), specifies Lease Stipulations and Required Operating Procedures (ROPs) to minimize negative impacts of human activities. The Lease Stipulations apply specifically to oil and gas companies with successful bids for leases on portions of the NPR-A. The ROPs apply to all other uses of the NPR-A. The Lease Stipulations and ROPs provide some protections for floodplains and wetlands, while recognizing that since much of the NRP-A is floodplains and wetlands, impacts can be minimized but not eliminated.

The 2022 Record of Decision also regulates off-highway vehicle (OHV) use. It places no restrictions on OHV travel for subsistence activities, but other travel is restricted to vehicles weighing ≤ 2,000 lbs (907 kg), and is only allowed in winter, when frost and snow cover is sufficient to protect the tundra. The Community Winter Access Trails are regulated under a separate permit.

ROP C-2 regulates the use of off-highway vehicles (OHVs). Ground operations are only allowed when “frost and snow cover are at sufficient depths to protect the tundra”, with estimates on dates in May when these conditions would end, with BLM making the decision as to the end of the winter travel season. It specifies low ground-pressure vehicles. It prohibits bulldozing of tundra and multiple passes on tundra without snow or ice roads. It specifies locating ice roads in ways to minimize damage to vegetation. It specifies that vehicle use “will be minimized” around the Colville, Kogosukruk (and its tributaries) and Kikiakrorak rivers in spring and summer and within ½ mile of known raptor nests.

ROP G-1 relates to reclamation, requiring a plan for restoration of ecosystem function, though it specifically states that the BLM can grant exceptions. Reclamation efforts of oil industry facilities in the Prudhoe Bay area have not been successful in restoring original tundra conditions. They remain sparsely vegetated gravel areas rather than the original tundra (Jorgenson, 1997).

ROP L-1 addresses summer travel on the tundra, allowing the BLM to permit it for low ground-pressure vehicles on a case-by-case basis, such as for spill prevention and response.

ROP M-2 requires equipment and vehicles to be weed-free, and specifies annual monitoring and control of non-native invasive species. Plans for those activities are required for any new operations.

Any of these regulations can be set aside through a one-time exception, a modification, or a waiver at the BLM’s discretion. There is also much leeway in the interpretation of “essential” roads and pipelines and other judgments embedded in these regulations.

Regulations for Special Areas

The Special Area status conveys some additional lease stipulations, but does not protect the Areas from development impacts. For example, the northern part of the Utukok River Uplands is open for leasing, but that leasing would be governed by Lease Stipulation K-14, which includes provisions to protect caribou habitat.

Most of the Teshekpuk Special Area is protected by being closed to leasing and by Lease Stipulation K-9 to protect caribou habitat. However, the eastern portion of the Teshekpuk Special Area is already leased and oil development is already occurring. Also, all but the core of the Special Area around Teshekpuk Lake itself is “available for new infrastructure.” Lease Stipulation K-6 for the goose molting area applies to the northeast part of the Special Area, and Lease Stipulation K-8 for brant surveys applies to the northwest part of the Special Area. Lease Stipulation K-10 applies to a very small area in the northeast coast specified as a caribou movement corridor. Lease Stipulation K-11 applies to the “Southern Caribou Calving Area”, a somewhat larger area that includes the area of K-10, and only allows infrastructure related to off-shore oil and gas production. K-13 protects the Pik Dune area from surface occupancy.

The Colville River Special Area is all open for leasing, except for the portion that is in the Utukok River Uplands Special Area (the westernmost, upstream portion). The Colville River riparian vegetation is protected by Lease Stipulation K-1, which requires a 2-mile setback from the river for most activities, and by K-12 which prohibits surface development close to raptor nests. Peard Bay and Kasegaluk Lagoon and other coastal areas are covered by Lease Stipulation K-3, which prohibits leasing and new infrastructure. Essential pipelines and sand and gravel mining can be permitted.

The 2-mile setback for activities along the Colville River Corridor, with no surface occupancy (except for “essential pipeline and road crossings”), should provide adequate protection for its unique riparian vegetation. Similarly, the setbacks for the other smaller waterways should provide protection for their riparian habitat. These protections would be adequate only if they are enforced and not waived.

Considerations for improving regulations

The activity that affects the most tundra area in the NPR-A, seismic exploration (Table 3g.2), is also one of the most loosely regulated. For both seismic and development/construction, operators are allowed to determine when they deem the tundra is able to withstand winter travel. They are only held to account if BLM inspections after the fact find excessive disturbance. Seismic activities in the NPR-A have already been shown to cause permanent damage to tundra vegetation in about 1-3% of the area they affect (Jorgenson and Roth 1996; Yokel and Ver Hoef 2014). Up to now, all of this activity has taken place on the relatively flat coastal plain of the NPR-A. If exploration extends into the foothills, there will be even more need for regulation, as the slopes require heavier machinery (Figure 3g.7), and the snow cover is often redistributed by wind, leaving little on ridges and hill tops.

In 2022, AKDNR requested recommendations for improving regulation of seismic activity. The group of scientists who wrote Raynolds et al. (2020) put together the following suggestions.

AKDNR requirements for tundra opening – 30 cm (12 in) of tundra frozen to at least -5° C (23 F°), snow depth of 15 cm (6 in) for coastal plain, 23 cm (9 in) for foothills.

The importance of frozen ground and snow cover in minimizing disturbance due to tundra travel has long been recognized. However, the justification for the specific measurements used by AKDNR is not well documented. The most thorough study of the relationship between snow cover and disturbance due to winter traffic (Felix and Raynolds 1989) determined that, “Disturbance was found to be generally lower when snow depths were greater. In tussock tundra, plots with snow depths over 25 cm had significantly less disturbance than those with under 25 cm ($p < 0.05$). … Moderate-level disturbance (25-50% decrease in plant cover) did not occur on trails where snow depths were at least 25 cm in tussock tundra and 35 cm in moist sedge-shrub tundra. Low-level disturbances (observable, but less than 25% decrease in plant cover) occurred on trails with snow depths as high as 45 cm in tussock tundra and 72 cm in moist sedge-shrub tundra.”

There are no studies that support the AKDNR 15 cm or 23 cm cutoff for minimizing a particular level of tundra disturbance. These are depths that can be expected to occur in most years on the North Slope coastal plain and foothills respectively, by December or early January, based on AKDNR records of tundra opening dates.

Additional studies on the impacts of the relationship between snow cover and winter tundra travel would help provide clearer guidance on this issue. These studies could be carried out by monitors accompanying existing seismic program vehicles.

A better way to measure snow – snow-water equivalent (SWE).
SWE measures the amount of moisture in the snow (e.g., its mass rather than volume) and can be determined by sampling (coring) a section of the snowpack, weighing the snow, and dividing by the square area of the sample (cross-section of the corer). *SWE math is straightforward in metric units*.

SWE best quantifies the protective qualities of the snow regarding compression and abrasion of the vegetation and upper soil layers. For the same snow depth, the protective qualities (the SWE) can vary by a factor of five, depending on whether the snow is dense wind slab or weak and loose hoar crystals. Felix and Raynolds (1989b) showed that snow slabs (high-density, wind-packed snow) provided greater protection than loose snow.

SWE could be the basis for the initial tundra opening and for measurements along travel routes. The SWE of the snowpack in northern Alaska is highly variable, and is a product of snow density and snow depth. Snow density commonly ranges from 0.2 to 0.5 g/cm^3, and was found to average about 0.3 g/cm^3 in the NPR-A (Benson and Sturm 1993; Glude and Sloan 1980; Sloan et al. 1979, Table 1; Sturm and Liston 2003, Table 1).

Based on this average 30% snow density, 15 and 23 cm snow depth would correspond to SWE values of 5 and 6.9 cm, and 25 cm of snow (10 inches) would equal SWE of 7.5 cm. Appropriate cutoffs corresponding to existing AKDNR snow depth cutoffs would be 5 and 7 cm SWE (2 and 3 inches SWE) for the coastal plain and foothills respectively.

SWE could be measured in a systematic way, both for initial opening minimums and ongoing sampling throughout seismic campaigns. We recommend at least 30 measurements along an “L” where each arm is 50 m long (15 measurements along each arm). These measurements could be repeated every 10 km of travel, or every 3 days, whichever is reached first, and need to be repeated after either snowfalls or wind storms. The measurement sites could be located in areas representative of general conditions, and favor neither scoured nor drifted areas.

It is critical that there be a plan for terminating overland travel in areas or at times when minimum snow conditions are not met.

Vehicle ground pressure limits – It would be preferable to regulate tundra travel by ground pressure rather than vehicle weight, as that is the factor most closely associated with level of impact (Felix and Raynolds 1989a).

High ground-pressure vehicles could be prohibited from seismic exploration in flatter areas such as the thaw-lake plains and deltas of the Coastal Plain of the NPR-A (such as the Colville Delta). In the Foothills (Figure 3g.1), large steel-tracked tractors may be necessary to get the camp vehicles up steeper inclines, but could be limited in number, and have specific minimum SWE values for travel.

Tire/track requirements - Rubber tracks cause less damage than steel, and could be required for all but a few permitted high ground-pressure vehicles (see above).

Maps of snow distribution

Although snow is quite variable from year to year, there are patterns on the landscape where snow is consistently shallower and deeper. Long-term snow distribution data shown as maps would be very helpful for planning seismic programs, especially in the Foothills. Collecting this information and creating snow maps is quite possible these days with Structure-from-Motion mapping or LiDAR mapping that first maps the summer ground surface and then the winter snow pack. Subtracting the two scenes gives a snow depth map. Seismic crews could be equipped with current maps of this type for any work in the Foothills area, so as to be able to plan ahead and route camp trails through areas of deeper snow. These maps would also be important for planning "escape routes" with typically deeper snow, if snow conditions deteriorated rapidly.

Maps of terrain and vegetation

Detailed terrain/slope maps (1-m resolution) could be required for route planning in the Foothills, to avoid steep banks (which has practical benefits for ease of travel as well as reducing impacts), and to know where snow ramps might be necessary. Ecological land classification maps, as described in ROP E-12 can be used to identify areas throughout NPR-A that are likely to have ice-rich permafrost, are most sensitive to surface disturbance, and which could have higher minimum SWE values. Maps at the Landsat scale (30-m) could be adequate for this purpose. These maps would also identify areas that are least sensitive, such as river gravel, where travel could be concentrated.

Prepacking snow for seismic campaigns

Prepacking would not be helpful on the seismic grids as the vehicles that do the pre-packing probably have greater ground-pressure (and thus impacts) than the seismic vehicles. Also, snow collection/harvesting would be difficult as the 3-D seismic trails are so closely spaced.

For the camp trails, prepacking would reduce impacts, and seems like a reasonable stipulation if SWE is close to or under the minimum required. Prepacking could be allowed only after the initial requirements for tundra opening are met, and with low ground-pressure vehicles used for snow packing and gathering/harvesting/redistributing to add to areas of low snow cover.

Monitoring – In-person monitoring could be required for any extensive seismic program. The monitor could collect valuable data on snow depths and densities to help minimize impacts to the tundra and provide data for follow-up studies.

Section Definitions

Description of land cover units in NSSI Landcover Map (Ducks Unlimited, 2013)

Alder: Total shrub cover is >25% and dominated by *Alnus viridis* ssp. *crispa***.** Common shrubs include *Salix alaxensis*, *Salix pulchra*, *Vaccinium uliginosum, Vaccinium vitis-idaea, Betula nana, Ledum palustre* ssp. *decumbens* and *Empetrum nigrum.* Common herbaceous species include *Eriophorum vaginatum, Carex lugens* (tussock tundra) and *Equisetum* spp. Mosses include *Hylocomium splendens* and *Dicranum* spp. Tussock tundra is common in the gaps between alder patches.

Low-Tall Willow: Total cover of shrubs >20 cm is >25% and dominated by willows. *Salix alaxensis* dominates floodplains and small active streams on the coastal plain, foothills and Brooks Range. *Salix glauca* is common on active dunes and bluffs along sand sheet lakes. *Salix pulchra*, often with *Eriophorum angustifolium* or *Carex aquatilis* in the understory, dominates water-tracks in the foothills and low-centered polygons or flat wetlands. *Salix niphoclada* dominated sites are uncommon and occur on floodplains and unstable mountain sideslopes. *Salix richardsonii* dominated sites are also uncommon but widespread occurring on foothill sideslopes, floodplains and low-centered polygons or flat wetlands often with *Eriophorum angustifolium* in the ground layer.

Birch-Ericaceous Low Shrub: Total shrub cover is >25% and typically dominated by *Betula nana >20 cm tall. Co-dominants include Salix pulchra and Salix glauca. Other species include Cladonia rangiferina, Dryas octopetala, Hierochloe alpina and Ledum palustre ssp. decumbens.* On high-centered polygon, the high-center is dominated by the plants given above and the troughs are typically dominated by *Carex aquatilis, Eriophorum angustifolium or Eriophorum chamissonis.*

Tussock Low Shrub: Total shrub cover is >25% and typically dominated or co-dominated by *Betula nana, Salix pulchra*, *Ledum palustre* ssp. *decumbens* and *Vaccinium uliginosum* >20 cm tall. *Eriophorum vaginatum* is the primary tussock-former in most stands, but *Carex lugens* also dominates or co-dominates. Other shrubs include *Vaccinium vitis-idaea* and *Empetrum nigrum*. Forbs are sometimes common and include *Equisetum arvense* and *Rubus chamaemorus.* Common nonvascular species include *Sphagnum* spp., *Hylocomium splendens, Aulacomnium turgidum* and *Dicranum elongatum.* On high-centered polygons, the high-center is dominated by the plants given above and the troughs are typically dominated by *Carex aquatilis, Eriophorum angustifolium* or *Eriophorum chamissonis.*

Tussock Tundra: *Eriophorum vaginatum* is the primary tussock-former in most stands, but *Carex lugens* also dominates or co-dominates. Total cover of shrubs >20 cm tall is <25%, however shrubs <20 cm typically exceed 25% cover. Common shrubs include *Betula nana*, *Salix pulchra*, *Ledum palustre* ssp. *decumbens*, *Vaccinium vitis-idaea* and *Vaccinium uliginosum*. Common nonvascular species include *Sphagnum* spp., *Hylocomium splendens* and *Aulacomnium turgidum.* On high-centered polygon, the high-center is dominated by the plants given above and the troughs are typically dominated by *Carex aquatilis, Eriophorum angustifolium* or *Eriophorum chamissonis.*

***Dryas* Dwarf Shrub:** This class is dominated or co-dominated by *Dryas octopetala* or *Dryas integrifolia*. *Dryas integrifolia* dominates upper floodplain terraces and sometimes pingos and rounded hills, whereas *Dryas octopetala* dominates ridges in the foothills and sideslopes and ridges in the Brooks Range. Other common dwarf shrubs include *Cassiope tetragona, Arctostaphylos alpina, Vaccinium uliginosum* and *Salix reticulata.* Common herbaceous species include *Equisetum arvense* and *Carex scirpoidea*. Common non-vascular species include *Rhytidium rugosum, Hylocomium splendens, Umbilicaria* spp.*, Racomitrium lanuginosum* and biological crusts.

Dwarf Shrub – Other: Dwarf shrub (≤ 0.2 m tall) cover is ≥ 25%, dominated by dwarf shrubs other than *Dryas* spp. Species diversity is high and supports numerous plant associations. Common dwarf shrubs include *Cassiope tetragona*, *Empetrum nigrum, Vaccinium uliginosum, Vaccinium vitis-idaea, Harrimanella stelleriana, Arctostaphylos* spp., *Betula nana, Diapensia lapponica, Dryas octopetala, Loiseleuria procumbens, Ledum palustre* ssp. *decumbens, Salix reticulata, Salix arctica, Salix phlebophylla* and *Salix rotundifolia*. Common herbaceous species include *Hierochloe alpina, Arnica lessingii, Carex lugens* and *Equisetum* spp. Common nonvascular species include *Aulacomnium turgidum, A. palustre, Cetraria* spp., *Ditrichum* spp. *Cladina* spp. and *Hylocomium splendens.* On high-centered polygons, the high-center is dominated by shrubs such as *Salix pulchra, Salix reticulata, Salix arctica, Salix phlebophylla, Ledum palustre* ssp. *decumbens, Vaccinium vitis-idaea.* Herbaceous species include *Carex lugens, Poa arctica* and *Hierochloe alpina.* The troughs are typically dominated by *Carex aquatilis* or *Eriophorum angustifolium.*

Mesic Sedge-Dwarf Shrub: This class is co-dominated by sedges and dwarf- or low-shrubs. Species composition is highly diverse with high species richness. Common herbaceous species include *Carex lugens, Carex aquatilis and Carex microchaeta*.

Common shrubs include *Arctostaphylos rubra, Dryas octopetala, Dryas integrifolia, Ledum decumbens, Salix arctica, Salix phlebophylla, Salix reticulata, Salix rotundata and Vaccinium uliginosum*. Nonvascular cover is often high including *Hylocomium splendens, Scorpidium cossonii, Ptilidium ciliare, Sanionia uncinata* and *Aulacomnium turgidum*. On flat-topped polygons, the centers are often dominated by *Carex aquatilis* and *Salix pulchra*. Flat-topped polygons may be bordered by slightly elevated perimeters or shallow troughs. The slightly elevated perimeters may support low shrubs (>0.2 to <1.3 m tall) and tussocks. Whereas troughs may support *Carex aquatilis* or *Eriophorum angustifolium* sometimes with standing water.

Freshwater Marsh *Arctophila fulva:* It is often dominated by monocultures of *Arctophila fulva.* Other emergent species may occur, including *Carex aquatilis, Eriophorum angustifolium* and *Hippuris vulgaris*. Species diversity is low.

Freshwater Marsh *Carex aquatilis:* This class is typically dominated *by Carex aquatilis* or *Eriophorum angustifolium*. Other emergent species may occur including *Carex utriculata, Carex rotundata, Carex saxatilis, Eriophorum chamissonis, Eriophorum scheuchzeri, Menyanthes trifoliata* and *Equisetum fluviatile*.

Wet Sedge: Wet sedges dominate the vascular canopy. Diagnostic species include *Carex aquatilis, Carex chordorrhiza or Eriophorum angustifolium*. Shrubs occur on raised microsites and common species include *Betula nana, Salix fuscescens, Vaccinium uliginosum* and *Andromeda polifolia*. Common non-vascular species include *Aulacomnium* spp., *Scorpidium scorpioides, Drepanocladus* spp. and *Sphagnum* spp. On low-centered polygons, the centers are dominated by wet sedge species, primarily *Carex aquatilis* and *Eriophorum angustifolium*. Elevated perimeters may support low shrubs (>0.2 to <1.3 m tall) and tussocks. Common shrubs include *Betula nana, Salix pulchra, Ledum palustre* ssp. *decumbens, Vaccinium vitis-idaea, Vaccinium uliginosum* and *Empetrum nigrum*. The primary sedges are *Eriophorum vaginatum* and *Carex lugens* and common mosses include *Sphagnum* spp., *Polytrichum strictum* and *Hylocomium splendens*.

Sparse Vegetation: On floodplains, common early seral species include *Salix alaxensis, Dryas* spp., *Festuca rubra* ssp. *arctica, Chamerion latifolium, Artemisia alaskana, Artemisia tilesii,* and *Hedysarum boreale* ssp. *mackenziei*. Bryophyte cover sometimes exceeds 25%.

On coastal dunes, common species include *Leymus mollis* and *Honckenya peploides*. On inland dunes forbs and graminoids such as *Artemisia campestris* ssp. *borealis, Deschampsia cespitosa, Elymus alaskanus* ssp. *alaskanus, Astragalus* *alpinus, Poa pratensis* ssp. *alpigena, Taraxacum officinale* ssp. *ceratophorum* are often present. Common shrubs include *Salix glauca, Salix alaxensis or Dryas integrifolia*. Several rare species such as *Koeleria asiatica*, *Poa hartzii*, *Poa subulata*, *Rumex graminifolius* and *Mertensia drummondii* occur regularly on inland dune sites. Bryophyte cover is typically low although some sites support extensive biological crusts.

In the hills and Brooks Range this class occurs on relatively stable sites and also unstable colluvial and talus slope where vascular plants grow in more stable microsites. Common species include *Smelowskia calycina* var. *porsildii, Potentilla elegans, Potentilla uniflora, Potentilla villosula, Cardamine bellidifolia, Minuartia macrocarpa, Silene uralensis* ssp. *uralensis, Festuca brachyphylla, Luzula confusa, Luzula arcuata* and *Poa arctica.* Crustose lichens are abundant on exposed rock. Common foliose and fruticose lichens include *Umbilicaria, Cladina, Alectoria, Brodoa oroarctica, Sphaerophorus globosus, Melanelia* and *Stereocaulon.* Moss cover may be >25% cover and include *Racomitrium lanuginosum* and *Dicranum fuscescens*.

Lichen dominated sites include foliose and fruticose. Non-vascular species include *Umbilicaria* spp., *Rhizocarpon geographicum, Cladina stellaris, Racomitrium lanuginosum, Flavocetraria* spp. and *Alectoria ochroleuca*. Common dwarf shrubs include *Loiseleuria procumbens, Betula nana, Ledum palustre* ssp. *decumbens, Empetrum nigrum* and *Vaccinium uliginosum*.

Bare Ground: See Sparsely Vegetated class description, but vascular plant cover is less than 10%

Tundra literature cited

Bader, H.R. (2006). Alaska North Slope tundra travel model and validation study. In (p. 273). Fairbanks, AK: Alaska Department of Natural Resources, Division of Mining, Land and Water. Available from: https://www.osti.gov/biblio/881572.

Benson, C.S., & Sturm, M. (1993). Structure and wind transport of seasonal snow on the Arctic slope of Alaska. *Annals of Glaciology, 18*, 261-267. https://www.cambridge.org/core/journals/annals-of-glaciology/article/structure-and-wind-transport-of-seasonal-snow-on-the-arctic-slope-of-alaska/6778FF898FAEFC71475A812C2ED9E7AE.

Crawford, R.M.M. (Ed.) (1997). *Disturbance and recovery in arctic lands: an ecological perspective*. Dordrecht: Kluwer Academic Publishers. Available from: https://www.amazon.com/Disturbance-Recovery-Arctic-Lands-Perspective/dp/0792344189.

Ducks Unlimited, Inc. (2013). North Slope Science Initiative Landcover Mapping Summary Report. In: K.A. Boggs, T.A. Boucher, J.S.S. Campbell, D.D.U. Fehringer, S.B. Guyer, L.M. Jenkins, & J.N. Payne (Eds.) (p. 51). Rancho Cordova, CA: Ducks Unlimited, Inc.

Elmendorf, S., Henry, G.H.R., Hollister, R.D., Bjork, R.G., Bjorkman, A.D., Callagahan, T.V., Collier, L.S., Cooper, E.J., Cornelissen, J.H.C., Day, T.A., Fosaa, A.M., Gould, W.A., Gretarsdottir, J., Hik, D.S., Hofgaard, A., Jarrad, F., Jonsdottir, I.S., Keuper, F., Klanderud, K., Klein, J.A., Koh, S., Kudo, G., Lang, S.I., Loewen, V., May, J.L., Mercado-Díaz, J.A., Michelsen, A., Molau, U., Myers-Smith, I.H., Oberbauer, S.F., Pieper, S., Post, E., Rixen, C., Robinson, C.H., Schmidt, N.M., Shaver, G.R., Stenstrom, A., Tolvanen, A., Totland, Ø., Troxler, T., Wahren, C.H., Webber, P.J., Welker, J.M., & Wookey, P.A. (2012). Global assessment of experimental climate warming on tundra vegetation: heterogeneity over space and time. *Ecology Letters, 15*, 164–175. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2011.01716.x.

Felix, N.A., & Raynolds, M.K. (1989a). The effects of winter seismic vehicle trails on tundra vegetation in northeastern Alaska, U.S.A. *Arctic and Alpine Research, 21*, 188-202. Available from: https://ecos.fws.gov/ServCat/DownloadFile/132612?Reference=87292.

Felix, N.A., & Raynolds, M.K. (1989b). The role of snow cover in limiting surface disturbance caused by winter seismic exploration. *Arctic, 42*, 62-68: Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/64695.

French, N.H.F., Jenkins, L.K., Loboda, T.V., Flannigan, M., Jandt, R., Bourgeau-Chavez, L.L., & Whitley, M.A. (2015). Fire in arctic tundra of Alaska: past fire activity, future fire potential, and significance for land management and ecology. *International Journal of Wildland Fire, 24*, 1045-1061. Available from: https://www.publish.csiro.au/wf/WF14167.

Glude, J.W., & Sloan, C.E. (1980). Reconnaissance snow surveys of the National Petroleum Reserve in Alaska, April 1979. In (p. 13). Anchorage AK: U.S. Geological Survey, Water Resources Investigations. Available from: https://pubs.usgs.gov/publication/ofr791342.

Jones, B.M., Rykhus, R., Lu, Z., Arp, C.D., & Selkowitz, D.J. (2008). Radar imaging of winter seismic survey activity in the National Petroleum Reserve-Alaska. *Polar Record, 44*, 227–231. Available from: https://www.cambridge.org/core/journals/polar-record/article/abs/radar-imaging-of-winter-seismic-survey-activity-in-the-national-petroleum-reservealaska/96071CC9AFBB698A106AE9C33071E9CE.

Jorgenson, J.C., Hoef, J.M.V., & Jorgenson, M.T. (2010). Long-term recovery patterns of arctic tundra after winter seismic exploration. *Ecological Applications, 20*, 205-221. Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1890/08-1856.1.

Jorgenson, M.T., & Roth, J.E. (1996). Reconnaissance survey and monitoring of seismic trail impacts on the Colville River Delta, 1997-1998. In. Fairbanks, Alaska: Prepared for ConocoPhillips Alaska by ABR, Inc.

Jorgenson, M. T. 1997. Patterns, rates of, and factors affecting natural recovery on land disturbed by oil development in arctic Alaska. Pages 421-442 in R. M. M. Crawford, editor. Disturbance and recovery in arctic lands: an ecological perspective. Kluwer Academic Publishers, Dordrecht.

Kade, A.N., & Walker, D.A. (2008). Experimental alteration of vegetation on nonsorted circles: effects on cryogenic activity and implications for climate change in the Arctic. *Arctic, Antarctic, and Alpine Research, 40*, 96-103. Available from: https://www.tandfonline.com/doi/full/10.1657/1523-0430%2806-029%29%5BKADE%5D2.0.CO%3B2.

Kanevskiy, M., Shur, Y., Fortier, D., Jorgenson, M.T., & Stephani, E. (2011). Cryostratigraphy of late Pleistocene syngenetic permafrost (yedoma) in northern Alaska, Itkillik River exposure. *Quaternary Research, 75*, 584-596. Available from: https://www.cambridge.org/core/journals/quaternary-research/article/abs/cryostratigraphy-of-late-pleistocene-syngenetic-permafrost-yedoma-in-northern-alaska-itkillik-river-exposure/E7A1D96F205D221465FEA252B07B440F.

Kanevskiy, M., Shur, Y., Jorgenson, M.T., Ping, C.-L., Michaelson, G., Fortier, D., Stephani, E., Dillon, M., & Tumskoy, V. (2013). Ground ice in the upper permafrost of the Beaufort Sea coast of Alaska. *Cold Regions Science and Technology, 85* 56–70. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0165232X12001644?via%3Dihub.

Lawson, D.E. (1982). Long-term modifications of perennially frozen sediment and terrain at East Oumalik, northern Alaska (CRREL Report 82-36). In (p. 33). Hanover, NH: Cold Regions Research and Engineering Laboratory. Available from: https://apps.dtic.mil/sti/tr/pdf/ADA123731.pdf.

Liljedahl, A.K., Boike, J., Daanen, R.P., Fedorov, A.N., Frost, G.V., Grosse, G., Hinzman, L.D., Iijma, Y., Jorgenson, J.C., Matveyeva, N.V., Nescoiu, M., Raynolds, M.K., Romanovsky, V.E., Schulla, J., Tape, K.D., Walker, D.A., Wilson, C.J., Yabuki, H., & Zona, D. (2016). Pan-Arctic ice-wedge degradation in warming permafrost and its influence on tundra hydrology. *Nature Geoscience*, 10.1038/NGEO2674. Available from: https://www.nature.com/articles/ngeo2674.

Makopoulou, E., Karjalainen, O., Elia, L., Stevens, A.B., Lantz, T.C., Lipovsky, P., Lombardo, L., Nicu, I.C., Rubensdotter, L., Rudy, A.C.A., & Hjort, J. (2024). Retrogressive thaw slump susceptibility in the northern hemisphere permafrost region. *Earth Surface Processes and Landforms, 2024*, 1-13. Available from: https://onlinelibrary.wiley.com/doi/10.1002/esp.5890.

Nowacki, G., Spencer, P., Fleming, M.D., Brock, T., & Jorgenson, M.T. (2001). Ecoregions of Alaska: 2001. *U.S. Geological Survey, Open-File Report 02-297 (map). Available from: https://pubs.usgs.gov/publication/ofr2002297.*

Orians, G., Albert, T., Brown, G., Cameron, R., Cochran, P., Gerlach, S., Gramling, R., Gryc, G., Hite, D., Kennicutt II, M., Lachenbruch, A., Lowry, L., Pielou, C., Sedingr, J., Lindstedt-Siva, K.J., Speer, L., & Walker, D.A. (Eds.) (2003). *Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope*. Washington, D.C.: National Academies Press. Available from: https://nap.nationalacademies.org/catalog/10639/cumulative-environmental-effects-of-oil-and-gas-activities-on-alaskas-north-slope.

Raynolds, M.K., Jorgenson, J.C., Jorgenson, M.T., Kanevskiy, M., Liljedahl, A.K., Nolan, M., Sturm, M., & Walker, D.A. (2020). Landscape impacts of 3D-seismic surveys in the Arctic National Wildlife Refuge, Alaska. *Ecological Applications, 30*, e02143. Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1002/eap.2143.

Raynolds, M. K., D. A. Walker, K. J. Ambrosius, J. Brown, K. R. Everett, M. Kanevskiy, G. P. Kofinas, V. E. Romanovsky, Y. Shur, & P. J. Webber. (2014a). Cumulative geoecological effects of 62 years of infrastructure and climate change in ice-rich permafrost landscapes, Prudhoe Bay Oilfield, Alaska. Global Change Biology 20:1211-1224. Available from: https://onlinelibrary.wiley.com/doi/10.1111/gcb.12500.

Raynolds, M.K., Walker, D.A., & Buchhorn, M. (2014b). Vegetation changes related to 45 years of heavy road traffic along the Spine Road at Prudhoe Bay, Alaska. In, *Arctic Change 2014*. Ottawa, Canada.

Sloan, C.E., Trabant, D., & Glude, J.W. (1979). Reconnaissance snow surveys of the National Petroleum Reserve in Alaska, April 1977 and April-May 1978. In (p. 31). Anchorage AK: U.S. Geological Survey, Water Resources Investigations. Available from: https://pubs.usgs.gov/publication/ofr791342.

Sturm, M., & Liston, G.E. (2003). The snow cover on lakes of the Arctic Coastal Plain of Alaska, U.S.A. *Journal of Glaciology, 49*, 370-380 Available from: https://www.cambridge.org/core/journals/journal-of-glaciology/article/snow-cover-on-lakes-of-the-arctic-coastal-plain-of-alaska-usa/DE920C1D770C9D01CA96F1FA22347D89.

U.S. Bureau of Land Management (2008). Environmental assessment: Conduct 3-D seismic, Anadarko. In: Anchorage, Alaska, US: U.S. Dept. of Interior, Bureau of Land Management

U.S. Bureau of Land Management (2012). National Petroleum Reserve-Alaska Integrated activity plan environmental impact statement. In: B. Arctic District (Ed.). Fairbanks, Alaska, USA. Available from: https://eplanning.blm.gov/public_projects/nepa/5251/41003/43153/Vol1_NPR-A_Final_IAP_FEIS.pdf.

U.S. Bureau of Land Management (2013). National Petroleum Reserve-Alaska Integrated Activity Plan Record of Decision, C-2 Best Management Practice, p. 54.

U.S. Bureau of Land Management (2022). National Petroleum Reserve in Alaska - Integrated Activity Plan Record of Decision. Available from: https://eplanning.blm.gov/public_projects/117408/200284263/20058238/250064420/2022_NPRA_IAP_ROD_508.pdf.

U.S. Bureau of Land Management (2023a). October 2023 Update on BLM North Slope Permitting and Activities. 55 p. Available from: https://www.doi.gov/sites/doi.gov/files/4-blm-north-slope-rac-update-october-2023.pdf.

U.S. Bureau of Land Management, ConocoPhillips Ptarmigan Seismic Survey Environmental Assessment (2023b). Available from: https://eplanning.blm.gov/public_projects/2026861/200565567/20088920/250095102/ConocoPhillips%20Seismic%20Environmental%20Assessment.pdf.

Yokel, D.A., & Ver Hoef, J.M. (2014). Impacts to, and recovery of, tundra vegetation from winter seismic exploration and ice road construction. In (p. 61). Fairbanks, Alaska: Bureau of Land Management, Arctic District.

3h: Polar Bears

1. Introduction

Polar bears (*Ursus maritimus*) occur within the National Petroleum Reserve in Alaska (NPR-A) and BLM mentioned them (89 FR 38714) as one of “[t]he many important surface resources of the Reserve” (89 FR 38713).

On May 7, 2024, the BLM issued a final rule (89 FR 38712) governing:

> “the management of surface resources and Special Areas in the National Petroleum Reserve in Alaska (Reserve or NPR–A)...[This] rule revises the framework for designating and assuring maximum protection of Special Areas’ significant resource values and protects and enhances access for subsistence activities throughout the NPR–A.”

The BLM clarified in the final rule (89 FR 38712, pg. 38757) that:

> “Significant resource value means any surface value, including subsistence, recreational, fish and wildlife, historical, scenic, or other surface value that the Bureau identifies as significant and supports the designation of a Special Area.”

They (89 FR 38712, pg. 38757) further clarified that:

> “Special Areas means areas within the Reserve identified by the Secretary or by statute as having significant resource values and that are managed to assure maximum protection of such surface values, to the extent consistent with the requirements of the Act for the exploration and production of the Reserve.

Currently, five Special Areas are identified.

In this section, the aim is to identify and summarize existing information on polar bears relevant to determining the need for the recognition of additional polar bear-related “significant resource values” (SRV) and the related identification of “Special Areas” within the NPR-A that contain those SRVs. By design, this summary is short and focused on this issue, rather than exhaustive. Attention is focused on information about polar bear subpopulations that occur in Alaska. More detailed and exhaustive reviews of polar bear status, habitat use, and threats are available (e.g., Wiig et al. 2015; IUCN/SSC/PBSG 2023; U.S. Fish and Wildlife Service 2023b). Information in these reviews, along with the considerable and strong scientific and Traditional Ecological Knowledge (TEK) literature on polar bears, informed the work here.[1]

[1] This literature included: recent BLM proposed and final rules related to such identification; relevant federal polar bear status reviews (USFWS 2023b), stock assessments (USFWS 2019; listing documents, and recent biological

2. Summary of Species Description and Current Status

2.A. Distribution, subpopulation structure, and estimates of global abundance

Throughout the circumpolar Arctic, polar bears occur in, and are uniquely adapted to, sea ice habitats, "particularly in near shore annual ice over the continental shelf where biological productivity is highest" (Derocher et al. 2004:163; see also summaries in Stirling and Derocher 2012, Wiig et al. 2015, IUCN/SSC/PBSG 2023:1, USFWS 2023b) and in adjacent coastal terrestrial areas (e.g., see summary in USFWS 2023b). Within this large area, information reviewed by the IUCN/SSC/PBSG has indicated that polar bears "occur in 19" (but see update below) "relatively discrete subpopulations" (IUCN/SSC/PBSG 2023:2) with the recognized boundaries of these subpopulations depicted on Figure 3h.1. As some gene flow and limited demographic exchange occurs between subpopulations, Wiig et al. (2015:5) summarized that the recognized "subpopulations cannot be considered distinct demographic units and the term "management units" may be more accurate." The International Union for Conservation of Nature Polar Bear Specialist Group (IUCN/SSC/PBSG) (2023:2) clarifies that the boundaries "are intended to identify discontinuities to movement, and that they "are likely dynamic over long periods and are predicted to shift with climate warming and the resulting loss of sea-ice habitat." Derocher et al. (2004:172) hypothesized that changes in the distribution of sea ice may cause changes in habitat connectivity and related polar bear movements that lead to alteration of current subpopulation boundaries, including the potential merger of the Southern Beaufort (SB) and Northern Beaufort (NB) subpopulations. Based on a review of new information, the IUCN/SSC/PBSG has very recently concluded that recognition of a 20th subpopulation, a Southeast Greenland subpopulation, is warranted (https://www.iucn-pbsg.org/2024/06/18/20th-working-meeting-of-the-iucn-ssc-polar-bear-specialist-group/). As a formal report regarding the relevant (June 2024) meeting is not yet available, our discussion below continues to refer to 19 subpopulations. The decision by the IUCN/SSC/PBSG to recognize a Southeast Greenland subpopulation does not impact findings or conclusions below regarding the recognition of polar bear SRVs or modifications to existing SAs in the NPR-A.

Amstrup et al. (2008) described that the recognized subpopulations can be further grouped into four main sea ice "ecoregions" in which patterns of ice freeze-up, breakup, and drift differ from one another. While the IUCN/SSC/PBSG summarized (2023:2) that loss of sea ice is expected in all ecoregions unless action is taken to address climate change, climate change impacts will differ due to the underlying differences in productivity, sea ice, and other characteristics between the ecoregions (IUCN/SSC/PBSG 2023:2).

---

opinions on activities within NPR-A; Alaska Native polar bear co-management documents and polar bear traditional knowledge studies; polar bear peer review literature; and documents produced by international organizations with scientific expertise and focus on polar bears, including the International Union for Conservation of Nature (IUCN) Polar Bear Specialist Group (IUCN/SSC/PBSG); and Polar Bears International.

One source of uncertainty regarding the status of polar bears worldwide derives from the fact that there is “high uncertainty” regarding the status and the discreteness of some subpopulations, especially those in the Russian Arctic (IUCN/SSC/PBSG 2023:5). Because reliable data are not available, there are not current abundance estimates for 4 of the (previously recognized) 19 subpopulations: Arctic Basin, East Greenland, Kara Sea, and Laptev Sea subpopulation; and data are deficient to make conclusions about the short-term (over ~1 polar bear generation (11.5.yr)) trend of 9/19 (updated to 10/20 at the June 2024 meeting) of the subpopulations (see “Status Table for the World’s Polar Bear Subpopulations, Vers:20231017 in IUCN/SSC/PBSG 2023:60; see also the narrative update at https://www.iucn-pbsg.org/2024/06/18/20th-working-meeting-of-the-iucn-ssc-polar-bear-specialist-group/). Of the 10 subpopulations with sufficient data quality to make estimates about short term trend, information in IUCN/SSC/PBSG (2023:60-61) indicates that: 2 have likely decreased and 1 has very likely decreased; 5 are likely stable; and 2 have likely increased; see also the narrative update from the IUCN/SSC/PBSG June 2024 meeting (https://www.iucn-pbsg.org/2024/06/18/20th-working-meeting-of-the-iucn-ssc-polar-bear-specialist-group/). While noting that current estimates of global abundance “must be interpreted with caution”, in part because of underlying differences in data quality and quantity, the IUCN/SSC/PBSG (2023:5, citing Regehr *et al.* 2016) provides a global abundance estimate of 26,000 (95% Confidence Interval [CI] = 22,000–31,000). Wiig et al. (2015:2) “highlight[ed] the large amount of uncertainty in statistical projections of Polar Bear abundance” over time. However, as pointed out by Stirling and Derocher (2012:2694, citing examples in Regehr et al., 2007, 2010), while this uncertainty exists, “the negative effects of climate warming, including declines in the abundance of individual subpopulations, have been demonstrated.”

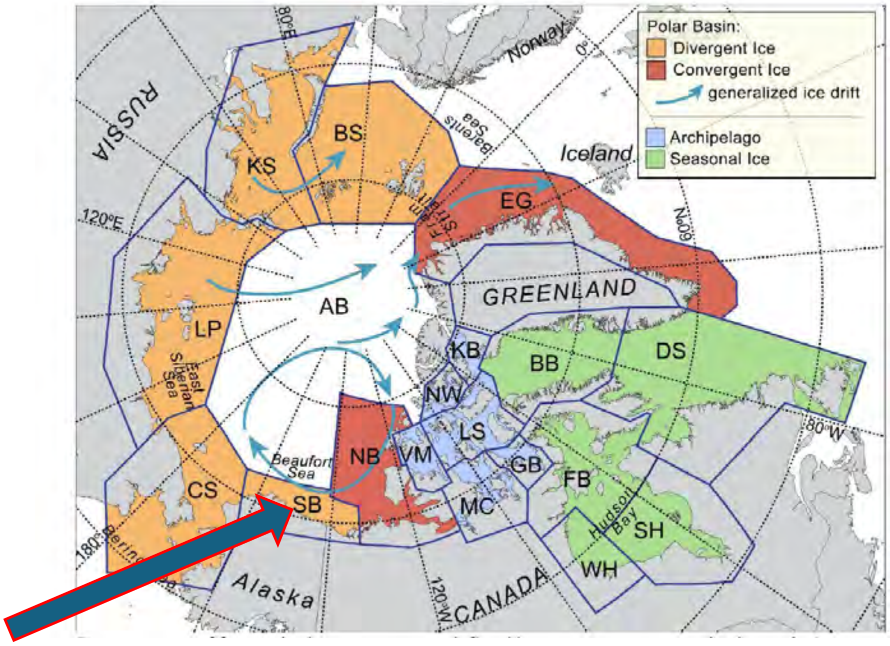

Figure 3h.1. Map depicting the boundaries and locations of 19 of the 20 (a 20th was recognized at the June 2024 IUCN/SSC/PBSG meeting: see update at https://www.iucn-pbsg.org/2024/06/18/20th-working-meeting-of-the-iucn-ssc-polar-bear-specialist-group/) recognized subpopulations of polar bears and the locations of four Arctic sea ice ecoregions that differ in sea ice characteristics. This figure is reproduced from Figure 1 of IUCN/SSC/PBSG (2023:7). The arrow identifies the location of the Southern Beaufort Sea (SB) subpopulation which occurs in the NPR-A and inhabits a Divergent Ice Ecoregion. The Chukchi Sea (CS) population is directly to the west of the SB and adjacent to it.

2.B. Polar Bears in Alaska

The USFWS (2019a:1, citing Garner et al. 1990, Garner et al. 1994, Amstrup 2000, Amstrup et al. 2000, 2001a, 2002, 2004, 2005) reports that two stocks [the Southern Beaufort Sea (SB) and the Chukchi Sea (CS)] "occur in Alaska…[and] range throughout the Beaufort and Chukchi Seas, including the nearshore habitats." They report that these subpopulations (termed stocks under the MMPA) "overlap seasonally in the eastern Chukchi and western Beaufort Seas", clarifying that "[a]n extensive area of overlap between the Southern Beaufort Sea stock and the Chukchi/Bering seas stock occurs between Point Barrow and Point Hope, centered near Point Lay" (USFWS 2019a:2, citing Garner et al. 1990, Garner et al. 1994, Amstrup 2000, Amstrup et al. 2000, 2001a, 2002, 2004, 2005). While acknowledging the aforementioned, because of the management boundary recognized by the IUCN/SSC/PBSG of Icy Cape, the USFWS assumes that "all polar bears occurring in the NPR-A belong to the SB subpopulation" (USFWS 2022:85). However, as information about polar bear habitat use from both populations may help inform needed protections and polar-bear SRVs within the NPR-A - especially during a period of rapid change, including forced changes in polar bear use of terrestrial habitats - information about both subpopulations is summarized, but with considerably greater focus on the SB subpopulation.

2.B.1.Delineation and Summary of Status of Southern Beaufort (SB) Subpopulation

Data from mark-recapture and radiotelemetry studies “through the 1980s indicated that polar bears in the SB region comprised a single subpopulation, with an eastern boundary between Paulatuk and Baillie Island, Northwest Territories (NWT), Canada, and a western boundary near Icy Cape, Alaska, U.S.” (IUCN/SSC/PBSG 2023: citing Amstrup et al. 1986; Amstrup and DeMaster 1988; Stirling et al. 1988). However, more recent data from studies of satellite radio-collared females indicates that 50% of the bears at Utqiağvik were from the SB (50%) and 50% from the Chukchi Sea (CS) subpopulations and that there was overlap of SB and NB polar bears to the east at Tuktoyaktuk, NWT (see details in IUCN/SSC/PBSG 2023:30). The latter findings resulted in a revision of the boundary between the NB and SBs subpopulations which has been accepted by the IUCN/SSC/PBSG. However, until a new subpopulation estimate for the SB becomes available, the estimate of Bromaghin et al. 2015 (which estimated abundance for the SB using the previous boundary) is still used (see below). Recent analysis by Scharf et al. (2019) supports the existing SB-CS boundary (IUCN/SSC/PBSG (2023:31).

The IUCN/SSC/PBSG (2023:60) summarized that the most recent estimate (Bromaghin et al. 2015) of abundance for the SB subpopulation was approximately 900 (90% CI = 606-1212) in 2010. Subpopulation abundance likely decreased between 1983-2015, and between 2001 to 2015. Recent reanalysis by Atwood et al. (2020) of mark-recapture data from 2001-2016 supported previous conclusions that abundance declined from 2003-2006 in the Alaska portion of the SB subpopulation and suggested that abundance stabilized through 2015. Findings of Bromaghin et al. (2021) from the Alaska portion of the SB indicated that survival was poor from 2004-2009 (and again in 2012) and supported a conclusion of relatively stable abundance from 2006 to 2015 (with the exception of 2012; see discussion in IUCN/SSC/PBSG 2023:32). Bromaghin et al. (2021:14262) summarized that “the carrying capacity of the SBS has been eroding for nearly two decades,” with “large reductions…occur[ing] during punctuated periods of low survival” (Bromaghin et al. 2021:14263).

The SB subpopulation is one of five subpopulations that inhabit the Divergent Ice Ecoregion (see above). In this ecoregion, currents carry ice away from the shoreline and when new ice stops forming during warmer weather, an open water gap develops between the shoreline and the ice edge. As the climate warms, this seasonal gap has become much larger with the sea ice retreating to areas over the deeper waters of the polar basin, resulting in bears either coming ashore until ice freeze-up or following the retreat of ice northward. In both cases, the bears may be unable to access their primary prey and have to survive fasting periods for long periods of time during the summer months (e.g., see Whiteman et al. 2015, 2018). The IUCN/SSC/PBSG (2023:4) notes that the resultant “long fasts for bears of the Divergent Ice Ecoregion which, unlike those in the Seasonal Ice Ecoregion, are accustomed to feeding through the summer, make them among the most vulnerable of all polar bears to climate warming and loss of sea-ice habitats.” However, differences in productivity in habitats throughout the Divergent Ice Ecoregion likely amplify the ramifications of the consequences of the sea ice retreat and the subsequent effects of food deprivation and fasting periods for bears in less productive waters. Polar bears in the highly productive Chukchi Sea, with its relatively large continental shelf, may be able to withstand longer fasting periods than those in the Beaufort Sea, which “is among the least productive of arctic waters” (IUCN/SSC/PBSG 2023:4). Predicted patterns between sea ice loss, land use, and relationships with fasting duration that the bears must withstand are being observed in the SB subpopulation: the amount of time that SB polar bears are spending on land is increasing and is correlated with the extent of ice retreat (Atwood et al. 2016); and from the mid-1980s to the mid-2010s, the number of SB polar bears “in a physiological fasting state in April and May increased” (IUCN/SSC/PBSG 2023:32; see details in Cherry et al. 2009 and Rode et al. 2018). “[M]any polar bears” (IUCN/SSC/PBSG 2023:32) are feeding on bowhead carcass remains (Heereman and Peacock 2013). Concerns identified by the IUCN/SSC/PBSG (2023:60, citing Rode et al. 2018, Atwood et al. 2020, 2021, Wilson and Durner 2020, Bromaghin et al. 2021, Rode et al. 2022) include: “declining body condition and increased frequency of fasting, periods of low survival,…growing reliance on land during summer…, and the growing potential for human-polar bear conflict arising from increased industrial development of the coastal plain.” These concerns informed the identification of SRVs in this report.

2.B.2. Delineation and Summary of Status of the Chukchi Sea Subpopulation

The IUCN/SSC/PBSG (2023:17) describes the eastern boundary of the CS subpopulation to be at Icy Cape, AK and the western boundary near Chaunskaya Bay in NE Russia. Citing Regehr et al. (2018), the IUCN/SSC/PBSG (2023:60) provides an estimate of 2937 (95% CI = 1552–5944) for the CS subpopulation in 2016 with the trend between 2008-2016 “likely stable,” but “data deficient” to assess long term (≥2 polar bear generations, ≥23 yrs.). The recent (May 2019) stock assessment report for Chukchi bears estimates 2000 bears as reflecting the best available scientific information (U.S. Fish and Wildlife Service 2019b). The IUCN/SSC/PBSG (2023:60) reported that springtime body condition and recruitment indices have been good but that 2004-2010 autumn observations “suggest declining cub survival.” As has been reported for other populations, they summarized that land use is increasing with longer ice-free periods (IUCN/SSC/PBSG 2023:60). While continued loss of sea ice is anticipated in this region (Wang et al. 2018), recent findings (Rode et al. 2021) of stable or improving body condition and reproduction of CS polar bears captured in the US during a period of substantial sea ice decline (1986-1994 and 2008-2011), suggest that the CS subpopulation may have some resiliency (IUCN/SSC/PBSG 2023:18) to at least the levels of summer sea ice loss that occurred during the studied time periods. However, between 2004-2010, maternity denning and cub production declined on Wrangel Island (IUCN/SSC/PBSG 2023:18, citing Ovsyanikov 2012).

2.C. Habitat Use and Prey

The habitat use and needs of polar bears have been well-studied and thoroughly described and discussed elsewhere (e.g., see Amstrup 2003; USFWS 2023b). Below, we focus on several key aspects of their habitat use and needs that are directly relevant to understanding the need for additional polar-bear supportive SRVs, changes to Special Areas, and changes to the approach in protections within the NPR-A: denning; use of land and recent changes to that use; foraging, including information about their use of terrestrial food resources that may become more important as supplements during increasingly long periods when they may be forced to be on land due to increases in the duration and extent of sea ice loss; and to a much lesser extent, resting during forced fasting periods.

Polar bears have evolved to live in sea ice habitats. As described by Stirling and Derocher (1993:241), they "depend on sea ice" for: finding and foraging on their primary prey, ice seals; finding mates and breeding; traveling to maternity dens; long distance movements; "sometimes", including in the SB subpopulation, "for maternity denning" (although most maternity dens are in snow on land); and rearing their cubs (Stirling and Derocher 2012). Their use of sea ice habitat varies with sex, reproductive status, and age (e.g., see discussions in Stirling and Derocher 2012, Laidre et al. 2020).

Historically, summer sea ice conditions over the polar bear's preferred habitat (Durner et al. 2009) of continental shelf waters $\leq$300m deep, allowed SB bears to remain near or over such productive waters year-round (Pagano et al. 2021, citing Durner et al. 2009, Pagano et al. 2012, Ware et al. 2017). Atwood et al. (2016:) summarized that prior to 2000, most SB polar bears (other than those that came on land to den) "remained on the sea ice year-round."

<u>Prey</u>.--"While there is "some geographic variation in their diet" (Derocher et al. 2004:163), polar bears have evolved to use sea ice over the productive waters of the continental shelf (Stirling and Derocher 2012; see also Atwood et al. 2016) as a platform to hunt, kill, and eat ice seals, especially ringed seals (*Pusa hispida*), their primary prey, and, to a lesser extent, bearded seals (*Erignathus barbatus*) (Stirling and Archibald 1977; Smith 1980; Stirling and Derocher 2012), and "occasionally" beluga whales (Bourque et.al. 2020:2094, citing Stirling and Archibald, 1977; Thiemann, Iverson, and Stirling, 2008). Pongracz and Derocher (2016:8, citing Bentzen et al. 2007; Cherry et al. 2011; Pilfold et al. 2012) summarized that in the SB subpopulation, data indicated that ringed seals "comprise the majority (53%-100%) of [their] diet." Bourque et al. (2020) noted that since the year 2000, proportions of SB bears onshore has increased (Atwood et al. 2016; Schliebe et al. 2008) and foraging on other alternative food types has been observed. However, quantitative fatty acid signature analysis by these authors (Bourque et al. 2020:1) showed that the predominant prey of SB polar bears remains ringed seals (46.4 ± 1.8%), "with much lower consumption of bearded seal (19.6 ± 2.0%), seabird (17.0 ± 1.2%), bowhead whale (15.0 ± 1.4%), and hardly any beluga whale (2.0 ± 0.5%)."

While emphasizing that information (e.g., Rode et al. 2010, 2015, 2023) indicates that the long-term viability of polar bears requires sufficient access to their primary prey of ice seals, information from multiple parts of the range indicates that polar bears may also occasionally forage on other marine mammals, and on terrestrial food resources. In general, Rode et al. (2015:138) concluded that: “[o]nly small numbers of polar bears have been documented consuming terrestrial foods even in modest quantities”; and “[w]here consumption of terrestrial foods has been documented, polar bear body condition and survival rates have declined even as land use has increased.” However, as supplemental food resources may become more important as polar bears in Alaska are forced to spend more time on land, information about such use is briefly discussed here.

Atwood et al. (2016) and others note that there is uncertainty regarding the extent to which polar bears have the behavioral plasticity to respond to the rapid changes that are occurring to their primary habitat, sea ice. However, Atwood et al. (2016:13, citing Gormezano and Rockwell 2013) note that polar bears in subpopulations such as the Southern Hudson Bay, WH, Foxe Basin, and Davis Strait “where sea ice completely melts” in the summer, exhibit more use of terrestrial habitat and show greater foraging flexibility. Atwood et al. (2016: 13) summarized that “[i]n the near-term, whether bears benefit from this behavioral flexibility will likely hinge on the trade-off between the availability of food resources (and net energetic benefit), and the risks associated with accessing them”, including risks from interspecific competition with grizzly bears (*Ursus arctos)* and increased “exposure to human-related activities”.

Rogers et al. (2015:1) stated that climate warming and changes to sea ice habitat may result in polar bear diets becoming more variable. In various parts of their range, polar bears are known to prey on, and scavenge on, other species of marine mammals. These species include walrus (*Odobenus rosmarus*) (primarily calves), beluga whales (*Delphinapterus leucas*), narwhal (*Monodon monoceros*), harp seals (*P. groenlandica*) (Derocher et al. 2004 and references cited therein), and bowhead whales (*Balaena mysticetus*) (see below). Using quantitative fatty acid signatures of polar bears harvested across Nunavut from 2010-2018, Galicia et al. (2021) found polar bear foraging patterns were congruent with known distributions of prey distribution spatial clusters of marine mammals. While ringed seal and, to a lesser extent, bearded seal, were the primary polar bear prey across Nunavut, spatial clusters were also found of Atlantic walrus (*Odobenus rosmarus rosmarus*), with hotspots of consumption of harbour seal (*Phoca vitulina*), harp seal (*Pagophilus groenlandicus*), and beluga whale. Galicia et al. (2021:1) also found hot spots of bowhead whale “suggesting carcasses are locally accessible to bears and may act as a supplemental food source in particular areas and seasons.” Evidence suggests that polar bear use of carcass remains of subsistence-harvested bowhead whales has a learned component (Herreman and Peacock 2013). The USFWS (2023b:18, citing references including Miller et al. 2015, Galicia et al. 2016, Laidre et al. 2018, and Lillie et al. 2019) summarized that “bowhead whale…carcasses from harvests, orca (*Orcinus orca*) predation or strandings have been an important and seasonally reliable food source in some regions, including the southern Beaufort Sea, Svalbard, and Chukotka, Russia”. McKinney et al. (2017) found that the body condition of male polar bears was positively correlated with bowhead whale consumption. Data provided by Fishbach et al. (2007:1402) indicates that most pre-denning bears did not visit these sites, but that use by pre-denning bears is increasing.

In Russia, polar bears from the CS subpopulation have been reported to "…congregate at walrus haulouts that occur on Wrangel Island and on the Chukotkan coast in some years, where they have been documented to hunt and kill live walruses as well as trigger stampedes and scavenge the resulting carcasses" (Ovsyanikov 1995; Kochnev 2002; Rode et al. 2015, citing Ovsyanikov 2005). However, noting that "some polar bears died of starvation on Wrangel Island" in 1990, even though there were up to 130,000 walrus present, Rode et al. (2022:17, citing Kochnev 1992; Ovsyanikov 1995) summarized that this food resource "has been insufficient to offset long periods onshore." Rode et al. (2015, citing Ovsyanikov 2005) also reported that CS polar bears may feed opportunistically on the carcasses of other marine (e.g., gray whales, *Eschrichtius robustus*) and terrestrial mammals (including reindeer *Rangifer tarandus and* muskox, *Ovibos moschatus*) and that "[d]uring peak lemming (*Synaptomys spp*.) years, polar bears actively dig them out of burrows…"

Indigenous hunters within the range of the CS subpopulation in Alaska reported observations of polar bears hunting (e.g., on beluga whales in the Shishmaref region), or scavenging on, other marine mammals. Voorhees et al. (2014:528) summarized that "[t]hroughout the study area, hunters reported that polar bears are more likely to scavenge on carcasses of walrus than to kill them, although hunters on St. Lawrence Island have observed bears actively hunting for walruses. Carcasses of walrus, beluga whale, bowhead whale…and gray whale…wash up on shore in the summer and fall and later become frozen in the shorefast ice, providing an important food source for bears in the region. Polar bears are commonly found scavenging along shorelines from December to March. Concentrations of carcasses can lead to large congregations of polar bears."

Indigenous respondents on St. Lawrence Island reported that they have observed polar bears eating caribou (Voorhees et al. 2014:532). In Svalbard, Stempniewicz et al. (2021) reported a documented case of a polar bear successfully hunting and eating a Svalbard reindeer and the same bear with another freshly killed reindeer 2 days later. Indigenous hunters also reported that they have observed polar bears summering on St. Lawrence Island eating a variety of plant and animal foods, including berries, fish, bird eggs, and greens (Voorhees et al. 2014:529). Some of these same food types were reported to Kalxdorff's (1997), as were "crabs, clams, squirrels (*Spermophilus parryii*), and seaweed, and birds" (Voorhees et al. 2014: 532, citing Kalxdorff (1997).

While these supplemental food resources are not likely to compensate for the long periods many bears are forced to be onshore, their impact as a supplemental local food resource for individual bears is not yet certain. Stirling and Derocher (2012:2702, citing Rode et al. 2010) summarized that "while polar bears consume a variety of terrestrial and freshwater food sources opportunistically, these are inadequate to provide the energy these bears require on an annual basis." Consumption of bowhead whales by SB whales did not compensate for the energy deficits bears incurred due to loss of access to seals (Rode et al. 2023). However, supplemental terrestrial foods may help some bears forced to be on land obtain calories and reduce the amount of loss of body fat and mass until they can return to sea to forage (for further discussion, see Voorhees et al. 2014, McKinney et al. 2017, USFWS 2023b and the many references cited therein). Rode et al. (2023:18) summarized that pregnant female SB polar bears "that summer onshore may increase the energy density of their diet via consumption of bowhead whale carcasses and by maintaining longer access to areas of higher prey densities during the summer sea ice minimum compared to bears summering on sea ice far offshore." Hence, as information from throughout many portions of the range indicates that some polar bears utilize terrestrial prey resources, including scavenging, or less frequently, preying on other marine mammal species, ensuring that terrestrial food resources such as marine mammals and marine mammal carcasses are available to polar bears may become more important as they are forced to spend more time on land.

Patterns in terrestrial habitat use in Alaska.--In ecoregions in which polar bears currently have year-round access to sea ice, polar bears can hunt throughout the year, but in regions in which the sea ice over productive waters melts completely in the summer, many polar bears are forced to go ashore where they "primarily fast on stored fat reserves until freeze-up" (Wiig et al. (2015:2). There is increasing information (e.g., Schliebe et al. 2008; Herreman and Peacock 2013) that as the duration and extent of sea ice retreat increase, use of land during the ice-free period is increasing (Wiig et al. 2015), including an increase in land use by SB bears. Evidence indicates that since the late 1990s, "land-use behavior has become more prevalent" (Atwood et al. 2016:12), with the percentage of radio-collared females from the SB subpopulation that came on shore tripling from 2000-2014. Their arrivals onshore were earlier, their departures later, and the time they spent on land increased by about 3 weeks. Similarly, results from Rode et al. (2015), who compared location data between 1986–1995 and 2008–2013 for radio-instrumented female polar bears from the CS subpopulation, showed that the "proportion of bears on land for > 7 days between August and October increased between the two periods from 20.0% to 38.9%, and the average duration on land increased by 30 days."

Pagano et al. (2021:2) summarized that rapid declines in summer sea ice have "reinforced a divergent movement strategy" (Pagano et al. 2021:2) in the SB subpopulation, with an estimated 10-27% of SB bears coming to land in the summer while the majority remain on retreating sea ice "over the deep waters of the Arctic Basin…" Bears captured in 2009 on ice over these deep waters were primarily fasting (Whiteman et al. 2015, 2017, 2018). In a recent study based on data from 408 radio-collared polar bear adult females in both the SB and CS, Rode et al. (2022:13) found that "[s]ince the mid-1980s, declines in sea ice were correlated with increases in the percent of bears summering onshore from an average of ~5% to ~30% by 2016 in the Alaska portion of the SB…and from ~10% to ~50% by 2017 in the CS…Increases in duration onshore during the same period were notably similar for the two subpopulations starting with averages ~20–30 days in the 1980s that increased to ~70 days by the 2010s."

This trend of increasing use of land by CS and SB polar bears is expected to continue due to anticipated continued reductions in summer sea ice due to greenhouse gas emissions. By forecasting sea ice loss based on a range of greenhouse gas emissions, Rode et al. (2022:1) estimated that by 2040, "50–62% of SB and 79–88% of CS bears will spend 90–108 and 110–126 days onshore during summer in the SB and CS, respectively." Summer sea ice is expected to continue to decline in the Arctic, with anticipated continued effects on SB habitat use patterns and "the increasing importance of land as an alternative summer refuge" (Pagano et al. 2021:1).

Atwood et al. (2016:6, citing, Schliebe et al. 2008) summarized that onshore, SB bears primarily inhabit a "narrow band of the coast or on barrier islands." At present, data suggest that along the US coast of the Beaufort Sea, where the remains of bowhead whales killed in subsistence harvests have been "sporadically aggregated at Point Barrow and consistently aggregated at Cross Island and Barter Island", polar bears are attracted to these sites and feed on the remains (Atwood et al. 2016). This food source may provide supplemental nutritional value to some SB polar bears (Miller and Reed 2015, see discussion above). Atwood et al. (2016:14) summarized that available data on polar bear distribution obtained during fall aerial surveys in 2010-2013 from Utqiaġvik to the Baillie Island, Canada border indicate that sites where the remains of bowhead whales are deposited affect polar bear distribution. Citing Herreman and Peacock (2013), they note that "[i]t is likely that most bowhead whale tissue is consumed by bears visiting sites that have been stocked with remains following fall whaling…, though scavenging on beach-cast whales also occurs." Their data showed that prior to stocking of sites with bowhead remains, 64% of bears were within 16 km of a site and 78% of all bears were within this distance following stocking (Atwood et al. 2016:12). These authors found that 40% of bears were near Barter Island, 33% near Cross Island, and less than 2% near Point Barrow.

Denning.--Polar bears from the SB subpopulation use habitat on the Alaska ACP for denning (Durner et al. 2013:19, citing Amstrup et al. 2004a), including extensive areas within NPR-A (e.g., see Figures 3h.2, 3h.3, and 3h.4). Polar bear cubs, which are born "blind, lightly furred, and helpless" (USFWS 2010:76090), depend on the protection, relative warmth, and stable environment provided by the maternal den to survive until they are large and developed enough to survive outside the den (e.g., Blix and Lentfer 1979; Durner et al. 2003; USFWS 2023a). SB polar bears give birth in dens excavated in snow on land or in snow caves on land-fast ice or drifting pack ice (Amstrup and Gardner 1994; Fischbach et al. 2007; USFWS 2010). However, based on evaluation of data on denning sites of satellite-collared females, Fischbach et al. (2007:1395) summarized that "[t]he proportion of dens on pack ice declined from 62% in 1985–1994 to 37% in 1998– 2004 (P = 0.044)" and that in the western Beaufort Sea, fewer dens occurred in pack ice habitat after 1998. The proportion of radio-collared females denning on land in the southern Beaufort Sea has increased. They anticipate that if Arctic sea ice continues to decline, this trend will continue. USFWS (2023a:104) also concluded that “[d]ecreased quality and quantity of sea ice may increase the importance of barrier islands and terrestrial habitat for foraging, denning, and resting. Fischbach et al. (2007) noted that the duration and extent of sea ice loss could become so severe that females foraging on the ice could be prevented from reaching land in Alaska to den and be forced to den in “deteriorating sea ice conditions” and in locations occupied by other subpopulations (Fischbach et al. 2007:1404).

Data indicate that polar bears exhibit fidelity to regions and substrate types for denning (Ramsay and Stirling 1990, Amstrup and Gardner 1994). Hence, to ensure future denning habitat availability, strong protections need to be in place to ensure future, not just active, denning habitat is not modified by human activities in such a way as to make the habitat unsuitable for denning. In Alaska, USFWS (75 FR 76087, citing Durner et al. 2003 and Durner et al. 2006) summarized that habitats that “receive proportionally greater use for denning than other areas” include “barrier islands…, river bank drainages, much of the North Slope coastal plain, and coastal bluffs that occur at the interface of mainland and marine habitat.” Polar bear dens are built in locations where “landscape or sea ice features…capture and accumulate wind-blown snow” (Bergen et al. 2007:1; Durner et al 2003). Durner et al. (2001, 2003, 2013) identified and delineated geographic areas in parts of the polar bear range in Alaska, including northern parts of NPR-A (Durner et al. 2013), that have landscape features suitable for polar denning (see Figures 3 and 5). For example, considerable maternal denning habitat is located along the Meade River, including denning habitat areas dozens of kilometers inland. USFWS has recognized “maternal denning habitat” (e.g., USFWS 2023a:85), also called “[p]otential denning habitat” in multiple documents and described its characteristics.

Information indicates that the majority of CS bears den on, especially, Wrangel Island (e.g., see Garner et al. 1994, Rode et al. 2015; Chinn et al. 2023), the Chukotka Coast, and Herald Island (Rode et al. 2015; see summary in USFWS 2019b). However, on the western coast of Alaska, in locations near (relative to polar bear home ranges) NPR-A, Indigenous respondents reported that they have observed dens in locations “around Point Lay, where high snowdrifts pile up against bluffs and riverbanks…in an inlet about 16 km north of Point Lay…[and] the north side of Tungak Creek, between Cape Beaufort and Kasegaluk Lagoon, and south of Utokok River, near a shelter cabin about 40 km from Point Lay. The bluffs along Icy Cape are also known as a denning area…”(Voorhees et al. 2014:529). Voorhees et al. (2014: 532) noted that CS and SB polar bears overlap in the area around Point Lay and, citing Amstrup and Gardner (1994), summarized that SB bears are “known to den in this region.” Locations of known dens discovered by various means are shown on Figure 2 of Durner et al. (2020:6), which is reproduced here as Figure 3h.2.

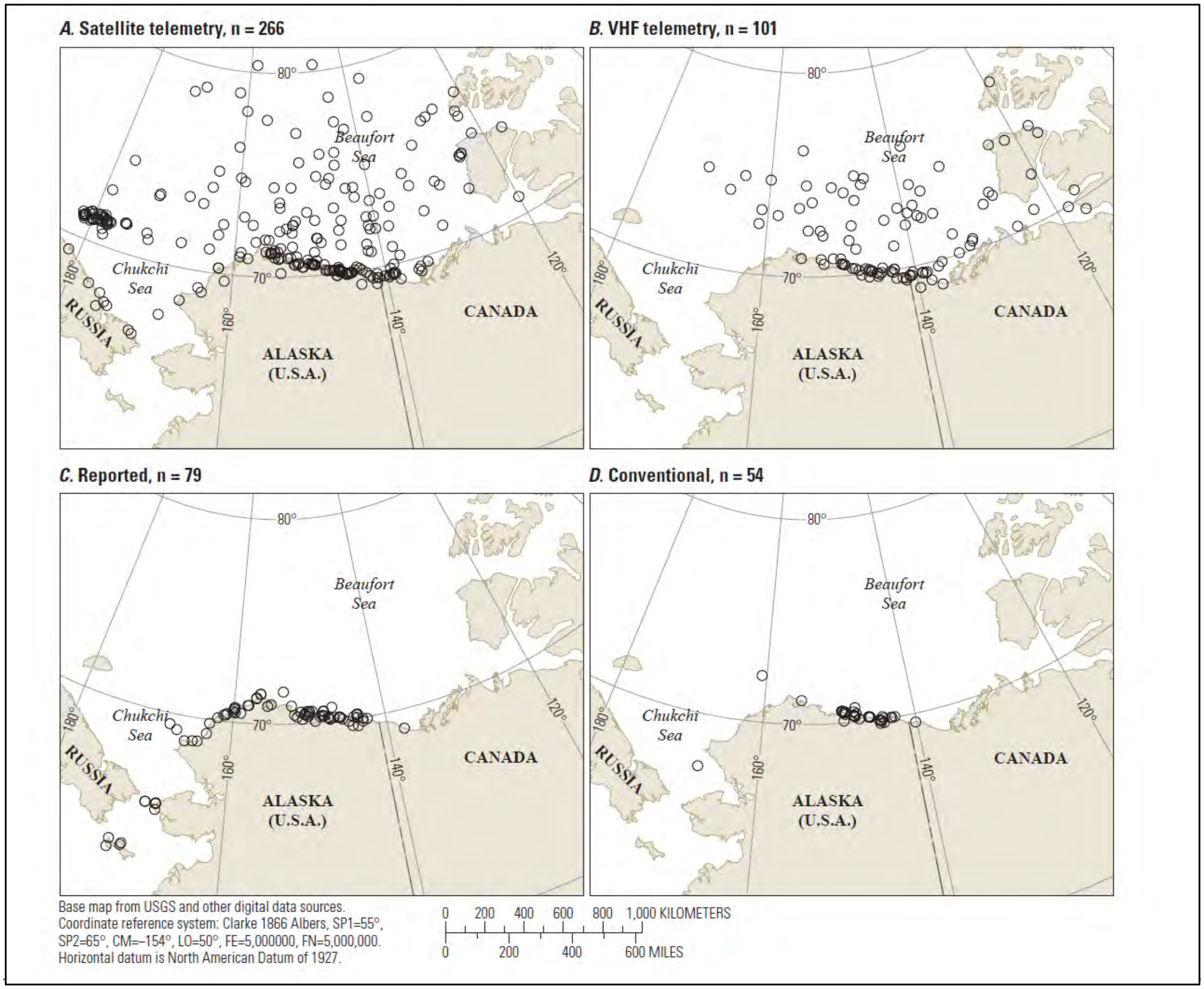

Figure 3h.2. "Distribution of polar bear maternal dens (hollow black circles) discovered through (A) satellite telemetry, (B) very high frequency (VHF) telemetry, (C) reported by others, and (D) during polar bear survey operations on sea ice and nearshore areas, for the Beaufort and Chukchi Seas and neighboring regions, 1910-2018." (Durner et al. 2020:6). Figure and figure legend reproduced from Figure 2, pg. 6 of Durner, G.M., Amstrup, S.C., Atwood, T.C., Douglas, D.C., Fischbach, A.S., Olson, J.W., Rode, K.D., and Wilson, R.R., 2020, Catalogue of polar bear (*Ursus maritimus*) maternal den locations in the Beaufort and Chukchi Seas and nearby areas, 1910–2018: U.S. Geological Survey Data Series 1121, 12 p., including appendices, https://doi.org/10.3133/ds1121. [Supersedes USGS Data Series 568.]

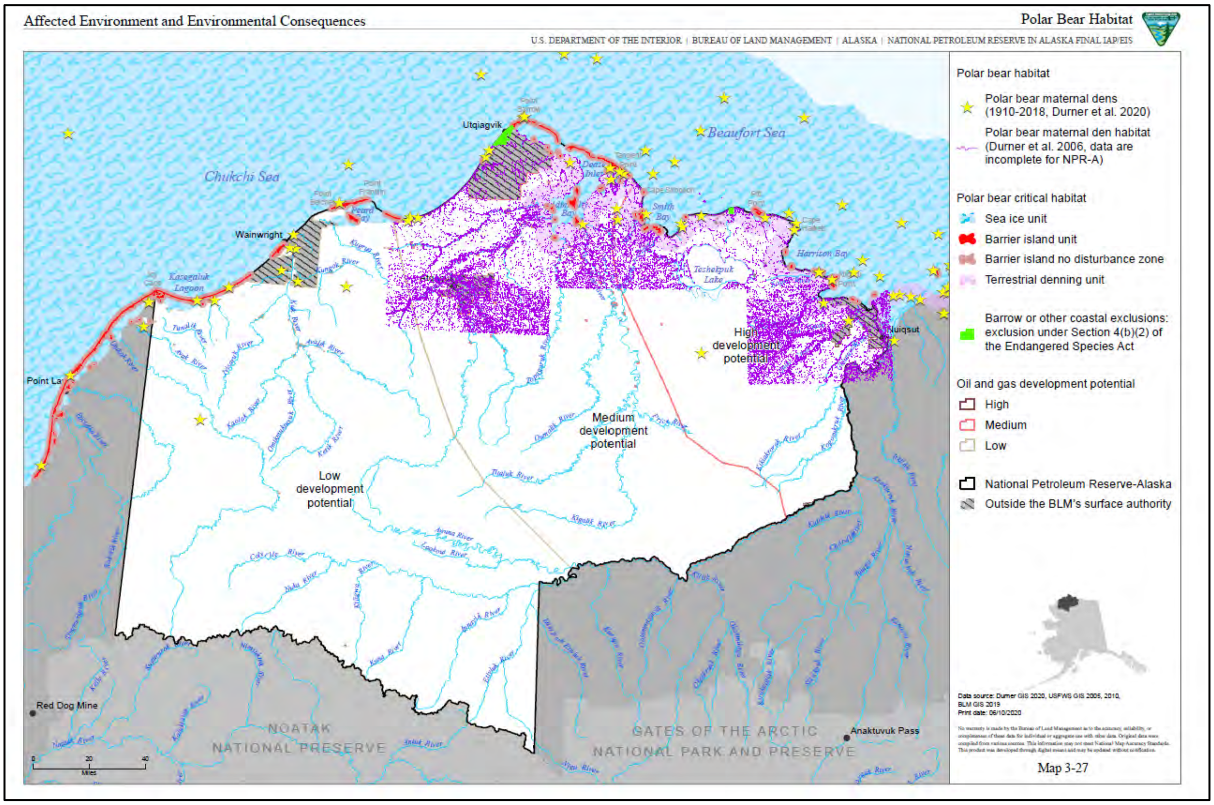

Figure 3h.3. Polar bear designated critical habitat, detected polar bear maternal den sites, and polar bear maternal den habitat. Figure reproduced from BLM (2020). NPR-A Final IAP EIS, Appendix A, Map 3-27.

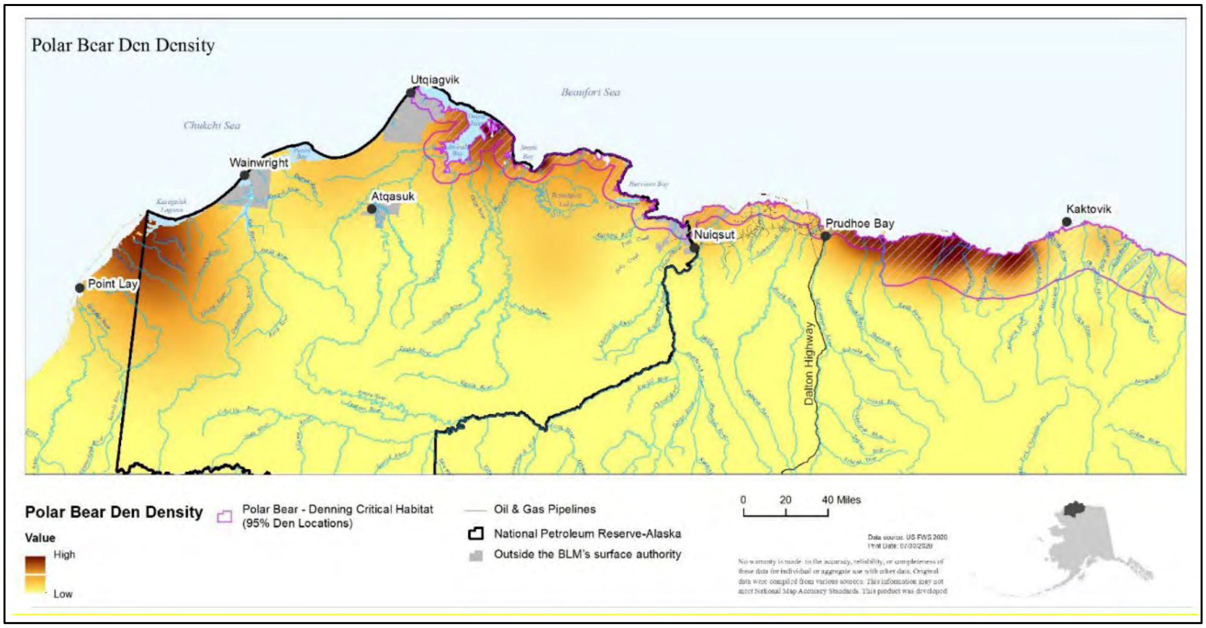

Figure 3h.4. Relative density of polar bears maternal dens on the North Slope of Alaska. (Map is a density kernel map developed by USFWS and U.S. Geological Service (USGS) scientists using Program R based on 33 den locations discovered by tracking VHF-radio telemetry and GPS collared females [den sites from Durner et al. 2010; G. Durner unpublished data) with land management and polar bear designated critical habitat boundaries added by BLM GIS specialists). Figure and figure legend reproduced, with minor modification to legend, from USFWS (2022:89), Final Biological Opinion for Integrated Action Plan.

2.D. Primary threat

Loss of Arctic sea ice.--There is ample scientific evidence that the most serious threat to the viability of polar bears is the "[l]oss of Arctic sea ice due to climate change" (Wiig et al. 2015:1; see also Amstrup et al. 2008, 2010; Stirling and Derocher 2012; 73 FR 28211; Regehr et al. 2016; USFWS 2023b and references cited therein). As summarized by Hunter et al. (2010:2894) and supported by numerous studies conducted since that time, Arctic "summer sea ice is expected to continue to decline", the decline poses a serious threat to the "continued persistence" of the SB subpopulation (Hunter et al. 2010; see also Obbard et al. 2010) and to polar bears worldwide (e.g., 73 FR 28211).

Meier and Stroeve (2022:11) summarized that:

> "The Arctic sea ice cover has undergone substantial changes in the past 40+ years, including decline in areal extent in all months (strongest during summer), thinning, loss of multiyear ice cover, earlier melt onset and ice retreat, and later freeze-up and ice advance. In the past 10 years, these trends have been further reinforced, though the trends (not statistically significant at $p < 0.05$) in some parameters (e.g., extent) over the past decade are more moderate."

While noting that "[t]he future of Arctic sea ice is dependent on future CO2 emissions" Meier and Stroeve (2022:11, citing Notz and SIMIP Community 2020), concluded that "[a]t this point, it is highly likely that ice-free conditions will emerge in September by the middle of the century (e.g., Notz and SIMIP, 2020). It is only under limited future emissions scenarios that the likelihood of largely sea ice-free conditions during summer can be avoided on a regular basis." They note that, due to year-to-year variability, there is "considerable uncertainty on exactly when this will happen" (Meier and Stroeve 2022:11). Notz and SIMIP Community (2020:1, italics not in original and added here for emphasis) reported that "in most simulations" of Arctic sea ice using state of the art global climate models, "the Arctic Ocean becomes practically sea-ice free (sea-ice area <1 million km^2) in September for the first time *before* the Year 2050." While declines in the extent and concentration of Arctic sea ice are occurring "everywhere in the Arctic", areas with the most pronounced summer declines include the Beaufort and Chukchi Seas (Meier and Stroeve 2022:11), the regions that support the existence of the SB and CS polar bears.

Analyses conducted by Amstrup et al. (2008) over a decade and a half ago indicated that sea ice loss driven by anthropogenic climate warming could lead to the disappearance of up to two thirds of the world's polar bears by mid-century if global greenhouse gas emissions continued unabated. Based on a stochastic demographic analysis to evaluate the impacts of future climate change on SB polar bears, Hunter et al. (2010) indicated that "[i]f current GCM outcomes are correct, there is a high probability that the Beaufort Sea population of polar bears will disappear by the end of the century. Because all polar bears are dependent on sea ice for securing their prey, it is reasonable to expect that the effects of global warming [on SB]…polar bears…will ultimately extend to polar bears throughout their range." Relationships between earlier breakup dates (which advances the date at which polar bears have to stop feeding on the ice and come ashore, and which lengthens fasting periods) and multiple indicators of negative effects on polar bears have been documented in the Western Hudson Bay subpopulation (Stirling and Derocher 2012) include a decline in: mean body condition of bears on land during the open water period; mean weights of females that were likely pregnant before denning; and survival of multiple age classes. Adult female body mass and cub survival in the Hudson Bay area are being negatively affected by increases in the number of ice-free days (IUCN/SSC/PBSG 2023:3). Studies in the SB subpopulation show that: survival declined as the duration of ice-free days increased (Regehr et al. 2010); sea ice declines were associated with reduced reproduction and body size (Rode et al. 2010, see also findings of Regehr et al. 2006); habitat use patterns were altered (e.g., Durner et al. 2009) with reductions in the extent of summer sea ice; and the proportion of fasting bears increased between 1985-86 to 2005-06 (Cherry et al. 2009).

Analyses conducted for the IUCN in 2015 confirmed the conclusion of a high threat to polar bears from continued sea-ice loss, with Wiig et al. (2015:2) highlighting the "potential for large reductions in the global Polar Bear population if sea-ice loss continues, which is forecast by climate models and other studies (IPCC 2013)" (see also findings of Regehr et al. 2016 which support this same general conclusion).

Data indicate that polar bears delay coming ashore until the ice concentration is insufficient for hunting (Atwood et al. 2016) and, possibly, before the distribution of low concentration sea ice is so widespread that long distance swims are required (Atwood et al. 2016:13). Long-distance swims result in increased energy expenditure (Pagano et al. 2012), mortality risk (Monnett and Gleason 2006; Durner et al. 2011), and may result in the loss of offspring (Pagano et al. 2012).

SB polar bears that stay on ice that retreats to unproductive, or less productive, deep water, may not have access to, or as good of access to (Frost et al. 2004; Pongracz and Derocher 2016; Whiteman et al. 2015, 2017, 2018), their primary prey of ice seals during that time. Earlier break-up of seasonal sea ice reduces the amount of time polar bears have to forage on seals, likely resulting in the bears coming ashore with less stored fat (Stirling and Derocher 1993). The increasing duration of periods of the loss of sea ice over the productive waters of the continental shelf "equates to a loss of preferred foraging habitat" (Atwood 2016:13) for polar bears, including SB polar bears and leads to an increase in the duration (Stirling and Derocher 1993:243) of forced fasts when they rely on accumulated fat reserves to survive (Amstrup et al. 2023:950). The duration of forced fasts (which is linked to the number of ice free days), energy reserves at the time of fast initiation, and the amount of energy the bears need to expend during the fasts, could affect demographic performance (Molnár et al. 2010), e.g., by affecting the female's ability to provide enough milk needed for cub survival (Amstrup et al. 2023). Modeling by Molnár et al. 2020:2) suggested that "prolonged fasting impacts cub recruitment first. Survival declines in yearlings, adult males and adult females with offspring follow, while solitary adult females succumb last…High rates of recruitment and survival failure following threshold exceedance…" Importantly, this relationship between ice loss and fasting duration can be used to project declines in parameters such as cub survival, even in regions where abundance estimates or other demographic data are lacking (Amstrup and Bitz 2023).

Large reductions in the extent of sea ice coupled with delays in the autumn of freeze up, may make it impossible for pregnant females still on the ice to reach coastal terrestrial denning habitats (Stirling and Derocher 1993: 243-244). Additionally, warmer winters could potentially result in a higher frequency of the collapse of maternity dens (Stirling and Derocher 1993).

High survival rates of adult females are required to sustain polar bear populations (Amstrup and Durner 1995; USFWS 2022:45) and polar bear survival and reproduction can be adversely affected by declines in body condition. Hence, factors that negatively affect female condition and her ability to support her young, can have effects at the population level (see Regehr et al. 2010; Rode et al. 2010). Additionally, as summarized by USFWS (2022:45, citing Derocher and Stirling 1996; Stirling et al. 1999), "[s]urvival of polar bear cubs-of-the-year has been directly linked to their weight and the weight of their mothers, with lower weights resulting in reduced survival."

Arctic sea ice habitat also supports essential life-history functions of ice seals, such as ringed seals and, thus, loss of sea ice may also lead to declines in the abundance of the primary prey of polar bears (Stirling and Derocher 1993; USFWS 2023b:iii), and to changes in relative abundances of other pinnipeds (Stirling and Derocher 1993). More generally, climate change may change Arctic ecosystems and their productivity (Stirling and Derocher 1993).

2.E. Other threats

Threats that may adversely affect polar bear habitat or polar bears "throughout their range", other than those related to climate change-driven loss of sea ice, include commercial activities (such as industrial development, shipping and ecotourism) and overutilization (e.g., via overharvesting, illegal take and due to conflicts between humans and bears) (USFWS 2023b:iii), contaminants, parasites and disease. USFWS (2023b:iii) concluded that all such other threats are less likely to affect the persistence of polar bears than the threat from climate change.

However, given that the loss of sea ice habitat is resulting in increases in the numbers of polar bears coming ashore and increases in the duration of time spent on land, activities on land that adversely affect the ability of polar bears to gain full benefit from important habitats (such as denning habitat) are likely to have larger effects than in the past. Additionally, polar bears have greater exposure to human activities on land than in the past. Below, we briefly summarize three additional potential threats to polar bears in Alaska.

Oil and gas activities.—Oil and gas activities occur, or may occur in the future, in multiple parts of the range of the polar bear, including both offshore and terrestrial parts of the range of the SB (see descriptions in USFWS 2022, 2023a). While it is beyond the scope of this section to summarize and evaluate all potential impacts from oil and gas exploration, development, and production activities, examples of types of observed and potential negative effects include, but may not be limited to:

- the release of greenhouse gases resulting in climate warming and loss of seasonal sea ice habitat (e.g., see summary in Amstrup and Bitz 2023);
- adverse effects on polar bear habitat from construction activities, movements of vehicles and equipment over land, aircraft activity, exploration activities (e.g., seismic surveys), and spills of toxic substances;
- adverse alteration of essential characteristics of polar bear habitat, such as the level of isolation, noise levels, landscape characteristics, pollution levels, or other characteristics of the habitat that make it suitable for denning, resting, undisturbed movements, and, in some cases, foraging on supplemental food sources;
- direct adverse effects on bears from spills, construction activities, movements of vehicles and equipment over land, aircraft activity, and exploration activities (e.g., seismic surveys), including, but not limited to:
    - physical harm (e.g., from spills, exposure of cubs, increased energy expenditure, physiological stress, interactions with humans, etc.); and
    - disturbance from mobile and stationary sources (USFWS 2023a:125) causing disruption of normal and essential activities, and modification of habitat use.

Potential effects on habitat use may include: abandonment of dens, either before or after cubs are born; cessation of foraging or displacement from terrestrial foraging areas; cessation of resting and displacement from resting areas; and modification of movement patterns, causing increases in energy expenditure. As discussed above, abandonment of dens before cubs are developed and large enough to survive outside the den is likely to result in a lethal effect – cub mortality – due to factors such as exposure, predation, and/or their limited mobility (e.g., see Blix and Lentfer 1979, Derocher and Wiig 1999, Amstrup et al. 2006, and USFWS (2022 and references cited therein).

While there are measures put in place to reduce the likelihood of activity very close (within 1 mile) to **detected** active dens (e.g., see USFWS 2022), data summarized by the USFWS indicate that the majority of dens are not detected:

> "…not all dens will be detected, in part detection is linked to the depth of the den beneath the snow. The most recent estimate of den detection probability based on data from Wilson and Durner (2020) and considering snow depth is 0.41 SD ±0.15 (USFWS 2021c)" (USFWS 2022:99).

USFWS (2023b:126) summarized that the efficacy of aerial infrared (AIR) surveys to locate active dens is "poor to moderate."

Disturbance can also cause changes in energy expenditure. USFWS (2022:96) pointed out that "onshore bears spend the majority of their time resting and limiting their movements on land. Exposure to aircraft traffic could result in changes in behavior, such as going from resting to walking or running, and these changes in behavior could be energetically costly." Such energetic costs may become increasingly more significant as bears are forced onto land for longer periods due to loss of seasonal sea ice.

Other potential impacts include potential contamination of polar bears and polar bear habitat from oil spills with individual and population impacts possible (e.g., see Wilson et al. 2018); impacts to prey; increases in human-bear conflicts, with adverse consequences to both bears and people; and possibly, increased access to hunters (USFWS 2023a).

Loss and/or modification of terrestrial habitat.—USFWS (2023b:56) summarized that "protection of terrestrial denning and summering habitats is, and will likely be, important to supporting the long-term persistence of polar bears." Key factors identified by USFWS (2023b:56) included: "an expanding anthropogenic footprint" which has the potential to degrade connectivity between habitats, and the quantity and quality of specific kinds of habitats. Erosion is leading to the loss of key habitats such as coastal and barrier island denning habitat (see Zimmerman et al. 2022).

Harvest and other human removals.--Concerns regarding the overharvesting of polar bears was a primary stimulus for existing international collaboration on polar bear management and research. The harvest of SB polar bears is governed by the Inuvialuit-Iñupiat Polar Bear Agreement, negotiated by the Inuvialuit Game Council and the North Slope Borough Fish and Game Management Committee (Inuvialuit Game Council, North Slope Borough Fish and Game Management Committee 2000); Brower et al. 2002). Meek (2011:438) concluded that "[t]he voluntary polar bear quotas developed under the Southern Beaufort Sea interlocal agreement have been largely successful at maintaining their agreed-upon level of harvest, and a reduction in kills of females." USFWS (2019a) reported that the current polar bear harvest quotas in that agreement are 56 total, with an allotment of 35 to the US and 21 in Canada. USFWS (2019:12-13) reports that "For the most recent 10-year period, 2006-2015, an average of 19 bears per year were taken from the U.S." and an average of "14.2 bears per year" were taken in Canada. USFWS (2023b:84) reports that the mean removal for the 5-year period 2016-17 to 2020-21 for the SB was 18.4 (shown as 18.6 in IUCN/SSC/PBSG 2023:60). Wiig et al. (2015:11) summarized that, for the SB subpopulation, harvest "represents an additive impact" to impacts from climate change.

For the CS subpopulation, Meek (2011:438) noted that the quotas which were agreed to under the U.S.–Russia Agreement "do not yet demonstrate a tight linkage between the number of bears in a population and adherence to quotas." For the CS subpopulation, the IUCN/SSC/PBSG (2023:60) indicates a 5-year mean of actual human removals of 12.4 bears in the U.S. and ~32 in Russia, although harvests are, as noted, illegal and not monitored in Russia (IUCN/SSC/PBSG 2023:60). For the CS subpopulation, Wiig et al. (2015:11) concluded that the combined harvests from legal subsistence take in the U.S. and illegal take in Russia “may exceed sustainable limits”.

Increases in inter-specific competition with increased land use.—Increased use of terrestrial habitat is also likely to increase competitive interspecific interactions with grizzly bears. Such competitive interactions have been observed at sites outside villages where the remains of subsistence-harvested bowhead whales are deposited and “[r]elatively large numbers of polar bears and some grizzly bears” congregate to feed (Miller et al. 2015:1317). Miller et al. (2015:Miller et al. (2015) reported that during such interactions, female polar bears with cubs displayed aggressive behavior more frequently than other classes of polar bears or grizzly bears. They reported also that grizzly bears “are socially dominant” during competitive interactions with polar bears over these carcasses (Miller et al. 2015: 1317).

3. Polar Bear Characteristics Relevant to the Identification of Polar Bear and Polar Bear-Supporting “Significant Resource Values”

Polar bears, as well as habitat that supports the conservation of polar bear over time, are “significant resource values” within the NPR-A. This is clear from polar bear:

- ecological uniqueness;
- cultural significance to people throughout the world due to their national and international recognition as a species under great threat from climate change and thereby as a species of high concern needing special cooperation and protections;
- cultural significance to Indigenous peoples throughout the Arctic and beyond;
- importance as a subsistence species to Indigenous peoples in the Arctic; and
- regulatory status within the U.S. as a species recognized under the Endangered Species Act as threatened with extinction and protected as a marine mammal under the Marine Mammal Protection Act;
- categorization as “vulnerable” by the IUCN Redlist.

3.A. Ecologically, polar bears are unique

Polar bears, the largest extant bear species (DeMaster and Stirling 1981; Stirling 1988; Stirling 2009) and an apex predator in much of their range, exhibit multiple “unique physical” (USFWS 2023b:14 and see Stirling 1988) and behavioral adaptations (Berta 2020; see also Stirling 1988 and Amstrup 2003) to Arctic sea ice habitats. As such, they are the only bear recognized and protected as a marine mammal under the Marine Mammal Protection Act.

3.B. The Polar Bear is of Unique and High Cultural National and International Significance in Both Indigenous and Non-Indigenous Cultures in the U.S., Canada, and other Arctic Nations

Polar bears serve as “a flagship species epitomizing the effects of climate-induced changes associated with global warming due to their dependence on declining arctic sea ice” (Rode et al 2024:1-2). They play an important role in fostering political and public concern about climate change and support for political action to address it (e.g., see discussion in Rode et al. 2021:1 and references cited therein). As Gehrke (2023:1) summarized, “[T]here is no animal more emblematic of the Arctic than the polar bear.”

A concrete expression of the significance of the polar bear to many cultures is that considerable resources have been expended by international, governmental, non-governmental, Indigenous, and scientific entities to collaborate on efforts to conserve the species. International scientific and conservation entities focused on the polar bear include the IUCN/SSC/PBSG and Polar Bears International. The multi-layered management of polar bears that includes international, national, and Indigenous efforts to conserve the species is also a potent reflection of the special value of polar bears.

Evidence indicates that polar bears are of cultural and material importance to Indigenous Arctic peoples (e.g., Brower et al. 2002; Voorhees et al. 2014 and references cited therein). Voorhees et al. (2014, citing Sodikoff 2012:7) identified the CS polar bear subpopulation as a “cultural keystone species” to Indigenous villagers within and along the northern Bering Sea and Chukchi Seas. The Alaska Nannut Co-Management Council (ANCC) (ANCC 2024a) describes the culture significance of the polar bear to their member tribes, stating: “We, the polar bear hunting Tribes of Alaska, proclaim that polar bears are essential to our cultural, nutritional and spiritual well-being and our way of life.” The ANCC (2024b) also states: “The Iñupiaq and St. Lawrence Island Yupik peoples of Alaska have important relationships with polar bears that go back thousands of years. As part of the Arctic ecosystem, our people have always co-existed with polar bears and relied on polar bears for survival…Our co-existence with polar bears is based on reciprocity and respect, expressed through celebrations of song and dance, artistic and spiritual traditions, and by sharing our resources.”

In some locations in Alaska, polar bears provide economic value from tourism, handicrafts, meat, etc. (Gehrke 2023). Wilder et al. (2017) noted that there is also local interest in polar bears because they can pose a threat to human safety.

3.C. Polar bears are an important subsistence species

Polar bears from the SB subpopulation are harvested by Iñupiat in Alaska and by the Inuvialuit in Canada (Joint Secretariat 2015; Polar Bear Range States 2015a) and CS polar bears are harvested in parts of Alaska (and taken illegally in Russia). The ANCC (2024b) stated that “[T]he subsistence harvest of polar bears is a cornerstone of our cultures—providing essential nutrition and materials for clothing, shelter, and art…”.

Findings from a study of Inuvialuit traditional knowledge of the polar bear summarized that “Harvesting polar bears and other animals has always been an integral part of who the Inuvialuit are as a people. In addition to nourishing their imaginations, spirituality and creative arts, these animals and the harvesting of them have until relatively recent times been the foundation of their economy” (Joint Secretariat. 2015:1).

4. Existing Special Areas that Identify Polar Bears or Marine Mammals as an SRV in the NPR-A

Currently, five Special Areas are identified within the NPRA (89 FR 38758). Based on Section 2361.20, two existing special areas include recognition of marine mammal habitat as an SRV that should be managed to assure maximum protection. BLM (89 FR 38758) specifies ‘[t]he Kasegaluk Lagoon Special Area shall be managed, to assure maximum protection of…significant resource values” that include, but are not limited to: “[i]mportant habitat for” unspecified “marine mammals”. The Peard Bay Special Area shall be managed, to assure maximum protection of…significant resource values” that include, but are not limited to: “Haul-out areas and nearshore waters for marine mammals.” (see also mention at 89 FR 38737 and mentions in the proposed rule, Dec. 7, 2023).

Neither polar bears, nor polar bear designated critical habitat, nor polar bear habitat more broadly, are specifically mentioned as an SRV for any of the existing Special Areas in Section 2361.20 (38 FR 38758). However, stating that “[t]he many important surface resources of the Reserve are described in detail in the preamble to the proposed rule,” BLM (89 FR 38714) summarizes that these include certain habitats (e.g., “extensive calving grounds for…Caribou” herds) and various kinds of animals, including “marine mammals including polar bears.” They summarize that “implications of climate change…are substantial, particularly for marine mammals that are threatened by continued Arctic warming.” In the “Current Conditions” section of the proposed rule, BLM referred to polar bears only once which states that “polar bears, which are increasingly using terrestrial habitats in the Teshekpuk Lake Special Area due to receding sea ice.” In the proposed rule, BLM summarized that “[T]he Kasegaluk Lagoon Special Area…has especially “high values for marine mammals” and that “[t]he Peard Bay Special Area …includes “haul-out areas and nearshore waters for marine mammals.” In contrast, for some SAs, BLM recognizes specific kinds of habitat, in some cases for specific species, such as the Arctic peregrine falcon or grizzly bear.

5. Need for Additional Polar Bear-Supportive SRVs to be Identified

Changes to BLM management in the NPR-A, including recognition of additional SRVs, recognition that Special Areas contain these SRVs, and increased management protections are needed to achieve maximum protection of polar bears and habitat that supports them within the NPR-A. The measures discussed below are responsive to the following facts.

Polar bears are threatened with extinction worldwide due to anthropogenic climate change-driven deterioration of summer sea ice habitat upon which they depend for foraging and other essential functions. As summarized in Section 2, information available from a number of studies indicates that, as climate change causes fragmentation and declines in the extent and duration of summer sea ice in the Beaufort Sea, land use by SB polar bears is increasing (e.g., Atwood et al. 2016; Schliebe et al. 2008). In response to this change in habitat use, terrestrial habitats are likely of increasing importance to the potential for the persistence of the polar bear and thus, the management of Arctic terrestrial habitats within and adjacent to, the current range of the polar bear is also increasing in importance. Within the NPR-A, polar bears use terrestrial habitat for denning and reproduction, resting, traveling (USFWS 2010 and references cited therein), foraging on supplemental food resources (see Section 2), and accessing sea ice habitat. Specifically, terrestrial denning became more common in the NPR-A during 2000–2015 as compared to 1982–1999, as denning activity shifted westwards on the Alaskan North Slope (Patil et al. 2022).

To enable BLM to ensure that the special resource values of polar bear habitat are protected to the maximum potential within the NPR-A, to inform development of alternatives for all actions, and to develop all protections within the NPR-A, BLM could consider highlighting polar bear SRVs and, to the extent possible with current information, identify Special Areas where they occur. Identification and protection of polar bear SRVs is also consistent with the 1973 Polar Bear Agreement. For example, Article II of The Agreement (https://polarbearagreement.org/resources/agreement/the-1973-agreement-on-the-conservation-of-polar-bears) states :

> “Each Contracting Party shall take appropriate action to protect the ecosystems of which polar bears are a part, with special attention to habitat components such as denning and feeding sites and migration patterns, and shall manage polar bear populations in accordance with sound conservation practices based on the best available scientific data.”

It is also consistent with Article 4 of the “Agreement between the Government of the United States of America and the Government of the Russian Federation on the Conservation and Management of the Alaska–Chukotka Polar Bear Population” which includes language specifying that the two countries “undertake all efforts necessary to conserve polar bear habitats, with particular attention to denning areas and areas of concentration of polar bears during feeding and migration.”

In its explanation of the need for the rule to revise "the framework for designating and assuring maximum protection of Special Areas' significant resource values", the BLM (2024:38713) stated that it was "necessary and appropriate…to develop new regulation that account for and respond to" (italics not in original and added here for emphasis) to the *"[r]apidly changing conditions, including the intensifying impacts of climate change*" on the NPR-A's natural environment and Native communities". There is a poor fit[2] between the current protection approach for polar bears in the NPR-A, the threat the species faces to its existence due to loss of sea ice habitat due to human-driven climate change, and the rapidity of change regarding the duration of time that polar bears are spending on land – including on the ACP (see more general discussion in Meek (2011). As Meek (2011:430) argued, "the American regime (i.e., all of the rules relating to a particular problem or species) governing human interactions with polar bears has largely operated at the same ecological scale over time, with a focus on reducing short-term disturbance from hunting and oil and gas development."

Given:

- the magnitude and rapid rate of fragmentation and loss (Pagano et al. 2021) of seasonal sea ice foraging habitat, sea ice and coastal habitat (e.g., see USFWS 2022:64) denning habitat and other change to polar bear habitat within the Arctic, including areas within and adjacent to the NPR-A;
- the high uncertainty about how well, and if, polar bears will be able to adapt to this temporal and spatial pattern of habitat change;
- the high risk to polar bears due to increasing loss of use of their primary sea ice habitat for many months of the year due to climate change;
- the increase in terrestrial habitat use by both SB and CS polar bears in response to the loss of their summer sea ice habitat, and the resultant likely increase in importance of terrestrial habitats to polar bear conservation; and
- the potential for oil and gas activities within the NPR-A to modify important polar bear terrestrial habitats in ways that may degrade their value to their conservation and may disturb and potentially harm polar bears

management to conserve polar bears should be *forward-looking, precautionary*, and allow for meaningful adaptive response to rapid change in polar bear status, habitat use, or in the habitat itself. Lacking such an approach to the identification of polar bear supporting resource values, options for management of terrestrial habitats that allow for supplemental foraging, resting (energy-conserving), and denning could be foreclosed or compromised – just as designation, and protection, of portions of polar bear terrestrial and barrier island denning habitat as critical habitat was foreclosed by human development that preceded the identification of polar bear critical habitat under the ESA.[3]

[2] As noted by Meek (2011:430) "'Fit' is an analytical tool…to examine institutional success by asking how well an identified policy solves a particular problem in terms of biophysical processes and governance approaches."

[3] "Within the Terrestrial Denning and Barrier Island units, critical habitat does not include manmade structures (e.g., houses, gravel roads, airport runways and facilities, pipelines, well heads, generator plants, construction

As summarized by Pagano et al. (2021:15):

> "Summer sea ice extent is forecasted to continue to decline. Continued declines in sea ice are likely to challenge SB polar bears to either further increase their home ranges or move to land in the summer. Our findings further highlight the increasing importance of land use for SB polar bears as an alternative summer refuge to mitigate the energetic losses that are incurred through following the retreating summer sea ice. Hence, management of terrestrial habitats along the Beaufort Sea coast is likely to have greater relevance as polar bears respond to further declines in summer sea ice."

Hence, identification of all habitat within the NPR-A that provides conservation value for polar bears – a species whose sea ice habitat is being profoundly and rapidly modified by climate change and which is threatened with extinction because of the degradation of their sea ice habitat – and recognition of such habitat as SRVs is urgently needed to highlight and prevent degradation of terrestrial habitats that provide some polar bears an "alternate summer refuge".

5.A. Polar Bear Terrestrial Denning Habitat Significant Resource Value

A priority for management to achieve "maximum protection" of polar bears within the NPR-A should be to recognize potential polar bear maternal denning habitat, which has been identified and mapped by Durner et al. (2013; See Figure 5 of that publication), as an SRV that supports the conservation of polar bears in the face of rapid loss of sea ice habitat and increasing land use by polar bears within the Arctic coastal plain of Alaska. While USFWS (2010) noted that "[A]ccess to terrestrial denning sites [from sea ice habitats] is dependent upon the location of the sea ice, amount of stable ice, ice consolidation, and the length of the melt season during the summer and fall (Fischbach et al. 2007, p. 1,395)", as more of the North Slope of Alaska is developed, including NPR-A, access to terrestrial sites can also be impeded or lengthened by development that creates zones that pregnant polar bear females avoid as they travel to, and search for, suitable den sites.

As discussed in Section 2, polar bears require dens to provide a warm and stable environment in which to give birth and raise their young cubs until the cubs are sufficiently large and developed to withstand arctic conditions outside of the den. Habitat suitable for the construction of maternal dens has topographic features that "are readily distinguished from the surrounding terrain in summer and catch snow in early winter" (Durner et al. 2003:55). Durner et al. (2003:55), who stated that den landforms are "easily identified," highlighted the fact that:

camps, sewage treatment plants, hotels, docks, seawalls, and the land on which they were constructed) that existed on the effective date of the rule." U.S. Fish and Wildlife Service, 2023a:87.

> "Knowledge of den structure and site characteristics will allow resource managers to identify habitats with the greatest probability of holding dens. This information may assist resource managers in preventing negative impacts of mineral exploration and extraction on polar bears."

Designated terrestrial denning critical habitat and maternal denning habitat for the polar bear (as identified by Durner et al. 2013) occurs within the NPR-A (see Figure 3h.3 and Figure 5 in Durner et al. 2013; see also Figure 4 in Patil et al. 2022). As noted above, denning in the NPR-A has become more common than it was in the 1980s and 1990s (Patil et al. 2022). USFWS (2023a:101) summarized that the "increase in the proportion of dens occurring in the terrestrial environment may increase the potential for disturbance at dens from industrial development and other human activities." While protection of denning habitats is vital for the survival of this species, the characteristics of such habitats that make them suitable for denning can also be destroyed or altered by oil and gas or other industrial activities. The habitat can also become unsuitable due to human presence during den selection or during occupation. USFWS (2010:76096) pointed out, polar bear females are unlikely to use habitat that is suitable for denning "if disturbed by the presence of humans." Denning females typically seek secluded areas away from human activity. Disturbance of dens during the period when cubs are too small and underdeveloped to survive outside the den will likely result in the death of cubs (e.g., Blix and Lentfer 1979; USFWS 2023a:131 and references cited therein). The long-term functional usefulness of such habitats requires management that ensures habitats suitable for denning are not altered (e.g., by construction, dredging, infrastructure emplacement, etc.) in such a way that forecloses their use by polar bears for denning, e.g., by changing the landscape characteristics that render the site suitable, or by siting sources of disturbance nearby, etc. Thus, to ensure that areas within NPR-A are managed to ensure maximum protection of denning habitats, there is a need for recognition of polar bear denning habitat as an SRV, with focused protection built into BLM's management of the NPR-A. **Such protection should ensure that permitted usage does not alter the habitat in such a way as to forego future use of that habitat by polar bears by altering the landscape features that make the habitat suitable for denning or by introducing human disturbance that would either cause a female polar bear to forego denning at an otherwise suitable site or abandon such habitat after denning there**.

BLM should consider giving priority to recognition of, and protection of, both designated terrestrial den critical habitat and maternal denning habitat (also referred to in some documents as "potential polar bear terrestrial denning") as an SRV within NPR-A. This habitat, which has been identified by Durner et al. (2013), has "landscape features in which maternal dens are likely to occur" (Durner et al. 2013:197). This habitat has been identified as potential denning habitat by the USFWS in recent Biological Opinions on the NPRA (e.g., see USFWS 2022). Durner et al. (2013:197) mapped potential denning habitat using a "fine-grain digital elevation model derived from Interferometric Synthetic Aperture Radar (IfSAR)", a technique they found to be as effective as photogrammetric methods. The geospatial data needed to map polar bear maternal den habitat within the NPR-A is available from USGS (https://data.usgs.gov/datacatalog/data/USGS:ASC412;

see also Figure 3h.3 and Durner et al. 2013), as are the locations of detected denning sites (Durner et al. 2020; see also Figure 3h.2) and designated polar bear terrestrial denning habitat (https://catalog.northslopescience.org/dataset/1754).

A major focus of conservation measures for polar bears in the ACP has been aimed at the identification and protection of maternal dens (e.g., in the determination of critical habitat under the ESA (USFWS 2010). Currently, much of the focus of existing management measures appears to be aimed primarily at attempting to identify active dens, protecting **identified** active dens and reducing the likelihood of disturbing actively denning bears (e.g., agency reliance on industry's voluntary compliance with Incidental Take Regulations (USFWS 2021, 86 FR 42982)) These requirements are not forward-looking or sufficient to facilitate polar bear conservation given the shortcomings in den detection technology (see discussion of den detection in Section 2.E), a general lack of protections for non-denning bears, and the degree and speed of change that is occurring to this species' primary habitat. Current protections are also not aimed at "giving [polar bears] room to move and places to go", i.e., to support the option for terrestrial habitat to provide some level of local compensation for lost sea ice denning habitat, terrestrial denning habitat lost to erosion, or denning habitat lost to emplacement of human structures before the designation of critical habitat. They are not sufficient to protect all actively denning bears. However, in their "[b]est practices for avoiding bear encounters and impacts to bears", USWFS (e.g., 2023b:16) recognizes the need to protected denning habitat, noting that best practices related to protection of denning habitat and actively denning bears includes avoidance of the establishment of "infrastructure in or near polar bear denning habitat." Recognition of these denning-related SRVs and identification of locations where they occur is needed to facilitate implementation of this best practice.

5.B. Polar Bear Supplemental Food Resource/Alternative Prey Area SRV

Need for Recognition.--As: the extent and duration of seasonal Arctic sea ice loss is expected to continue to decline (e.g., Meier and Stroeve 2022), the amount of time that SB polar bears are spending on land is correlated with the extent of ice retreat (Atwood et al. 2016), and "[the] increased reliance on coastal onshore habitat as sea ice has declined may affect the feeding ecology of SB polar bears", it is critical that the management of land within the range of polar bears include action to ensure that polar bear access to alternative food resources is not impeded or disturbed, and, that such alternative food sources are themselves conserved.

Description of SRV.--Haulouts, stranding areas, and carcass concentration sites for other marine mammals within the NPR-A are supportive of polar bear conservation as sources of potential supplemental food resources. Thus, in addition to haulouts being identified as SRVs for the species themselves (e.g., as a walrus SRV or a spotted seal SRV) such haulouts and any areas that are known stranding area or carcass concentration sites, also merit identification as SRVs that are supportive of polar bear conservation as supplemental sources of nutrition while the polar bears are on land. This type of SRV would include haulouts for walrus and haulouts for seal species. It would also include known stranding or carcass collection sites for other marine mammals within the NPR-A. The BLM already acknowledges that “marine mammal haulout” sites are significant resource values and these sites warrant consideration for identification as habitat for potential alternative food resources for polar bears. Recognizing potential food web linkages also highlights that the futures of various Arctic species are not all independent of each other, and thus, should serve to strengthen the protection afforded these kinds of sites.

Documentation of marine mammal carcass locations include the North Slope Borough Stranded Marine Mammal Surveys (NSB 2024) and Figure 1 in Willoughby et al. (2020; see also Willoughby et al. 2020, 2022a, b). Preliminary data from NSB beach survey monitoring near Utqiaġvik during the open water period (June-Oct. 2011-2014) provided by Brower et al. (2015) detected beach cast carcasses of walrus, ringed seal, bearded seal, gray whale, bowhead whale, beluga whale, spotted seal, and harbor porpoise (https://www.north-slope.org/wp-content/uploads/2022/04/The_Stranding_Survey_Project_IB_RST_2015.pdf).

Conservation of polar bears needs to broadly consider steps that can be taken to afford polar bears the opportunity to obtain nutrition during periods when they are forced to be onshore due to the reduction of sea ice needed for foraging. Thus, as the duration of land use is increasing, and as “[i]ncreased durations on land can only be accommodated if bears come onshore in sufficient body condition to withstand longer periods of food deprivation, **or obtain increased access to food while on shore**” (Rode et al. 2015, bold font not in original and added here for emphasis), management of habitat should seek to facilitate and protect such access. Identification of this SRV would help to foster such protection.

5.C. Polar Bear Nearshore Resting Areas During the Ice-free Period

Due to the sharp, and increasing, reductions in the extent of seasonal sea ice habitat, many of these SB polar bears are forced to endure longer periods of fasting. Even as some polar bears do begin to access supplemental food sources, such as marine mammal carcasses, evidence (e.g., Rode et al. 2015) indicates such supplemental prey does not compensate sufficiently for polar bear’s loss of access to their primary prey. Thus, the bears on shore need to conserve energy and studies in other locations (e.g., Derocher and Sterling 1990a) found that “[a]ll bears moved less than bears on the sea ice, and movements were consistent with a strategy of energy conservation.” USFWS (2022:95) acknowledged that disturbed non-denning bears may respond behaviorally or physiologically to noise, and “may move away from the source of disturbance and increase vigilance behavior”. With respect to responses to mobile sound sources, USFWS (2022:96) stated “[s]hould encounters occur, polar bears would likely move away from the source of disturbance, resulting in a short-term temporary behavioral disturbance." With respect to aircraft, USFWS (2022:97) summarized that "[e]xposure to aircraft traffic is expected to result in changes in behavior, such as going from resting to walking or running, and therefore has the potential to be energetically costly." However, current management, which often appears to assume disturbance of non-denning resting polar bears is a "minor individual level effect" (USFWS 2022:97) does not appear to be fully responsive to the increasing periods of time that SB polar bears are being forced to spend on land due to reductions in summer sea ice and the related increase in the number of bears in a physiological fasting state during certain times of the year (see discussion and references in Section 2.B.1): i.e., it is not responsive to the need for polar bears forced to be on land to conserve energy. Thus, the importance of habitats for resting should be recognized within all Special Areas in which polar bear habitat is recognized. This is especially true of polar bear designated critical habitat in SAs near the coast. Protections should be developed that avoid displacement of polar bears that are resting, and/or that may be undergoing forced fasting due to loss of seasonal sea ice. Congregation areas of polar bears should be managed to avoid displacement.

5.D. Polar Bear Movement Corridors

USFWS (2023b:126) summarized that "Polar bears are most likely to be encountered along coastal movement corridors along the Beaufort Sea coast between July and October." They identify high use areas as "all land within 2 km (1.2 miles) of the Chukchi and Beaufort Sea coasts." They also recognize that polar bears may congregate at bowhead whale carcass collection sites. More generally, bears need to be able to move to and from sea ice and terrestrial habitats, to denning sites, to sites with terrestrial supplemental food resources, etc. Thus, based on the aforementioned, polar bear movement corridors merit recognition and protection as a SRV. Coastal portions of all Special Areas contain this SRV.

6. Identification of Locations Where "Special Areas" Merit Reinforcement, Expansion, or Identification Within The NPR-A to Provide Additional Protections for Polar Bear Significant Resource Values

In order to achieve "maximum protection" of polar bears, a species that is threatened with extinction throughout its range, and important polar bear habitats within the NPR-A, BLM should consider: identifying and explicitly recognizing polar bear-relevant SRVs that occur within the Reserve; and identifying areas that contain them. This should include identifying existing Special Areas that contain them, expanding SAs as needed, and identifying new SAs if needed to encompass them. As described below, these include the Teshekpuk Lake Special Area, the Kasegaluk Lagoon Special Area, Colville River Special Area, and the Peard Bay Special Area.

Recognition of Polar Bear SRVs in the Teshekpuk Lake Special Area.—Within the Teshekpuk Lake Special Area BLM should consider recognizing polar bear SRVs and should consider specifying that this Special Area be managed to assure maximum protection for both polar bears and for important habitats for polar bears, a threatened species. Polar bear SRVs within Teshekpuk Lake include, but may not be limited to, the following habitats needed for polar bear denning, movements, resting, and foraging on supplemental food resources:

- All designated polar bear critical habitat within the SA. This habitat should be clearly delineated on Teshekpuk SA maps.[4]
- All polar bear maternal denning habitat (also referred to as "potential denning habitat" as identified by Durner et al. (2013) and at USGS https://data.usgs.gov/datacatalog/data/USGS:ASC412; see also Fig. 3h.3., reproduced here from Map 3-27 of DOI, BLM 2020. Specific mapping within the SA should identify polar bear maternal habitat located along and surrounding:
    - the Katikpik River, Fish Creek, and Judy Creek.
    - The Chipp and Ikpikpuk Rivers
- Polar bear movement corridors along coastal habitat, including to and from the sea to denning habitat, known congregation sites, etc.
- Polar bear resting habitat
- Terrestrial food resources that polar bears may increasingly need to utilize, if possible, to partially compensate for lost on-ice foraging opportunities.

Recognition of Polar Bear SRVs in the Kasegaluk Lagoon Special Area.--Results from multiple sources indicate that polar bear SRVs within Kasegaluk Lagoon, include, but may not be limited to the following important habitats for polar bear maternal denning, foraging on supplemental food resources, movements, and resting.

- All polar bear denning habitat.--In this area, polar bear denning habitat can be identified and mapped using both the locations of detected dens (e.g., see Figure 3h.2), from maps depicting the relative density of detected polar bear dens (see Figure 3h.4).

[4] Critical habitat has been designated for polar bears. Under Section (5) (A) of the ESA, "[t]he term "critical habitat" for a threatened or endangered species means— (i) the specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of section 1533 of this title , on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 1533 of this title , upon a determination by the Secretary that such areas are essential for the conservation of the species." Hence, all polar bear critical habitat is a "significant resource value" that merits special recognition and maximum protection by BLM within the NPR-A. All designated critical habitat for the polar bear contained within NPR-A should be identified as an SRV.

- Habitats that can provide food for polar bears, including areas providing access to sea ice and habitats with potential supplemental food resources, which include haulout and carcass collection areas for Pacific walrus and spotted seal, as well as carcasses of walrus, beluga whale, gray whale (e.g., see Willougby et al. 2020, 2022b), other cetaceans, and spotted seal. Walrus and spotted seal haulout areas are already identified as SRVs (for the relevant species themselves) in Kasegaluk Lagoon SA, but, given observations from other locations of polar bears scavenging and preying on walrus and other marine mammals, the potential for these SRVs to provide at least some support to polar bear conservation in the future should be recognized.

The current boundaries of the Kasegaluk Lagoon Special Area merit expansion, or a new SA designated, to include polar bear denning habitat to the south of those boundaries as depicted in Figure 3h.4.

Recognition of Polar Bear SRVs in the Colville River Special Area.--Within the Colville River Special Area, BLM should consider recognizing the occurrence of polar bear SRVs including:

- Polar bear maternal denning habitat (see Durner et al. 2019), which has been identified to occur along the Colville River, especially in and directly adjacent to, the northeastern portion of the SA south of Nuiqsut (see Figure 3h.3). Management of this habitat should ensure that it is not modified in ways that would foreclose the use of this habitat by polar bears for denning.

Recognition of Polar Bear SRVs in the Peard Bay Special Area.--Within the Peard Bay SA, BLM should consider recognizing an SRV for important polar bear habitat including:

- Polar bear denning habitat within and habitat that provides access to and from important barrier island habitat (e.g., see Figure 3h.3).
- Existing and potential polar bear foraging habitats including areas providing access to sea ice and habitats with potential supplemental food resources. These habitats include haulout and carcass collection areas for Pacific walrus and spotted seal, as well as carcasses of walrus, beluga whale, gray whale (e.g., see Willougby et al. 2020, 2022b), other cetaceans, and spotted seal. Marine mammal haulout areas are already identified as occurring in the Peard Bay SA, but, as in Kasegaluk Lagoon, given observations from other locations of polar bears scavenging and preying on walrus and other marine mammals, the potential for these SRVs to provide at least some support to polar bear conservation in the future should be recognized and the habitat managed to conserve its value both for the species hauling out and potentially as habitat where polar bears can access supplemental food resources.

7. Polar Bear literature cited

Alaska Nannut Co-Management Council (ANCC), 2024a. Home, ANCC Website. Available from: https://nannut.org/.

Alaska Nannut Co-Management Council (ANCC), 2024b. About ANCC, ANCC Website. Available from: https://nannut.org/about-ancc/.

Alaska Nannut Co-Management Council, n.d. Constitution of the Alaska Nannut Co-Management Council. [WWW Document]. Available from: https://nannut.org/about-ancc/.Webpage (accessed 7.24.24).

ANCC. 2024b. Polar Bear Co-Management. Webpage. Available from: https://nannut.org/polar-bear-co-management/.

Amstrup, S.C., 1993. Human Disturbances of Denning Polar Bears in Alaska. Arctic 46:246-250. Available from: https://www.jstor.org/stable/40511412.

Amstrup, S.C. 2000. Polar Bear. In: J.C. Truett and S.R. Johnson (Eds.), The Natural History of an Oil Field: Development and Biota (pp. 133–157). Academic Press, Inc., New York, New York, USA. Available from: https://www.amazon.com/Natural-History-Arctic-Oil-Field/dp/0127012354.

Amstrup, S.C., 2003. Polar bear, Ursus maritimus, in: George A. Feldhamer, P.D., Bruce C. Thompson, P.D., Joseph A. Chapman, P.D. (Eds.), Wild Mammals of North America. Johns Hopkins University Press, pp. 587–610. Available from: https://doi.org/10.56021/9780801874161.

Amstrup, S.C., 2011. Polar Bears and climate change: Certainties, uncertainties, and hope in a warming world., in: R. T. Watson, T. J. Cade, M. Fuller, G. Hunt, E. Potapov (Eds.), Gyrfalcons and Ptarmigan in a Changing World, Volume I. The Peregrine Fund, Boise, Idaho, USA. The Peregrine Fund, pp. 11–20. Available from: http://dx.doi.org/10.4080/gpcw.2011.0100.

Amstrup, S.C., Bitz, C.M., 2023. Unlock the Endangered Species Act to address GHG emissions. *Science* 381,949-951. DOI:10.1126/science.adh2280.

Amstrup, S.C, DeMaster, D.P. 1988. Polar bear– Ursus maritimus, in: Lentfer, J.W. (Ed.), Selected Marine Mammals of Alaska: Species Accounts with Research and Management Recommendations,. Marine Mammal Commission, Washington, DC., pp. 39–56. Available from: https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB88178462.xhtml.

Amstrup, S.C., Durner, G.M., 1995. Survival rates of radio-collared female polar bears and their dependent young. Can. J. Zool. 73, 1312–1322. Available from: https://doi.org/10.1139/z95-155.

Amstrup, S.C., Gardner, C., 1994. Polar Bear Maternity Denning in the Beaufort Sea. The Journal of Wildlife Management 58, 1–10. Available from: https://doi.org/10.2307/3809542.

Amstrup, S.C., Stirling, I., Lentfer, J.W., 1986. Past and Present Status of Polar Bears in Alaska. Wildlife Society Bulletin (1973-2006) 14, 241–254. Available from: https://www.jstor.org/stable/3782240.

Amstrup, S.C., Durner, G., Stirling, I., Lunn, N.J., Messier, F., 2000. Movements and distribution of polar bears in the Beaufort Sea. Canadian Journal of Zoology 78:948-966. Available from: https://cdnsciencepub.com/doi/abs/10.1139/z00-016.

Amstrup, S.C., Durner, G.M., McDonald, T.L., Mulcahy, D.M., Garner, G.W., 2001. Comparing movement patterns of satellite-tagged male and female polar bears. Can. J. Zool. 79, 2147–2158. Available from: https://doi.org/10.1139/z01-174.

Amstrup, S.C., Durner, G.M., Fischbach, A.S., Simac, K., Weston-York, G., 2002. Polar Bear Research in the Beaufort Sea. In: N. Lunn, E. W. Born, and S. Schliebe (Eds.), Proceedings of the 13th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, Nuuk, Greenland (pp. 109-125). IUCN, Gland, Switzerland, and Cambridge, U.K. vii + 153 pp. Available from: https://portals.iucn.org/library/node/8136.

Amstrup, S.C., McDonald, T.L., and Durner, G., 2004. Using satellite radiotelemetry data to delineate and manage wildlife populations. Wildlife Society Bulletin 32(3):661–679. Available from: https://wildlife.onlinelibrary.wiley.com/doi/abs/10.2193/0091-7648(2004)032[0661:USRDTD]2.0.CO;2.

Amstrup, S.C., Durner, G.M., Stirling, I., McDonald, T.L., 2005. Allocating harvests among polar bear stocks in the Beaufort Sea. Arctic 58:247–259. Available from: https://www.jstor.org/stable/40512710.

Amstrup, S.C., Stirling, I., Smith, T.S., Perham, C., Thiemann, G.W., 2006. Recent observations of intraspecific predation and cannibalism among polar bears in the southern Beaufort Sea. Polar Biol 29, 997–1002. Available from: https://doi.org/10.1007/s00300-006-0142-5.

Amstrup, S.C., Marcot, B.G., Douglas, D.C., 2008. A Bayesian Network Modeling Approach to Forecasting the 21st Century Worldwide Status of Polar Bears. Pages 213-268 *in* Eric. T. DeWeaver, Cecilia M. Bitz, and L.-Bruno Tremblay (eds.). Arctic Sea Ice Decline: Observations, Projections, Mechanisms, and Implications. Geophysical Monograph Series 180. Available from: https://doi.org/10.1029/180GM14.

Amstrup, S.C., DeWeaver, E.T., Douglas, D.C., Marcot, B.G., Durner, G.M., Bitz, C.M., Bailey, D.A., 2010. Greenhouse gas mitigation can reduce sea-ice loss and increase polar bear persistence. Nature 468, 955–958. Available from: https://doi.org/10.1038/nature09653.

Atwood, T.C., Peacock, E., McKinney, M.A., Lillie, K., Wilson, R., Douglas, D.C., Miller, S., Terletzky, P., 2016. Rapid Environmental Change Drives Increased Land Use by an Arctic Marine Predator. PLOS ONE 11, e0155932. Available from: https://doi.org/10.1371/journal.pone.0155932.

Atwood, T.C., Bromaghin, J.F., Patil, V.P., Durner, G.M., Douglas, D.C., Simac, K.S., 2020. Analyses on subpopulation abundance and annual number of maternal dens for the U.S. Fish and Wildlife Service on polar bears (Ursus maritimus) in the southern Beaufort Sea, Alaska (No. 2020–1087), Open-File Report. U.S. Geological Survey. Available from: https://doi.org/10.3133/ofr20201087.

Atwood, T.C., Rode, K.D., Douglas, D.C., Simac, K.S., Pagano, A.M., Bromaghin, J.F., 2021. Long-term variation in polar bear body condition and maternal investment relative to a changing environment. Global Ecology and Conservation 32: e01925. Available from: https://www.sciencedirect.com/science/article/pii/S2351989421004753?via%3Dihub.

Bentzen, T.W., Follmann, E.H., Amstrup, S.C., York, G.S., Wooller, M.J., O'Hara, T.M., 2007. Variation in winter diet of southern Beaufort Sea polar bears inferred from stable isotope analysis. Can. J. Zool. 85, 596–608. Available from: https://doi.org/10.1139/Z07-036.

Bergen, S., Durner, G.M., Douglas, D.C., and Amstrup, S.C., 2007. Predicting movements of female polar bears between summer sea ice foraging habitats and terrestrial denning habitats of Alaska in the 21st Century: proposed methodology and pilot assessment. U.S. Department of the Interior, U.S. Geological Survey Administrative Report. U.S. Geological Survey, Reston, Virginia, USA. Available from: https://polarbearscience.com/wp-content/uploads/2017/09/usgs_polarbear_bergen_movements_lowres.pdf.

Berta, A., Sumich, J.L., Buell, C., 2020. Return to the Sea: The Life and Evolutionary Times of Marine Mammals. University of California Press. IBSN 978-0-520-35552-1. Available from: https://www.amazon.com/Return-Sea-Evolutionary-Marine-Mammals/dp/0520270576.

Biddlecombe, B.A., Bayne, E.M., Lunn, N.J., McGeachy, D., Derocher, A.E., 2021. Effects of sea ice fragmentation on polar bear migratory movement in Hudson Bay. Marine Ecology Progress Series 666, 231–241.Available from: https://doi.org/10.3354/meps13684.

Blix, A.S., Lentfer, J.W., 1979. Modes of thermal protection in polar bear cubs: at birth and on emergence from the den. American Journal of Physiology 236:R67–74. Available from: https://journals.physiology.org/doi/abs/10.1152/ajpregu.1979.236.1.r67.

Bourque, J., Atwood, T.C., Divoky, G.J., Stewart, C., McKinney, M.A., 2020. Fatty acid-based diet estimates suggest ringed seal remain the main prey of southern Beaufort Sea polar bears despite recent use of onshore food resources. Ecology and Evolution 10, 2093–2103. Available from: https://doi.org/10.1002/ece3.6043.

Bromaghin, J.F., McDonald, T.L., Stirling, I., Derocher, A.E., Richardson, E.S., Regehr, E.V., Douglas, D.C., Durner, G.M., Atwood, T., Amstrup, S.C., 2015. Polar bear population dynamics in the southern Beaufort Sea during a period of sea ice decline. Ecological Applications 25, 634–651. Available from: https://doi.org/10.1890/14-1129.1.

Bromaghin, J.F., Douglas, D.C., Durner, G.M., Simac, K.S., Atwood, T.C., 2021. Survival and abundance of polar bears in Alaska's Beaufort Sea, 2001–2016. Ecology and Evolution 11, 14250–14267. Available from: https://doi.org/10.1002/ece3.8139.

Brower, C.D., Carpenter, A., Branigan, M.L., Calvert, W., Evans, T., Fischbach, A.S., Nagy, J.A., Schliebe, S., Stirling, I., 2002. The Polar Bear Management Agreement for the Southern Beaufort Sea : An Evaluation of the First Ten Years of a Unique Conservation Agreement. Arctic 55, 362–372. Available from: https://doi.org/10.14430/arctic720.

Brower, I., Hepa, L. Storms, S., Sarren, R., Skin, J., Leavitt, I. Hanns, C., Ramey, D., George, C., Stimmelmayr, R., Hepa, T. 2015. North Slope Beach Survey Monitoring Program. Poster presented at the *2015 Alaska Marine Science Symposium, Anchorage, Alaska.* Available from: https://www.north-slope.org/departments/wildlife-management/studies-research-projects/health-assessment-of-subsistence-resources/stranded-marine-mammal-surveys/.

Canada, Norway, Denmark, Russia, and United States, 1973. Agreement on the Conservation of Polar Bears. Available from: http://pbsg.npolar.no/en/agreements/agreement1973.html.

Cherry, S. G., Derocher, A. E., Stirling, I., Richardson, E. S., 2009. Fasting physiology of polar bears in relation to environmental change and breeding behavior in the Beaufort Sea. *Polar Biology*, *32*, 383–391. Available from: https://doi.org/10.1007/s0030 0-008-0530-0.

Cherry, S.G., Derocher, A.E., Hobson, K.A., Stirling, I., Thiemann, G.W., 2011. Quantifying dietary pathways of proteins and lipids to tissues of a marine predator. Journal of Applied Ecology, 48: 373-381. Available from: https://doi.org/10.1111/j.1365-2664.2010.01908.x.

Chinn, S.M., Liston, G.E., Wilson, R.R., 2023. Assessing past and future climatic influences on the availability of polar bear maternal denning habitat on Wrangel Island. Ecological Modelling 484, 110479. Available from: https://doi.org/10.1016/j.ecolmodel.2023.110479.

DeMaster, D.P., Stirling, I., 1981. *Ursus maritimus*. Polar bear. Mammalian Species 145:1–7. Available from: https://swfsc-publications.fisheries.noaa.gov/publications/CR/1981/8111.PDF.

Department of the Interior, Bureau of Land Management (BLM). 2024. Final Rule. Management and Protection of the National Petroleum Reserve in Alaska. 89 FR 38712, May 7, 2024.

Derocher, A.E., Stirling, I., 1990a. Distribution of polar bears (Ursus maritimus) during the ice-free period in western Hudson Bay. Can. J. Zool. 68, 1395–1403. Available from: https://doi.org/10.1139/z90-208.

Derocher, A.E., Stirling, I., 1990b. Observations of aggregating behaviour in adult male polar bears (Ursus maritimus). Can. J. Zool. 68, 1390–1394. Available from: https://doi.org/10.1139/z90-207.

Derocher, A.E., Stirling, I., 1996. Aspects of survival in juvenile polar bears. Can. J. Zool. 74, 1246–1252. Available from: https://doi.org/10.1139/z96-138.

Derocher, A.E., Wiig, Ø., 1999. Infanticide and Cannibalism of Juvenile Polar Bears (Ursus maritimus) in Svalbard. ARCTIC 52, 307–310. Available from: https://doi.org/10.14430/arctic936.

Derocher, A.E., Wiig, Ø., Andersen, M., 2002. Diet composition of polar bears in Svalbard and the western Barents Sea. Polar Biol 25, 448–452. Available from: https://doi.org/10.1007/s00300-002-0364-0.

Derocher, A.E., Lunn, N.J., Stirling, I., 2004. Polar Bears in a Warming Climate. Integrative and Comparative Biology 44, 163–176. Available from: https://doi.org/10.1093/icb/44.2.163.

Dickson, B., Cooney, R., 2005. Biodiversity and the precautionary principle: risk and uncertainty in conservation and sustainable use. Earthscan, London. Available from: https://www.taylorfrancis.com/books/edit/10.4324/9781849770583/biodiversity-precautionary-principle-rosie-cooney-barney-dickson.
Donaldson, G.M., Chapdelaine, G., Andrews J.D. 1995. Predation of thick-billed murres, *Uria lomvia*, at two breeding colonies by polar bears, *Ursus maritimus*, and walruses, *Odobenus rosmarus*. Canadian Field Nat. 109:112–114.
Durner, G.M., Amstrup, S.C., Ambrosius, K.J., 2001. Remote identification of polar bear maternal den habitat in northern Alaska. Arctic 54:115–121. Available from: https://www.jstor.org/stable/40512366.
Durner, G.M., Amstrup, S.C., Fischbach, A.S., 2003. Habitat Characteristics of Polar Bear Terrestrial Maternal Den Sites in Northern Alaska. ARCTIC 56, 55–62. Available from: https://doi.org/10.14430/arctic602.
Durner, G.M., Amstrup, S.C., Ambrosius, K.J., 2006. Polar Bear Maternal Den Habitat in the Arctic National Wildlife Refuge, Alaska. Arctic 59, 31–36. Available from: https://www.jstor.org/stable/40512765.
Durner, G.M., Douglas, D.C., Nielson, R.M., Amstrup, S.C., McDonald, T.L., Stirling, I., Mauritzen, M., Born, E.W., Wiig, Ø., DeWeaver, E., Serreze, M.C., Belikov, S.E., Holland, M.M., Maslanik, J., Aars, J., Bailey, D.A., Derocher, A.E., 2009. Predicting 21st-century polar bear habitat distribution from global climate models. Ecological Monographs 79, 25–58. Available from: https://doi.org/10.1890/07-2089.1.
Durner, G.M., Whiteman, J.P., Harlow, H.J., Amstrup, S.C., Regehr, E.V., Ben-David, M., 2011. Consequences of long-distance swimming and travel over deep-water pack ice for a female polar bear during a year of extreme sea ice retreat. Polar Biol 34, 975–984. Available from: https://doi.org/10.1007/s00300-010-0953-2.
Durner, G.M., Simac, K.S., Amstrup, S.C., 2013. Mapping polar bear maternal denning habitat in the National Petroleum Reserve -- Alaska with an IfSAR digital terrain model. Arctic 66, 139–245. Available from: https://doi.org/10.14430/arctic4291.
Durner, G.M., Douglas D.C., Atwood T.C. 2019. Are polar bear habitat resource selection functions developed from 1985–1995 data still useful? *Ecol Evol*. 9: 8625–8638. Available from: https://doi.org/10.1002/ece3.5401.
Durner, G.M., Amstrup, S.C., Atwood, T.C., Douglas, D.C., Fischbach, A.S., Olson, J.W., Rode, K.D., Wilson, R.H., 2020. Catalogue of polar bear (Ursus maritimus) maternal den locations in the Beaufort and Chukchi Seas and nearby areas, 1910–2018 (No. 1121), Data Series. U.S. Geological Survey. Available from: https://doi.org/10.3133/ds1121.
Federal Grants. Alaska Nanuuq Commission Co-Management of Polar Bears. Available from: https://www.federalgrants.com/Alaska-Nanuuq-Commission-Co-Management-of-Polar-Bears-36488.html.
Ferguson, S.H., Messier, F., Taylor, M.K., 1997. Space use by polar bears in and around Auyuittuq National Park, Northwest Territories, during the ice-free period. Can. J. Zool. 75, 1585–1594. Available from: https://doi.org/10.1139/z97-785.
Fischbach, A.S., Amstrup, S.C. Douglas, D.C., 2007. Landward and eastward shift of Alaskan polar bear denning associated with recent sea ice changes. *Polar Biol.* **30**, 1395–1405. Available from: https://doi.org/10.1007/s00300-007-0300-4.

Freeman, M.M.R., 2001. Culture, commerce, and international co-operation in the global recovery of Polar Bears. Pac. Conserv. Biol. 7, 161–168. Available from: https://doi.org/10.1071/pc010161.

Frost, K.J., Lowry, L.F., Pendleton, G., H.R. Nute, H.R., 2004. Factors affecting the observed densities of ringed seals, *Phoca hispida*, in the Alaskan Beaufort Sea, 1996–1999. Arctic 57:115–128. Available from: https://www.jstor.org/stable/40512613.

Galicia, M.P., Thiemann, G.W., Dyck, M.G., Ferguson, S.H., Higdon, J.W., 2016. Dietary habits of polar bears in Foxe Basin, Canada: possible evidence of a trophic regime shift mediated by a new top predator. Ecology and Evolution 6:6005–6018. Available from: https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.2173.

Galicia, M., Thiemann, G., Dyck, M., Ferguson, S., 2021. Polar bear diet composition reveals spatiotemporal distribution of Arctic marine mammals across Nunavut, Canada. Ecological Indicators 132, 108245. Available from: https://doi.org/10.1016/j.ecolind.2021.108245.

Garner, G.W., Knick, S.T., Douglas, D.C., 1990. Seasonal Movements of Adult Female Polar Bears in the Bering and Chukchi Seas. Bears: Their Biology and Management 8, 219. Available from: https://doi.org/10.2307/3872922.

Garner, G.W., Belikov, S.E., Stishov, M.S., Barnes, V.G., Arthur, S.M., 1994. Dispersal Patterns of Maternal Polar Bears from the Denning Concentration on Wrangel Island. Bears: Their Biology and Management 9, 401–410. Available from: https://doi.org/10.2307/3872726.

Gehrke, C., 2023. Wild polar bear conservation: A case of successful arctic science diplomacy? Marine Policy 155, 105783. Available from: https://doi.org/10.1016/j.marpol.2023.105783.

Gormezano, L.J., Rockwell, R.F., 2013. What to eat now? Shifts in polar bear diet during the ice-free season in western Hudson Bay. Ecol Evol 3, 3509–3523. Available from: https://doi.org/10.1002/ece3.740.

Hannah, L., 2008. Protected areas and climate change. Ann. NY Acad. Sci. 1134, 201–212. Available from: https://doi.org/10.1196/annals.1439.009.

Herreman, J., Peacock, E., 2013. Polar bear use of a persistent food subsidy: Insights from non-invasive genetic sampling in Alaska. Ursus 24(2), 148–163. Available from: https://doi.org/10.2192/URSUS-D-12-00030.1.

Hunter, C.M., Caswell, H., Runge, M.C., Regehr, E.V., Amstrup, S.C., Stirling, I., 2010. Climate change threatens polar bear populations: a stochastic demographic analysis. Ecology 91, 2883–2897. Available from: https://doi.org/10.1890/09-1641.1

Iles, D.T., Peterson, S.L., Gormezano, L.J., Koons, D.N., Rockwell, R.F., 2013. Terrestrial predation by polar bears: not just a wild goose chase. Polar Biol. 36, 1373–1379. Available from: https://doi.org/10.1007/s00300-013-1341-5.

Inuvialuit Game Council, North Slope Borough Fish and Game Management Committee, 2000. Inuvialuit-Inpuiat Polar Bear Management Agreement in the Southern Beaufort Sea. Available from: https://polarbearagreement.org/images/Docs/Inuvialuit_Inupiat_PB_Agreement_2000.pdf.

IUCN, 2015. New assessment highlights climate change as most serious threat to polar bear survival. Available from: https://www.iucn.org/content/new-assessment-highlights-climate-change-most-serious-threat-polar-bear-survival-iucn-red-list.
IUCN/SSC/PBSG (Polar Bear Specialist Group of the IUCN Species Survival Commission), 2023. Status Report on the World's Polar Bear Subpopulations. Available from: https://www.iucn-pbsg.org/wp-content/uploads/2024/01/PBSG-Status-Criteria-and-Report_Final_2023Oct17.pdf.
IUCN/SSC/PBSG (Polar Bear Specialist Group of the IUCN Species Survival Commission), 2024. Website for the Polar Bear Specialist Group of the IUCN Species Survival Commission. Available from: https://www.iucn-pbsg.org/.
Joint Secretariat, 2015. Inuvialuit and Nanuq: A Polar Bear Traditional Knowledge Study. Joint Secretariat, Inuvialuit Settlement region. 304. Available from: https://www.polarbearscanada.ca/sites/default/files/public/394_polar-bear-tk-report-low-res.pdf.
Kochnev, A.A., 1992. On polar bear observations near walrus coastal haul-outs on Wrangel Island in 1990. Wrangel Island State Nature Reserve. Ushakovskoye village, Russia.
Kochnev, A.A. 2002. Factors Causing Pacific Walrus Mortality on the Coastal Haulouts of Wrangel Island. In Aristov, A.A. et al (eds.) Marine Mammals (Results of research conducted in 1995-1998). Collection of articles. Moscow 2002. Pp.191-215. Translated from the original Russian language into English by O. Romanenko, Anchorage, Alaska, 2009. Available from: https://polarbearscience.com/wp-content/uploads/2019/04/kochnev_2002_factorscausingpacificwalrusmortalityonthecoastalhaulouts_engruss1.pdf.
Koenig, R., 2019. Polar bear encounter reported in Arctic Village, many miles south of normal range. Alaska Public Media. Available from: https://alaskapublic.org/2019/01/15/polar-bear-encounter-reported-in-arctic-village-many-miles-south-of-normal-range/.
Laidre, K.L., Stirling, I., Estes, J.A., Kochnev, A., Roberts, J., 2018. Historical and potential future importance of large whales as food for polar bears. Frontiers in Ecology and the Environment 16, 515–524. Available from: https://doi.org/10.1002/fee.1963.
Laidre, K.L., Atkinson, S., Regehr, E.V., Stern, H.L., Born, E.W., Wiig, Ø., Lunn, N.J., Dyck, M., 2020b. Interrelated ecological impacts of climate change on an apex predator. Ecological Applications 30, e02071. Available from: https://doi.org/10.1002/eap.2071.
Lawler, J.J., 2009. Climate Change Adaptation Strategies for Resource Management and Conservation Planning. Annals of the New York Academy of Sciences 1162, 79–98. Available from: https://doi.org/10.1111/j.1749-6632.2009.04147.x.
Lillie, K.M., Gese, E.M., Atwood, T.C., Conner, M.M., 2019. Use of subsistence-harvested whale carcasses by polar bears in the Southern Beaufort Sea. Arctic 72: 404–412. Available from: https://www.jstor.org/stable/26867461.
Lomac-MacNair, K., Andrade, J. P., Esteves, E., 2019. Seal and polar bear behavioral response to an icebreaker vessel in northwest Greenland. *Human-Wildlife Interactions*, *13*(2), 277–289. Available from: https://www.jstor.org/stable/27316126.

Lovecraft, A.L., Meek, C.L., 2011. The human dimensions of marine mammal management in a time of rapid change: comparing policies in Canada, Finland and the United States. Marine Policy, The Human Dimensions of Northern Marine Mammal Management In A Time Of Rapid Change 35, 427–429. Available from: https://doi.org/10.1016/j.marpol.2010.10.022.

Marine Mammal Protection Act of 1972 as Amended, as amended through 2018. Available from: https://www.mmc.gov/wp-content/uploads/MMPA_March2019.pdf.

Mawdsley, J.R., O'Malley, R., Ojima, D.S., 2009. A Review of Climate-Change Adaptation Strategies for Wildlife Management and Biodiversity Conservation. Conservation Biology 23, 1080–1089. Available from: https://doi.org/10.1111/j.1523-1739.2009.01264.x.

McCall, A.G., Pilfold, N.W., Derocher, A.E., Lunn, N.J., 2016. Seasonal habitat selection by adult female polar bears in western Hudson Bay. Population Ecology 58, 407–419. Available from: https://doi.org/10.1007/s10144-016-0549-y.

McKinney, M.A., Atwood, T.C., Iverson, S.J., Peacock, E., 2017. Temporal complexity of southern Beaufort Sea polar bear diets during a period of increasing land use. *Ecosphere* 8(1), e01633. Available from: https://doi.org/10.1002/ecs2.1633.

Meek, C.L., 2011. Putting the US polar bear debate into context: The disconnect between old policy and new problems. Marine Policy, The Human Dimensions of Northern Marine Mammal Management In A Time Of Rapid Change 35, 430–439. Available from: https://doi.org/10.1016/j.marpol.2010.11.005.

Meek, C.L., Lauren Lovecraft, A., Varjopuro, R., Dowsley, M., Dale, A.T., 2011. Adaptive governance and the human dimensions of marine mammal management: Implications for policy in a changing North. Marine Policy, The Human Dimensions of Northern Marine Mammal Management In A Time Of Rapid Change 35, 466–476. Available from: https://doi.org/10.1016/j.marpol.2010.10.021.

Meier, W.N., Stroeve, J., 2022. An Updated Assessment of the Changing Arctic Sea Ice Cover. Oceanography 35, 10–19. Available from: https://www.jstor.org/stable/10.2307/27182690.

Mildenberger, T.K., Berg, C.W., Kokkalis, A., Hordyk, A.R., Wetzel, C., Jacobsen, N.S., Punt, A.E., Nielsen, J.R., 2022. Implementing the precautionary approach into fisheries management: Biomass reference points and uncertainty buffers. Fish and Fisheries 23, 73–92. Available from: https://doi.org/10.1111/faf.12599.

Miller, S., Wilder, J., Wilson, R.R., 2015. Polar bear–grizzly bear interactions during the autumn open-water period in Alaska. Journal of Mammalogy 96, 1317–1325. Available from: https://doi.org/10.1093/jmammal/gyv140.

Molnár, P.K., Derocher, A.E., Thiemann, G.W., Lewis, M.A., 2010. Predicting survival, reproduction and abundance of polar bears under climate change, Biological Conservation, Volume 143, Issue 7, 1612-1622, ISSN 0006-3207. Available from: https://doi.org/10.1016/j.biocon.2010.04.004.

Molnár, P.K., Bitz, C.M., Holland, M.M., Kay, J.E., Penk, S.R., Amstrup, S.C., 2020. Fasting season length sets temporal limits for global polar bear persistence. *Nature Climate Change* 10(8), 732–738. Available from: https://doi.org/10.1038/s41558-020-0818-9.

Monnett, C., Gleason, J.S., 2006. Observations of mortality associated with extended open-water swimming by polar bears in the Alaskan Beaufort Sea. Polar Biol. 29, 681–687. Available from: https://doi.org/10.1007/s00300-005-0105-2.

NOAA. 2019-2023 Gray whale unusual mortality event dead animal locations. Available from: https://noaa.maps.arcgis.com/apps/webappviewer/index.html?id=d1d0c95853ae4499a9f27fb14d7a1f50.

Notz, D., Simip Community, 2020. Arctic Sea Ice in CMIP6. Geophysical Research Letters 47, e2019GL086749. Available from: https://doi.org/10.1029/2019GL086749.

Obbard, M.E., G.W. Thiemann, E. Peacock, and T.D. DeBruyn, editors. 2010. Polar Bears: Proceedings of the 15th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, Copenhagen, Denmark, 29 June–3 July 2009. Gland, Switzerland. Available from: https://lindseyresearch.com/wp-content/uploads/2021/12/NHTSA-2021-0053-1554-74-Obbard-2010_Polar-Bears.pdf.

Ovsyanikov, N.G., 1995. Polar bear predation of walruses on Wrangell Island. Bulletin of the Moscow Association of Natural Scientists, Section of Biology. 1995. VOL. 100. Issue #4. Translated by Marina Bell, Anchorage, AK. Available from: https://www.arlis.org/docs/vol1/E/Walrus/Russian/Ovsyanikov.1995.PolarBearPredationWalrusWrangellIsland.BullM.pdf.

Ovsyanikov, N. 2005. Research and conservation of polar bears on Wrangel Island. Pages 167–171 *in* J. Aars, N.J. Lunn, and A.E. Derocher, editors. Proceedings of the 14th working meeting of the IUCN/SSC Polar Bear Specialist Group, June 2005, Seattle, Washington, USA. Available from: https://doi.org/10.2305/IUCN.CH.1999.SSC-AP.7.en.

Ovsyanikov, N.G., 2012. Occurrence of family groups and litter size of polar bears (*Ursus maritimus*) on Wrangel Island in the autumns of 2004-2010 as an indication of population status. Pp. 143–150 In Boltunov, A.N. (compiler). Marine Mammals of the Holarctic, Volume 2. Collection of Scientific Papers from the Seventh International Conference on Marine Mammals of the Holarctic, Suzdal, Russia, 24–28 September 2012. Marine Mammal Council, Moscow, Russia. Available from: https://iucn-csg.org/wp-content/uploads/2024/07/mmh2012_book_vol2.pdf.

Pagano, A.M., Durner, G.M., Amstrup, S.C., Simac, K.S., York, G.S., 2012. Long-distance swimming by polar bears (Ursus maritimus) of the southern Beaufort Sea during years of extensive open water. Can. J. Zool. 90, 663–676. Available from: https://doi.org/10.1139/z2012-033.

Pagano, A.M., Durner, G.M., Atwood, T.C., Douglas, D.C., 2021. Effects of sea ice decline and summer land use on polar bear home range size in the Beaufort Sea. Ecosphere 12, 1–19. Available from: https://doi.org/10.1002/ecs2.3768.

Pagano, A.M., Durner, G.M., Rode, K.D., Atwood, T.C., Atkinson, S.N., Peacock, E., Costa, D.P., Owen, M.A., Williams, T.M., 2018. High-energy, high-fat lifestyle challenges an Arctic apex predator, the polar bear. Science 359, 568–572. Available from: https://doi.org/10.1126/science.aan8677.

Pagano, A.M., Williams, T.M., 2021. Physiological consequences of Arctic sea ice loss on large marine carnivores: unique responses by polar bears and narwhals. Journal of Experimental Biology 224. Available from: https://doi.org/10.1242/jeb.228049.

Patil, V.P., Durner, G.M., Douglas, D.C., Atwood, T.C., 2022. Modeling the spatial and temporal dynamics of land-based polar bear denning in Alaska. Journal of Wildlife Management 86. Available from: https://doi.org/10.1002/jwmg.22302.

Peacock, E., Derocher, A.E., Thiemann, G.W., Stirling, I., 2011. Conservation and management of Canada's polar bears (Ursus maritimus) in a changing Arctic. Can. J. Zool. 89, 371–385. Available from: https://doi.org/10.1139/z11-021.

Pilfold, N.W., Derocher, A.E., Stirling, I., Richardson, E., Andriashek, D., 2012. Age and Sex Composition of Seals Killed by Polar Bears in the Eastern Beaufort Sea. PLOS ONE 7, e41429. Available from: https://doi.org/10.1371/journal.pone.0041429.

Polar Bear Range States, 2015a. Annex II. Details of Bilateral Agreements, Circumpolar Action Plan. Available from: https://polarbearagreement.org/circumpolar-action-plan.

Polar Bear Range States, 2015b. Circumpolar Action Plan: Conservation Strategy for Polar Bears. A product of the representatives of the parties to the 1973 Agreement on the Conservation of Polar Bears. Available from: https://polarbearagreement.org/resources/circumpolar-action-plan/cap-2015-2025-docs.

Polar Bear Range States, 1973. Agreement on the Conservation of Polar Bears. Available from: https://polarbearagreement.org/.

Pongracz, J.D., Derocher, A.E., 2016. Summer refugia of polar bears (Ursus maritimus) in the southern Beaufort Sea. Polar Biol 40, 753–763. Available from: https://doi.org/10.1007/s00300-016-1997-8.

Ramsay, M.A. and Stirling, I., 1990. Fidelity of female polar bears to winter-den sites. Journal of Mammalogy 71:233–236. Available from: https://www.jstor.org/stable/1382172.

Regehr, E.V., Amstrup, S.C., Stirling, I., 2006, Polar bear population status in the southern Beaufort Sea: U.S. Geological Survey Open-File Report 2006-1337, 20 p. Available from: https://polarbearscience.com/wp-content/uploads/2014/11/regehr-et-al-2006-sb-pbs.pdf.

Regehr, E.V., Lunn, N.J., Amstrup S.C., Stirling, I., 2007. Effects of earlier sea ice breakup on survival and population size of polar bears in western Hudson Bay. Journal of Wildlife Management, 71, 2673–2683. Available from: https://wildlife.onlinelibrary.wiley.com/doi/abs/10.2193/2006-180.

Regehr, E.V., Hunter, C.M., Caswall, H., Amstrup, S.C., Stirling, I., 2010. Survival and breeding of polar bears in the southern Beaufort Sea in relation to sea ice. Journal of Animal Ecology, 79, 117–127. Available from: https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/j.1365-2656.2009.01603.x.

Regehr, E.V., Laidre, K.L., Akçakaya, H.R., Amstrup, S.C., Atwood, T.C., Lunn, N.J., Obbard, M., Stern, H., Thiemann, G.W., Wiig, Ø., 2016. Conservation status of polar bears (Ursus maritimus) in relation to projected sea-ice declines. Biology Letters 12, 20160556. Available from: https://doi.org/10.1098/rsbl.2016.0556.

Regehr, E.V., Hostetter, N.J., Wilson, R.R., Rode, K.D., St. Martin, M., and Converse, S.J. 2018. Integrated population modeling provides the first empirical estimates of vital rates and abundance for polar bears in the Chukchi Sea. Scientific Reports 8:16780. Available from: https://www.nature.com/articles/s41598-018-34824-7.

Rode, K.D., Amstrup, S.C., Regehr, E.V., 2010. Reduced body size and cub recruitment in polar bears associated with sea ice decline. Ecological Applications 20, 768–782. Available from: https://doi.org/10.1890/08-1036.1.

Rode, K.D., Reist, J.D., Peacock, E., Stirling, I., 2010. Comments in response to “Estimating the energetic contribution of polar bear (Ursus maritimus) summer diets to the total energy budget” by Dyck and Kebreab (2009). Journal of Mammalogy 91, 1517–1523. Available from: https://doi.org/10.1644/09-MAMM-A-399.1.

Rode, K.D., Robbins, C.T., Nelson, L., Amstrup, S.C., 2015. Can polar bears use terrestrial foods to offset lost ice-based hunting opportunities? Frontiers in Ecology and the Environment 13, 138–145. Available from: https://doi.org/10.1890/140202.

Rode, K.D., Wilson, R.R., Regehr, E.V., Martin, M.S., Douglas, D.C., Olson, J., 2015. Increased Land Use by Chukchi Sea Polar Bears in Relation to Changing Sea Ice Conditions. PLOS ONE 10, e0142213. Available from: https://doi.org/10.1371/journal.pone.0142213.

Rode, K.D., Wilson, R.R., Douglas, D.C., Muhlenbruch, V., Atwood, T.C., Regehr, E.V., Richardson, E.S., Pilfold, N.W., Derocher, A.E., Durner, G.M., Stirling, I., Amstrup, S.C., St. Martin, M., Pagano, A.M., Simac, K., 2018. Spring fasting behavior in a marine apex predator provides an index of ecosystem productivity. Global Change Biology 24, 410–423. Available from: https://doi.org/10.1111/gcb.13933.

Rode, K.D., Regehr, E.V., Bromaghin, J.F., Wilson, R.R., St. Martin, M., Crawford, J.A., Quakenbush, L.T., 2021. Seal body condition and atmospheric circulation patterns influence polar bear body condition, recruitment, and feeding ecology in the Chukchi Sea. Global Change Biology 27, 2684–2701. Available from: https://doi.org/10.1111/gcb.15572.

Rode, K.D., Douglas, D.C., Atwood, T.C., Durner, G.M., Wilson, R.R., Pagano, A.M., 2022. Observed and forecasted changes in land use by polar bears in the Beaufort and Chukchi Seas, 1985–2040. Global Ecology and Conservation 40, e02319. Available from: https://doi.org/10.1016/j.gecco.2022.e02319.

Rode, K.D., Taras, B.D., Stricker, C.A., Atwood, T.C., Boucher, N.P., Durner, G.M., Derocher, A.E., Richardson, E.S., Cherry, S.G., Quakenbush, L., Horstmann, L., Bromaghin, J.F., 2023. Diet energy density estimated from isotopes in predator hair associated with survival, habitat, and population dynamics. Ecological Applications 33, e2751. Available from: https://doi.org/10.1002/eap.2751.

Rode, K.D., Wilson, R.R., Crawford, J.A., Quakenbush, L.T., 2024. Identifying indicators of polar bear population status. Ecological Indicators 159, 111638. Available from: https://doi.org/10.1016/j.ecolind.2024.111638.

Rogers, M.C., Peacock, E., Simac, K., O’Dell, M.B., Welker, J.M., 2015. Diet of female polar bears in the southern Beaufort Sea of Alaska: evidence for an emerging alternative foraging strategy in response to environmental change. Polar Biol 38, 1035–1047. Available from: https://doi.org/10.1007/s00300-015-1665-4.

Scharf, H.R., Hooten, M.B., Wilson, R.R., Durner, G.M., Atwood, T.C., 2019. Accounting for phenology in the analysis of animal movement. Biometrics 75, 810–820. Available from: https://doi.org/10.1111/biom.13052.

Schliebe, S., Rode, K.D., Gleason, J.S., Wilder, J., Proffitt, K., Evans, T.J., Miller, S., 2008. Effects of sea ice extent and food availability on spatial and temporal distribution of polar bears during the fall open-water period in the Southern Beaufort Sea. Polar Biol 31, 999–1010. Available from: https://doi.org/10.1007/s00300-008-0439-7.

Smith, T.G., 1980. Polar bear predation of ringed and bearded seals in the land-fast sea ice habitat. Can. J. Zool. 58, 2201–2209. Available from: https://doi.org/10.1139/z80-302.

Sodikoff, G.M., ed. 2012. The Anthropology of Extinction: Essays on Culture and Species Death. Bloomington and Indianapolis: Indiana University Press. Available from: https://iupress.org/9780253223647/the-anthropology-of-extinction/.

Stempniewicz, L., Kulaszewicz, I., Aars, J., 2021. Yes, they can: polar bears Ursus maritimus successfully hunt Svalbard reindeer Rangifer tarandus platyrhynchus. Polar Biol 44, 2199–2206. Available from: https://doi.org/10.1007/s00300-021-02954-w.

Stirling, I., 1988. Polar bears. University of Michigan Press, Ann Arbor, Michigan, USA. Available from: https://press.umich.edu/Books/P/Polar-Bears.

Stirling, I., 2009. Polar Bear Ursus maritimus, in Marine Mammal Encyclopedia. Pgs. 888-890. Available from: https://www.sciencedirect.com/science/article/abs/pii/B9780123735539002042.

Stirling, I., Andriashek, D., Spencer, C., Derocher, A.E, 1988. Assessment of the polar bear population in the eastern Beaufort Sea. Final Report to the Northern Oil and Gas Assessment Program. Canadian Wildlife Service, Edmonton, Alberta, Canada.

Stirling, I., Archibald, W.R., 1977. Aspects of Predation of Seals by Polar Bears. J. Fish. Res. Bd. Can. 34, 1126–1129. Available from: https://doi.org/10.1139/f77-169.

Stirling, I., Derocher, A.E., 1993. Possible impacts of climate warming on polar bears. Arctic 46, 2040-245. Available from: https://www.jstor.org/stable/40511411.

Stirling, I., Derocher, A.E., 2012. Effects of climate warming on polar bears: a review of the evidence. Glob Chang Biol 18, 2694–2706. Available from: https://doi.org/10.1111/j.1365-2486.2012.02753.x.

Stirling, I., Lunn, N.J., Iacozza, J., 1999. Long-term Trends in the Population Ecology of Polar Bears in Western Hudson Bay in Relation to Climatic Change. ARCTIC 52, 294–306. Available from: https://doi.org/10.14430/arctic935.

Thiemann, G., Molnár, P.K., Derocher, A., Lewis, M.A., 2010. Polar Bears Are Threatened by the Effects of Climate Change. Biological Conservation 143(7), 1612–1622. Available from: https://yorkspace.library.yorku.ca/server/api/core/bitstreams/f78d5408-8dee-44c5-b1f0-9dd57f7ca84e/content.

Thiemann, G.W., Iverson, S.J., Stirling, I., 2008. Polar Bear Diets and Arctic Marine Food Webs: Insights from Fatty Acid Analysis. Ecological Monographs 78, 591–613. Available from: https://doi.org/10.1890/07-1050.1.

Towns, L., Derocher, A.E., Stirling, I., Lunn, N.J., Hedman, D., 2009. Spatial and temporal patterns of problem polar bears in Churchill, Manitoba. Polar Biol 32, 1529–1537. Available from: https://doi.org/10.1007/s00300-009-0653-y.

United Nations Conference on Environment and Development: Rio Declaration on Environment and Development, 1992. International Legal Materials 31, 874–880.

U.S. Department of State. 2000. Agreement Between the Government of the United States of America and the Government of the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population. Signed October 16, 2000, Ratified by President April 17, 2007, Entered into Force September 23, 2007. Available from: https://www.state.gov/wp-content/uploads/2019/02/07-923-Russian-Federation-Conservation-Treaty.pdf.

U.S. Department of State. 2007. U.S.-Russia Bilateral Agreement on Polar Bear Conservation. Media note. Sept. 21, 2007. Archive. Available from: https://2001-2009.state.gov/r/pa/prs/ps/2007/sep/92595.htm.

U.S. Fish and Wildlife Service (USFWS), 2008. Determination of threatened status for the polar bear (*Ursus maritimus*) throughout its range; final rule. U.S. Fish and Wildlife Service. Federal Register 73:28212–28303.

U.S. Fish and Wildlife Service (Service), 2010. Designation of critical habitat for the polar bear (*Ursus maritimus*) in the United States; Final Rule. Federal Register 75:76086–76137

U.S. Fish and Wildlife Service, 2019a. Polar Bear (Ursus maritimus): Southern Beaufort Sea Stock Assessment Report. May 2019. Anchorage, Alaska. See also 86 Fed Reg at 33337 (Notice of Availability. Available from: https://www.fws.gov/sites/default/files/documents/polar-bear-southern-beaufort-sea-stock-assessment-report-may-2019.pdf.

U.S. Fish and Wildlife Service. 2019b. Polar Bear (Ursus maritimus): Chukchi/Bering Sea Stock Assessment Report. May 2019. Anchorage, Alaska. (p.10); see also 86 Fed Reg at 33337 (Notice of Availability of SAR).

USFWS, 2021. Final Rule issuing Incidental Take Regulations for nonlethal, incidental, unintentional take by harassment of small numbers of polar bears and Pacific walruses during year-round oil and gas industry activities in the Beaufort Sea and adjacent northern coast of Alaska. 86 FR 42982, pp 42982-43074.

U.S. Fish and Wildlife Service, 2022. Biological Opinion for National Petroleum Reserve-Alaska Integrated Activity Plan. Fairbanks, AK.

U.S. Fish and Wildlife Service, 2023a. Biological Opinion for the Willow Master Development Plan. Fairbanks, AK.

U.S. Fish and Wildlife Service, 2023b. Species Status Assessment for the Polar Bear (Ursus maritimus). Version 1.0. 18 August 2023. Anchorage, Alaska.

USGS Alaska Science Center, Polar Bear Research Program, 2018. Denning Phenology, Den Substrate, and Reproductive Success of Female Polar Bears (Ursus maritimus) in the southern Beaufort Sea 1986-2013 and the Chukchi Sea 1987-1994. Available from: https://doi.org/10.5066/F7DF6PC9.

Vongraven, D., Aars, J., Amstrup, S., Atkinson, S.N., Belikov, S., Born, E.W., DeBruyn, T.D., Derocher, A.E., Durner, G., Gill, M., Lunn, N., Obbard, M.E., Omelak, J., Ovsyanikov, N., Peacock, E., Richardson, E., Sahanatien, V., Stirling, I., Wiig, Ø., 2012. A circumpolar monitoring framework for polar bears. Ursus 23, 1–66. Available from: https://doi.org/10.2192/URSUS-D-11-00026.1.

Voorhees, H., Sparks, R., Huntington, H.P., Rode, K.D., 2014. Traditional Knowledge about Polar Bears (Ursus maritimus) in Northwestern Alaska. ARCTIC 67, 523–536. Available from: https://doi.org/10.14430/arctic4425.

Wang, M., Yang, Q., Overland, J.E., Stabeno, P., 2018. Sea-ice cover timing in the Pacific Arctic: The present and projections to mid-century by selected CMIP5 models. Deep Sea Research Part II: Topical Studies in Oceanography, Synthesis of Arctic Research SOAR Phase II 152, 22–34. Available from: https://doi.org/10.1016/j.dsr2.2017.11.017.

Ware, J.V., Rode, K.D., Bromaghin, J.F., Douglas, D.C., Wilson, R.R., Regehr, E.V., Amstrup, S.C., Durner, G.M., Pagano, A.M., Olson, J., Robbins, C.T., Jansen, H.T., 2017. Habitat degradation affects the summer activity of polar bears. Oecologia 184, 87–99. Available from: https://doi.org/10.1007/s00442-017-3839-y.

Whiteman, J.P., Harlow, H.J., Durner, G.M., Anderson-Sprecher, R., Albeke, S.E., Regehr, E.V., Amstrup, S.C., Ben-David, M., 2015. Summer declines in activity and body temperature offer polar bears limited energy savings. Science 349:295-298. Available from: https://www.science.org/doi/abs/10.1126/science.aaa8623.

Whiteman, J.P., Harlow, H.J., Durner, G.M., Regehr, E.V., Rourke, B.C., Robles, M., Amstrup, S.C., Ben-David, M., 2017. Polar bears experience skeletal muscle atrophy in response to food deprivation and reduced activity in winter and summer, *Conservation Physiology*, Volume 5, Issue 1, cox049. Available from: https://doi.org/10.1093/conphys/cox049.

Whiteman, J., Harlow, H., Durner, G., Regehr, E., Amstrup, S., Ben-David, M., 2018. Phenotypic plasticity and climate change: can polar bears respond to longer Arctic summers with an adaptive fast?. Oecologia. 186. Available from: https://link.springer.com/article/10.1007/s00442-017-4023-0.

Wiig, Ø., Amstrup, S., Atwood, T., Laidre, K., Lunn, N., Obbard, M., Regehr, E. & Thiemann, G. 2015. *Ursus maritimus*. The IUCN Red List of Threatened Species: e.T22823A14871490. Available from: http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T22823A14871490.en.

Wilder, J.M., Vongraven, D., Atwood, T.C., Hansen, B., Jessen, A., Kochnev, A., York, G., Vallender, T., Hedman, D., Gibbons, M., 2017. Polar bear attacks on humans: Implications of a changing climate. Wildlife Society Bulletin 41:537–547. Available from: https://wildlife.onlinelibrary.wiley.com/doi/abs/10.1002/wsb.783.

Willoughby, A.L., Clarke, J.T., Ferguson, M.C., Stimmelmayr, R., Brower, A.A. 2017. Bowhead whale carcasses in the eastern Chukchi and western Beaufort seas, 2009–2017. Presented to the Scientific Committee of the International Whaling Commission. SC/67B/AWMP/02. Available from: https://archive.iwc.int/pages/download.php?ref=17163&size=&ext=pdf&k=&alternative=-1&usage=-1&usagecomment=.

Willoughby, A., Stimmelmayr, R., Brower, A., Clarke, J., Ferguson, M., 2020. Gray Whale Carcasses in the Eastern Chukchi Sea, 2009-2019. Paper SC/68b/IST/02 presented to the 68th International Whaling Commission Scientific Committee, May 2020, virtual meeting. Available from: https://archive.iwc.int/pages/download.php?direct=1&noattach=true&ref=17304&ext=pdf&k=.

Willoughby, A.L., Ferguson, M.C., Stimmelmayr, R., Brower, A.A., 2022a. Bowhead whale (*Balaena mysticetus*) carcasses documented during the 2019 aerial surveys in the eastern Chukchi and western Beaufort seas: a follow-up to evidence of bowhead whale and killer whale (*Orcinus orca*) co-occurrence during 2009–2018. Polar Biol 45, 1723–1728. Available from: https://doi.org/10.1007/s00300-022-03097-2.

Willoughby, A.L., Stimmelmayr, R., Brower, A.A., Clarke, J.T., Ferguson, M.C., 2022b. Gray whale (*Eschrichtius robustus*) and killer whale (*Orcinus orca*) co-occurrence in the eastern Chukchi Sea, 2009–2019: evidence from gray whale carcasses observed during aerial surveys. Polar Biol. 45, 737–748. Available from: https://doi.org/10.1007/s00300-022-03015-6.

Wilson, R.R., Durner, G.M., 2020. Seismic Survey Design and Effects on Maternal Polar Bear Dens. The Journal of Wildlife Management 84, 201–212. Available from: https://doi.org/10.1002/jwmg.21800.

Wilson, R.R., Perham, C., French-McCay, D.P., Balouskus, R., 2018. Potential impacts of offshore oil spills on polar bears in the Chukchi Sea. Environ Pollut. 235, 652–659. Available from: https://doi.org/10.1016/j.envpol.2017.12.057.

Wilson, R.R., Regehr, E.V., St. Martin, M., Atwood, T.C., Peacock, E., Miller, S., Divoky, G., 2017. Relative influences of climate change and human activity on the onshore distribution of polar bears. Biological Conservation 214, 288–294. Available from: https://doi.org/10.1016/j.biocon.2017.08.005.

Wilson, R.H., Regehr, E.V., Martin, M.S., Atwood, T.C., Peacock, E.L., Miller, S., Divoky, G.J., 2017b. Relative influences of climate change and human activity on the onshore distribution of polar bears. Biological Conservation 214, 288–294. Available from: https://doi.org/10.1016/j.biocon.2017.08.005.

Zimmermann, M., Erikson, L.H., Gibbs, A.E., Prescott, M.M., Escarzaga, S.M., Tweedie, C.E., Kasper, J.L., Duvoy, P.X., 2022. Nearshore bathymetric changes along the Alaska Beaufort Sea coast and possible physical drivers. Continental Shelf Research 242. Available from: https://doi.org/10.1016/j.csr.2022.104745.

4: Indigenous Science and Lifeways

This chapter focuses on Iñupiat Lifeways in and around the National Petroleum Reserve – Alaska (NPR-A or Reserve), the values, principles, practices, and teachings of the Iñupiat people, and how to be in relationship with their homelands. In the exploration of Indigenous perspectives, it is essential to acknowledge the complexities inherent in the relationship between Iñupiat peoples and the extractive oil and gas economies. The communities discussed in this document are currently reliant on oil and gas as a singular and volatile economic source, which undermines Indigenous lifeways, traditional subsistence economy, and environmental sustainability.

This chapter emphasizes Indigenous Knowledge and Wisdom, aiming for cross-cultural communication at an epistemological level to foster broader understanding and implementation. It is based on the principles of relationship and reciprocity, highlighting the attributes, values, norms, practices, language, and material concepts of the Iñupiaq people. Through storytelling, Iñupiat history, culture, and oral traditions are shared in the same manner as their intergenerational transfer of knowledge, focusing on worldview, relationships to reality, and natural law.

The literature review and ethnographic interviews focus on Iñupiaq concepts of how to be in relationship with animals, the land, and each other, underscoring the interconnectedness of all beings and the environments they inhabit. Working to understand how Iñupiat communities perceive their existence as being in a continuous relationship with the land rather than viewing it as a mere resource. Unfortunately, Western dominant interpretations often disregard these profound connections, leading to a clash that perpetuates misunderstanding and dispossession. To move forward, it is vital to engage with both worldviews critically, seeking to reconcile and bridge the gaps that exist. Doing so can foster a deeper appreciation of Indigenous relationships with the earth and create pathways towards a more respectful coexistence that honors both perspectives.

Indigenous protocols include genealogical relations that are layered with reciprocal responsibilities, processes of renewal, and an understanding that humans must be humble toward other beings, entities, and collectives. Therefore, ethnographic interviews were prioritized from both the literature review written about the Iñupiat by explorers and anthropologists and the contemporary interviews with Iñupiat Elders. An informal interview style was used primarily to honor cultural norms, fostering the natural flow of information through relationship building and storytelling to allow the wisdom keeper to provide information on respectful engagement of spiritual beliefs, ancestors, oral history, traditional lands, family, community, and all our relations (birds, plants, animals, fish, insects, unseen, and in-between) as co-collaborators.

Highlighting the importance of Indigenous Knowledge and Wisdom is a vital component of sustainable practices and cultural preservation. By valuing the interconnectedness of all beings and fostering respectful dialogue between differing worldviews, the gap that often separates Indigenous perspectives from mainstream narratives can be bridged. Emphasizing relationship, reciprocity, and humility in research methodologies not only honors the wisdom of the Iñupiat, but also enriches our collective understanding of the world. As we work towards a more inclusive future, it is essential to engage with and support Indigenous communities in their efforts to maintain their cultural heritage and connection to the land, paving the way for respectful coexistence and mutual appreciation.

“Almost every source describes the long record of Native use and occupation that took place before European contact as ‘prehistory.’ Indigenous groups, however, possess a history of thousands of years of occupancy and exodus, relocation and settlement, exploration and discovery, embedded throughout the generations in legal process, artistic declaration, symbolic regalia, and oral tradition at least as accurately, and in many cases more accurately, than the European system of writing that was used for many years after contact to remove rights and appropriate lands. We must always remember that before contact, Native cultures possessed vigorous legal systems, effective educational systems, efficient health systems, elaborate social orders, sophisticated kinship systems, complex languages, profitable trade systems - every social institution needed for a culture to flourish for thousands of years."

- Ernestine Saankalxt Hayes (Hayes, 2018).

Those social institutions have connected the Iñupiat of the North Slope since time immemorial, and the connection between people and animals is key to their way of life. Rather than existing in isolated villages separated by hundreds of miles of tundra, snaking silty rivers, and harsh conditions, Iñupiat people travel and move in tune with the land, seasons, animals, and each other.

The four largest villages in the National Petroleum Reserve in Alaska (Reserve) are Wainwright, Utqiaġvik, Atqasuk, and Nuiqsut.

The Reserve is made up of different ecosystems, all of which provide Iñupiat and animals with abundant nourishment, materials for shelter, fuel, clothing, tools, or transportation, all of which are utilized in a harmonious relationship to the environment. The Arctic Ocean laps at the northern border, the Colville River cuts through the tundra’s east side, and the Brooks Range’s jagged peaks linger just south of the Reserve. All of these different landscapes play vital roles in the lives of the Iñupiat.

The land within the Reserve is one of the most diverse pieces of undisturbed land in the world. Protecting this place is important for the people and animals living within its boundaries and for the collective global health. The Arctic is warming four times faster than anywhere else on the planet (Rantanen, 2022). Iñupiat, living on the land, are seeing firsthand the effects of climate change on the land, animals, and their own health.

Robert Thompson, Iñupiaq Elder, says that if he could rename the National Petroleum Reserve, he would name it “Iñupiat Homelands.”

Using Indigenous Knowledge and Wisdom to examine the land, animals, and ecosystem will give land-managing agencies a holistic perspective of how best to govern the Reserve.

According to the Inuit Circumpolar Council, “Indigenous Knowledge is a systematic way of thinking applied to phenomena across biological, physical, cultural, and spiritual systems. It includes insights based on evidence acquired through direct and long-term experiences and extensive and multigenerational observations, lessons, and skills. It has developed over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation” (Indigenous Knowledge).

“We [Iñupiat people] have been plopped into a world not of our making,” Iñupiaq Elder Victoria Hykes-Steere said. I am really sad that we weren’t given an opportunity to use our worldview and live our lives in a way where we are happy and content. Instead, we are in a situation where it’s resource extractive, and it damages the planet in a way we never traditionally damaged anything.”

In 2021, the Biden and Harris administration formally recognized Indigenous Knowledge as one of the “important bodies of knowledge that contributes to the advancement of scientific, technical, social, and economic advancements of the United States and our collective understanding of the natural world” (The United States, 2022).

With about 6,000 residents living within the Reserve’s borders, the majority of those residents being Iñupiat, who have lived with the land since time immemorial, it would be hard to argue that anyone else knows the land better. By integrating Iñupiaq Indigenous Knowledge and Wisdom into the proposed recommendations for special areas in the Reserve, we are giving the land, the people, and our future the respect they deserve.

Way of Life

Trade

“Trade, in short, was the factor which brought tremendously widely separated people together and which promoted the spread of ideas and cultural elements from one center to another” (Spencer, 1959).

Through Indigenous Knowledge and Wisdom earned from generations of living with the environment, the Iñupiat have mastered the art of living in such harsh environmental conditions. The ability to travel and trade is, and has always been, integral to their way of life.

In the Iñupiaq language, “miut” means “people of” (Webster and Zibell). Nunamiut translates to people of the land, and Taremiut translates to people of the coast.

Nunamiut and Taremiut depend on each other's resources and will travel far distances to engage in trade. Every community or family has their own specific routes and yearly routines.

There are many different types of trade. In the modern-day Iñupiat society, most trading occurs during large gatherings for festivals like Kivgik (The Messenger Feast) or Nalukataq (Annual Whaling Festival). Historically, Iñupiat also traded via trade fairs and by forming connections with trading partners in different communities.

The main trading sites of the northern Arctic were Sisualik, located on the northwest coast near present-day Kotzebue, and Niġliq, located on the north coast at the delta of one of the western mouths of the Colville River (Burch, 2006; Spencer, 1959). Another mentioned trading station was at the Utokak Delta on the Kasegaluk lagoon (Spencer 1959).

Sisualik was the largest of the trading sites, at its peak hosting up to 2000 people in the springtime (Burch, 2006). The event lasted for two to four weeks in the summer and involved trading, feasting, dancing, and a Beluga harvest (Burch, 2006). Most Iñupiat who traveled to Sisualik were from Western Alaska, including the people of Wainwright who would travel south to the Kobuk, down the Utokak River, portage to Noaktak, and down to Hotham Inlet (Spencer 1959).

Iñupiat from the North Slope would gather at Niġliq, a well-known trading center at the delta of one of the western mouths of the Colville River. The people of Utqiaġvik and Nuvuk (a community located on Point Barrow) traveled along the Arctic coast to Niġliq (Spencer, 1959).

Iñupiaq Elder Thomas Brower Sr. (Paniattaaq) spoke about his travels to the Niġliq trade fair in 1910 or 1911 in a double-ended whalers' sailing boat. He brought sea mammal oil to trade for furs and hides (Brower T, 1983).

Niġliq was a smaller gathering than Sisualik, as it was only habited for a couple of weeks a year, whereas Susualik was right next to Kotzebue, a permanent habitation. At these trade fairs, both commercial trading and trading between trading partners occurred (Burch, 2006). Trading partners would take precedence over commercial trading (Burch, 2006).

Iñupiaq Elder Adam Leavitt (Qapqan) recalls traveling from Barrow with his family for trading at Nigliq. Adams' father would trade with other families regularly, even bringing items from orders taken the previous year (Leavitt, 1983).

These trade fairs served as a time of peace. It is recalled that Iñupiat had both relations of trade and war (Burch, 2006). Each nation had borders, which were well known by others and enforced. During times of trade, these borders would open up, allowing access (Burch, 2006). This shows the value of trading, which could bring peace between nations that would also engage in wars.

Table 4.1. Iñupiaq names for different cycles or months (Webster and Zibell). Names vary from village to village. This is the North Alaskan Dialect (Webster and Zibell).

Month	**Iñupiaq name**	**Meaning**
January	Sikiñaatchiak	“New sunshine”
February	Sikiñaasugruk	“Longer sunshine”
March	Paniksiksiivik	“Skin bleaching”
April	Kilgich Tatkiat	“White hawks coming”
May	Suvlugvik	“Rivers flow”
June	Igñivik	“Birth time”
July	Iñukkuksaivik	“Raising time”
August	Akavirvik	“Moulting time” (caribou lose velvet)
September	Tinnivik	“Birds fly (migrate)”
October	Nuliagvik	“Breeding time (caribou)”
November	Nippivik	“Sunset time”
December	Sikiñgilak	“No sunshine”

The Alaska National Interest Lands Conservation Act (ANILCA) was passed in 1980 and defines subsistence uses as “ the customary and traditional uses by rural Alaska residents of wild renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools, or transportation; for the making and selling of handicraft articles out of nonedible byproducts of fish and wildlife resources taken for personal or family consumption, for barter, or sharing for personal or family consumption- and for customary trade” (96th Congress, 1980).

The seasons are the same across the communities in the Reserve, but each community, and sometimes family, has its own seasonal cycles for Indigenous Lifeways and subsistence activities. Please note this is a generalized overview of cycles and seasons.

Spring starts the cycle. Whaling overtakes subsistence activities in coastal villages; there is no springtime whaling in Nuiqsut, but often, community members will travel to Utqiaġvik to participate in the spring whale hunt (Alaska, 1986; U.S. DOI 1979). Bowheads are the primary harvest, but belugas and walrus are also taken (Alaska, 1986; U.S. DOI 1979). Caribou, furbearers, and upland birds start their spring migration, and seals begin to "sun themselves" on top of the ice and are hunted (Burch, 2006).

The summer thaw creates more of a sporadic schedule, allowing people to hunt, eat, and sleep whenever they want, as there is no impending darkness (Burch, 2006). In early summer, snow melts during the day, and the ground refreezes at night, allowing hunters to sleep during the day and do their traveling across the frozen tundra at night (Burch, 2006). Although fishing is done year-round, it hits its peak in the summer when waters open up (Alaska, 1986; U.S. DOI 1979). Summer is also a time of trading and the whaling celebration, Nalukataq. Moose and caribou are also hunted at this time; their coats are the softest in the summer and are known to be fattest and full of the most nutrition in late summer and early fall (Burch, 2006).

Fall is a time of intense activity when people focus on caribou, fish, and seals (Burch, 2006). Before freeze up, in the fall, fall whaling occurs (Alaska, 1986; U.S. DOI 1979). Seals, moose, and brown bears are also hunted throughout the fall, and berry picking is done along rivers (Alaska, 1986; U.S. DOI 1979). If the community engages in polar bear harvests, polar bears are hunted in late fall or early winter, as this is when bears are in the best condition (Voorhees, Sparks, Huntington, Rode, 2014).

The winter solstice period was known as the holiday season, a time for socializing and celebrations such as Kivgiq or The Messenger Feast. Extensive travel still happens via snow machine as it is easier to travel across the tundra when it's covered in snow than in the summer months (Burch, 2006). Trapping furbearers is the main winter activity, but ice fishing and ptarmigan hunting also occur, with the occasional caribou hunt (Alaska, 1986; U.S. DOI 1979). As the days lengthen, caribou and furbearer hunting increases, as preparations for spring whaling bring the cycle full circle (Alaska, 1986; U.S. DOI 1979).

Faye Nusunginya (Kimmialuk) was raised in Utqiaġvik and lived her life in tune with the seasons and cycles. She recalls traveling up the Meade River to Kaiġvik, where they would leave their boats and start hunting caribou on foot, with three to four dogs helping them (Nusunginya, 1982). When they harvested their supply of caribou, they would head back to Utqiaġvik before freeze up. Faye and her family spent a winter at Tapkaluk Island hunting polar bears. After winter, they spent Spring in Utqiaġvik for whale hunting and seal hunting (Nusunginya, 1982). Faye also spent time on the Meade River fishing with her father at the site of Pulayaaq in the summers (Nusunginya, 1982).

The Rivers of the Arctic are like veins circulating blood through the human body. They act as a place of gathering, highways for travel, access to hunting and fishing.

Iñupiaq Elder Mary Edwardson (Amayun) was raised in Utqiaġvik and spent much of her time in the Ikpikpuk Rivers area. Her grandfather, Qiugaq, liked to fish on the Chipp

River in the fall before freeze up. Mary saw a lot of changes in that river over her lifetime, including some of the old fishing spots she fished drying up (Edwardsen M, 1983).

Mary's husband, Charlie Edwardson Sr. (Aaluk), was also raised in Utqiaġvik. Charlie relates a story about how an Elder named Amaġuaq taught him to find fish (Edwardsen C, 1982).

"(He) gave (us) a story, and told us where to go hunting. I look for fish and we don't know where they are, and he describes them; how the lake looks, there's a bank here, and when we go down to around Half Moon Three, we'd start to look for a place. We'd take a net and set a net, see if there's fish in them, and finally we found them. (We) found the place where he was telling us. (He) said when they don't get a whale in the fall time, long time ago, see that's where they always go up, the people from the point, Nuvuŋmiut."

Traditional Knowledge and Wisdom lives within Elders, tradition, celebrations, ceremonies, songs, food, story-telling, and much more.

Nearly all Iñupiat use both coastal and inland resources. Iñupiat live in tune with the seasons, working with the seasons and weather for their subsistence harvests. As climate change shortens winters, lengthens summers, melts the sea ice, and affects weather patterns, it, in turn, affects the generations of traditional knowledge on subsistence harvests and is, therefore, a threat to food security (Otokiak, 2023).

Kivgiq - The Messenger Feast

Kivgiq, or Messenger Feast, is a traditional Iñupiat and Yup'ik festival that consists of sharing food, song and dance, and trades, allowing communities to connect and share information. Kivgiq is deeply rooted in Iñupiaq and Yup'ik culture; however, during the colonial period of the 1910s to 1980s, communities went almost seventy years without celebrating a Kivgiq. Since its revival in 1988, communities across North and West Alaska have celebrated Kivgiq every few years, most recently in 2023, hosted in Utqiaġvik.

"We can enjoy Western food, but it can not satisfy our physical or spiritual needs. For these, we still depend upon bowhead, seal, caribou, fish, and waterfowl," said former Utqiaġvik Mayor George Ahmaogak during the 1988 Kivgik revival. "We can enjoy Western entertainment, yet it falls short. There is a social and spiritual need inside us as Iñupiat, which can only be satisfied by our own traditions. This is why we revived Kivgiq. The result has been a happy one."

Origins

There are many different stories regarding the origins of Kivgiq. The story of the Eagle Mother bringing song and dance to people is one of the more popular ones in Utqiaġvik (Ikuta, 2007).

Sagdluaq, an Iñupiaq living along the Colville River, recounted the Traditional history of how song, dance, and the holy gift of the festival first came to mankind—the origin story of Kivgik. Knud Rasmussen recorded this story during his fifth Thule expedition and published it in his book Across Arctic America in 1927.

“There were once a man and a woman who lived near the sea,” Sagdluaq recalled. “The man was a great hunter, sometimes hunting game far inland, and sometimes seal in his kayak.”

The two then had a son, who grew to be a very skilled hunter. The father divided up the hunting, one going to the sea and one going caribou hunting inland. One day, the son did not return. The man and woman waited in vain and searched for him, but no trace could be found.

“They then had another son. And he grew up, and became strong and skillful like his brother,” Sagdluaq explained. “But he too disappeared one day in the same mysterious manner.”

The man and woman mourned the loss of their two sons. Then, a third son was born to them, and he grew up like his brothers. His brother’s weapons were passed down to him, and he became a strong hunter and brought home an abundance of meat.

One day, the son was hunting inland when he caught sight of a mighty young eagle circling above him. Before the boy could draw his arrow, the eagle removed its hood and turned into a human being.

“‘It is I who killed your two brothers,’” Sagdluaq repeated the eagle's words. “‘And I will kill you too unless you promise me that song festivals shall be held on your return. Will you or will you not?’”

At the time, the people of the North did not know how to sing, dance, or what the Kalukaq (box drum) was. The boy agreed but said he needed help.

“Then come with me, and my mother shall teach you,” Sagdluaq recalled. “As soon as you have learned to join words together in a song, and learned to sing it, and learned to dance for joy, then you shall be free to return to your home.”

The eagle was no longer a bird, but a young and powerful man in a dress of eagle skin. The two traveled over high mountains, through many valleys and passes, until they came to a house on top of a mighty cliff. As they approached, a strange beating sound, like mighty hammers, rang the boys' ears.

“That is my mother’s heart you hear beating!”

The two went into the house where Eagle Mother was sitting, aged, weak, and sad.

“This young man has promised to hold a song festival when he comes home; but he does not know how to put words together and make songs, nor how to sing a song, nor how to beat a drum and dance for joy. O Mother, human beings have no festivals, and here is this young man come to learn!”

These words awakened Eagle Mother more to life. She told the boy to build a Qargi (festival house). She taught him to make drums and to set words together to make songs and to dance. She instructed him to gather great quantities of meat, invite many people, and host the song-feast. When the young hunter had learned all he needed to know, the eagle took him back to the place they first met.

Upon the boys return home, he told his mother and father about his experiences. They started preparing, just as Eagle Mother had instructed.

“The young man went out over great far ways seeking others to join in the feast, for they lived alone and knew of no others near,” Sagdluaq said. “The young man met others coming in twos, some in dresses made of wolfskin, others in fox skins, or skins of wolverine; all in different dresses. He asked them all to the festival.”

As the celebration began, they ate, gave gifts, traded, sang, danced, and beat the drum that sounded just like the heart of the Eagle Mother. It was a beautiful success.

“[As] the guests went way, it was seen that those guests in the skins of different beasts, were beasts themselves, in human form,” Sagdluaq said. “For the old Eagle Mother had sent them; and so great is the power of festival that even animals can turn into human beings.”

Later as the young man was hunting, he again met the eagle, who escorted him back to the mountaintop where Eagle Mother lives.

“And lo, the old and weakly Eagle Mother was grown young again,” Sagdluaq said. “For when men hold festival, all the old eagles regain their youth; and therefore the eagle is the sacred bird of song and dance and festival.” (Rasmussen, 1932)

The Kivgiq festival is immensely significant in Iñupiat lives. It integrates communities along the North Slope as far east as Barter Island and as south as the Colville River, allowing people to access goods that are not accessible in their region. It also serves as a way to communicate, share vital information, and reinstate kinship among Iñupiat people (Spencer, 1959).

On the North Slope, Kivgiq was sponsored by an umialiq (whaling captain), who had a sufficient hunting season. This umialiq was known as the principal host. He would include other prominent captains of the community, who would also start setting aside meat for the feast; they were considered secondary hosts (Spencer, 1959). Soon, the whole community would become involved. Women would tan hides and sew clothing, seal blubber would be stored in seal pokes to be rendered into oil, kayaks, sleds, and umiaks were built, and choice sled dogs would be chosen (Spencer, 1959). Working together, this community would stockpile food and goods all to be given away or traded to guests during Kivgiq.

The principal host would pick two messengers (Kivgak) to invite the guest villages. The messengers were given staffs with markings and/or objects tied to them, each marking representing a message for a specific guest and requesting gifts to be brought (Spencer, 1959; Ikuta, 2007). If the guests accepted the invitation, they would send back a message specifying what goods they wanted in return (Ikuta, 2007).

“Long ago when Point Hope residents planned to celebrate Kivgiq, they selected two men who are strong and agile” Patrick Attungana from Point Hope recalled. “These men will then go to Kotzebue as messengers, probably with few items of clothing or a bite to eat in their pack-sack. [They do] this just by visualization. These people of long ago were strong.” (Hess, 1994).

The messengers would take great care to remember the message associated with each symbol.

“My father and Egasak were the [messengers],” Peter Shugluk recalled. “I realize here, how much remembering it took to name people’s names, with symbols. It was an endless list of names. Standing beside each other, Egasak and my father presented the staffs to the [guests]. Their esteem showed as they called out names; such a great ability remembering names.” (Hess, 1994)

Trading partners (niuvit) also played a vital role in Kivgiq. This relationship became a partnership, and trading partners often regularly invited each other to Kivgiq (Spencer, 1959; Hess, 1994).

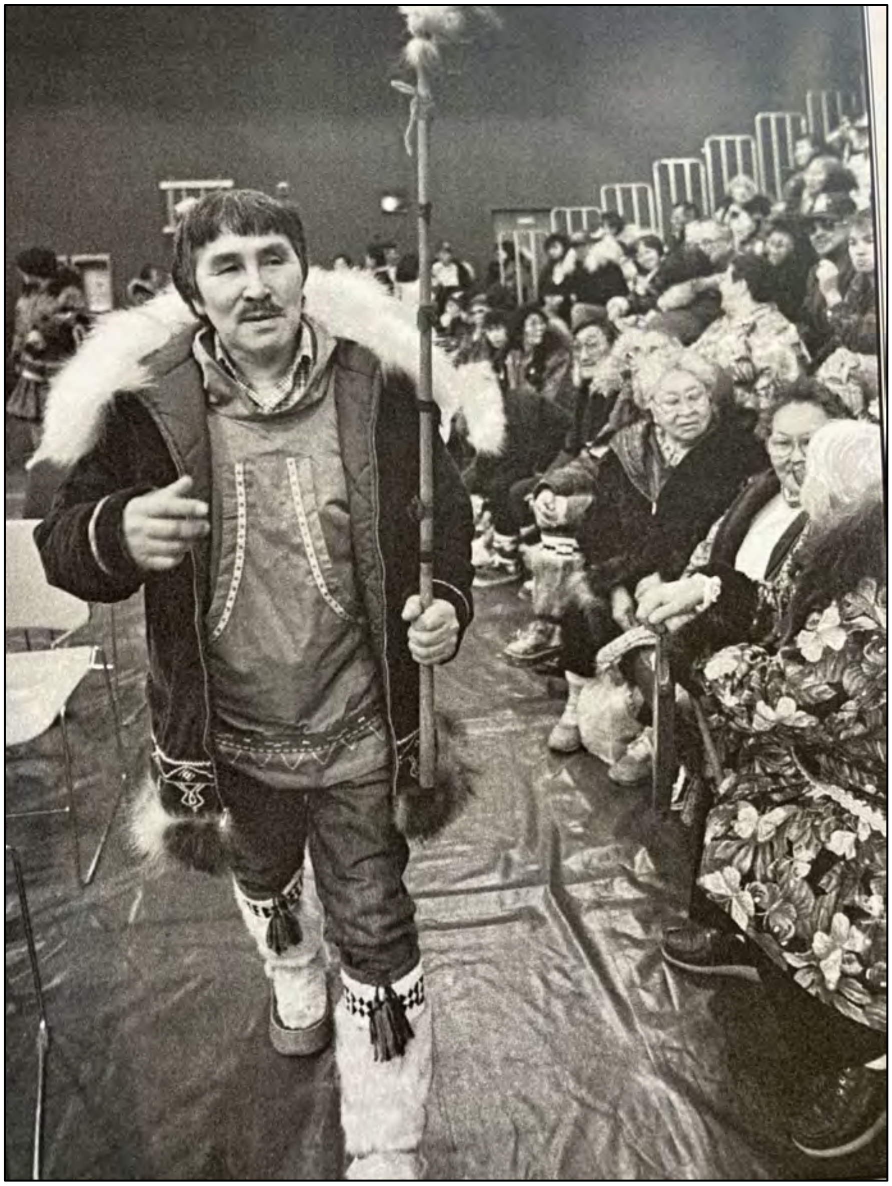

Figure 4.1. Messenger staff (Hess, 1994).

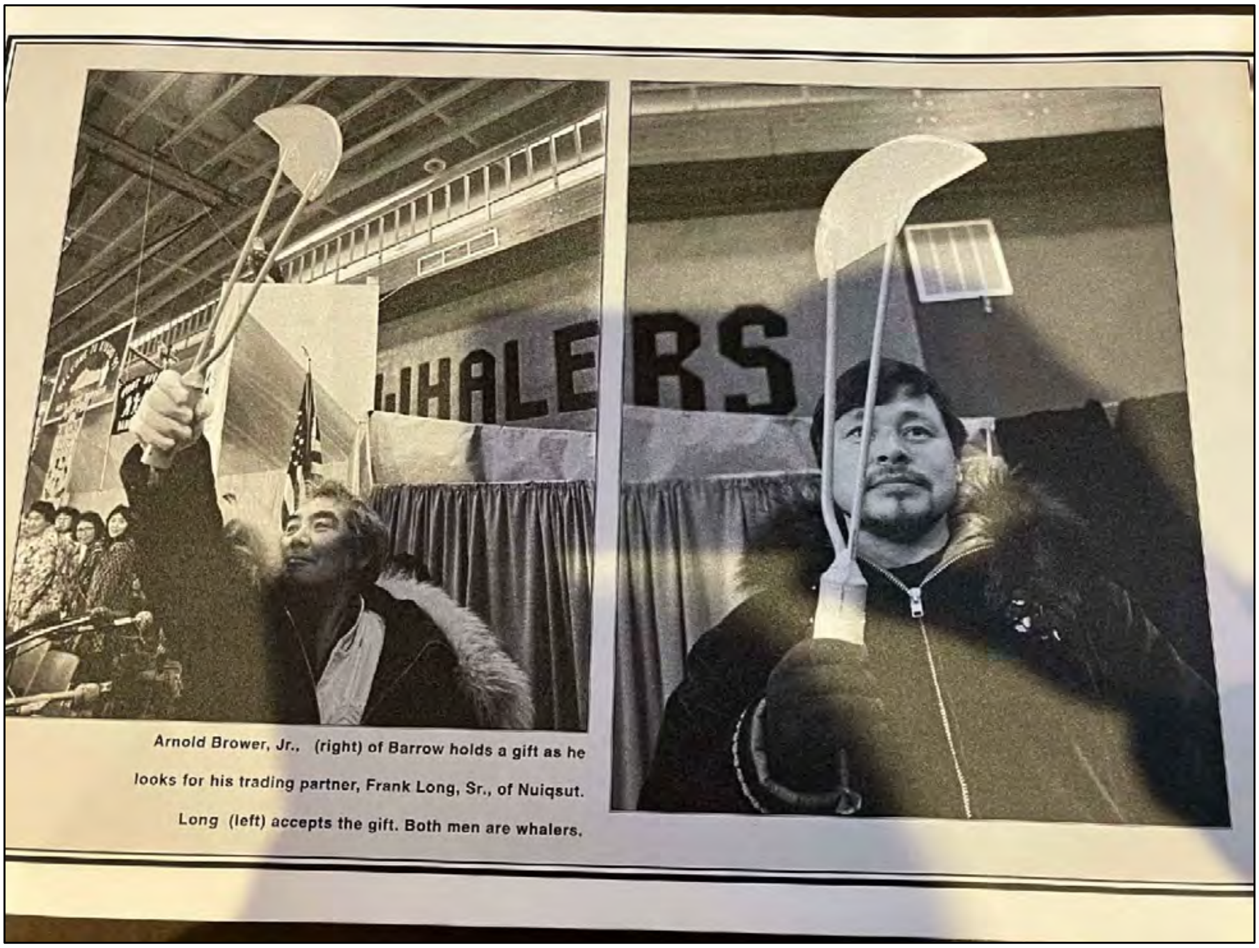

Figure 4.2. "Arnold Brower, Jr. (right) of Utqiaġvik holds a gift as he looks for his trading partner, Frank Long, Sr., of Nuiqsut. Long (left) accepts the gift. Both men are whalers" (Hess, 1994).

"There are always trading partners in each village, which would send out a message stating he would like to have this or that form his trading partner," Waldo Bodfish explained. "For instance would be a whole wolverine skin, or a couple of reindeer hides - enough for a parka."(Hess, 1994)

An important tradition of Kivgiq is the footrace held between the host and guest villages on the first day. The hosts and principal guests would select the fastest runners, Paaktuat (foot racers), in their community ahead of time, giving them time to train (Spencer, 1959). To select the runners, there would be a dance held in the qargi, where young men would rehearse dances that would be held during Kivgiq. The principal host would dance alongside his choice runner, and secondary hosts would then go dance along their choice (Hess 1994; Spencer 1959). The runners would then train for the race. Spencer wrote that daily, they would run out into the tundra to Pivinik, back, or down the beach from Utqiaġvik.

With the runners selected, the food and goods collected, the qargi built, and the village ready to host Kivgiq, it was just awaiting the arrival of their guests.

When the messengers approached the guest village, they would stop just outside of the village and wait to be seen and invited in (Spencer 1959). When all the requested people were gathered, the messengers would present their invitations and requests and often sang associated songs (Spencer 1959). If the guest accepted the invitation, they would request demands of their own. The guests were expected to profit more from this event than the hosts (Spencer 1959; Hess 1994). The invited guests were free to bring families and friends with them.

Guests could demand anything from the principal host, usually rare or costly food. The host, to uphold his own dignity and stature, would do anything in his power to obtain this request, no matter how difficult or expensive.

The guests would then accompany the messengers on the trip back to the host village. This trek would involve camping and sometimes take considerable time; for example, Utqiaġvik and Barter Island are over 300 miles away.

Upon arrival, the guest village would camp outside the host village, sometimes even miles away (Spencer 1959). They would build a snow house to accommodate them all. The foot race would then occur from the guest encampment to the host's qargi. The winning team (host vs. guest) would take "possession" of the qargi. If the guests won, they were free to enter the qargi whenever they chose (Spencer 1959).

After the race was completed, the entire group of guests approached the host village, waiting outside the qargi. The principal and secondary hosts approached them wearing their ceremonial attire, including bearskin mittens, feathered headdresses, and rich parkas of matched skins (Spencer 1959).

As they approached the guests, they had their bows and arrows drawn and looked angry (Spencer 1959). They would then shoot the arrows over the guests' heads.

After this, everyone would gather in the qargi and have their first gift exchange. These were known as token gifts, usually something small of great value, such as choice meats, ammunition, tobacco, or beads (Spencer 1959). The third day held the most dramatic gift-giving. The principal guests were brought into the qargi, where the goods were laid out in front of the box drum: skins, pokes of oil, weapons, sleds, kayaks, and umiaks (Spencer 1959).

After this large display of gifts, the guests and hosts spent the remainder of the time mingling. On the fourth day, a game of kickball occurred, the ball being made with a baleen-filled skin.

Figure 4.3. Baleen Ball (Alaska State Libraries Archives and Museum).

Dance / song / drumming

“Dancing is an experience of trying to translate a story that they are telling you,” Jakie Kunuk said. “Dancing puts those words into motion, into music. Again, you feel that story in the dance.” (Hess, 1994).

The Wolf Dance, also known by some as the box drum dance or the Eagle-Wolf dance, has been an integral part of Kivgiq. Although the messenger feast was more of a social gathering than a religious one (Spencer, 1959), the Wolf dance itself had religious elements (Kingston, 2001).

The dance is largely based on the origin story, meaning it has many interpretations and translations. In Yup'ik and Iñupiat belief systems, humans and animals coexist in a relationship characterized by equality and reciprocity (Kingston, 2001). Animals allow themselves to be killed by hunters only if the hunter and his wife abide by rules and rituals and act morally. The rituals would allow the spirit of the animal to be reborn (Kingston, 2001; Rasmusson, 1927; Spencer, 1959).

Figure 4.4. Wolf Dance (Alaska State Libraries Archives and Museum).

Figure 4.5. The box drum (Kaylukaq) symbolizes the Eagle Mother's heartbeat (Alaska State Libraries Archives and Museum).

In 1911, Utqiaġvik hosted a Kivgiq, inviting the guest village of Icy Cape. In 1913-1914 Utqiaġvik hosted another Kivgiq, and in the winter of 1914-1915, Wainwright hosted a Kivgiq, inviting the people of Utqiaġvik (Hess, 1994). Then it all stopped.

Colonization, environmental impacts, and the start of the Great Depression in 1929 all contributed to Kivgiq's disappearance (Ikuta, 2009).

In 1988, former Mayor George Ahmaogak and his assistant Rex Okakok decided it was time to revive Kivgiq. They noted that Elders often spoke of Kivgiq in Elder conferences (Hess, 1994). In the original days of Kivgiq, there had been no problems with drugs and alcohol. These social problems were brought along with colonialism. So, with the revival of Kivgiq, just like olden times, it would be held in a drug and alcohol-free environment.

Support for the revival grew quickly, including support from the Borough Assembly, ASRC, and the village corporations, which all agreed to help out.

They started asking the following questions: What was Kivgiq? And who could remember? Okakok started interviewing Elders along the North Slope to gather information, much of which the quotes in this paper are sourced. Since over seventy years had passed without a Kivgiq, only a few Elders had memories of past Kivgiqs, and most of them were very young when they experienced it (Hess, 1994).

"The drummers would get ready when the messengers were all in. Several would be doing the messenger dance," Gene Numnik recalled of a Utqiaġvik Kivgiq. "While all this was going on I found myself in someone's lap. I was so tired, as I was little."

Although many of the Elders Okakok spoke with had little memories of Kivgiqs they had attended, they did recall much information their families told them about Kivgiq.

"We decided not to try to host a Kivgiq exactly as it might have been done in the past," Okakok noted. "We would have a celebration in the spirit of Kivgiq, for our own time."

Okakok and Ahmaogak spent about a year planning and revitalizing Kivgiq to fit in with contemporary times while also incorporating and respecting traditions. While traditionally, the host village of Kivgiq would change year to year, it is now permanently held in Utqiaġvik due to the large number of guests invited. The North Slope Borough is the main sponsor of the feast, putting the mayor in charge of the majority of the events.

Traditionally, Kivgiq was held in the winter during the "Holiday Season," usually between December and January (Bruch, 2006). This has also translated to modern-day Kivgiq.

The mayor of Utqiaġvik no longer sends messengers out to invite guests, but the runners reenact the invitation through a short foot race (Hess, 1994). The first revived Kivgiq brought together more than 2,000 Iñupiat people from all over the Arctic, including Greenland, Siberia, Bering Strait, and Canada (Hess, 1994). In the past, where umialiks would sponsor a Kivgiq now over 50 umialiks all share the responsibility of providing food by bringing traditional foods of whale, seal, caribou, walrus, ect to be shared (Hess, 1994).

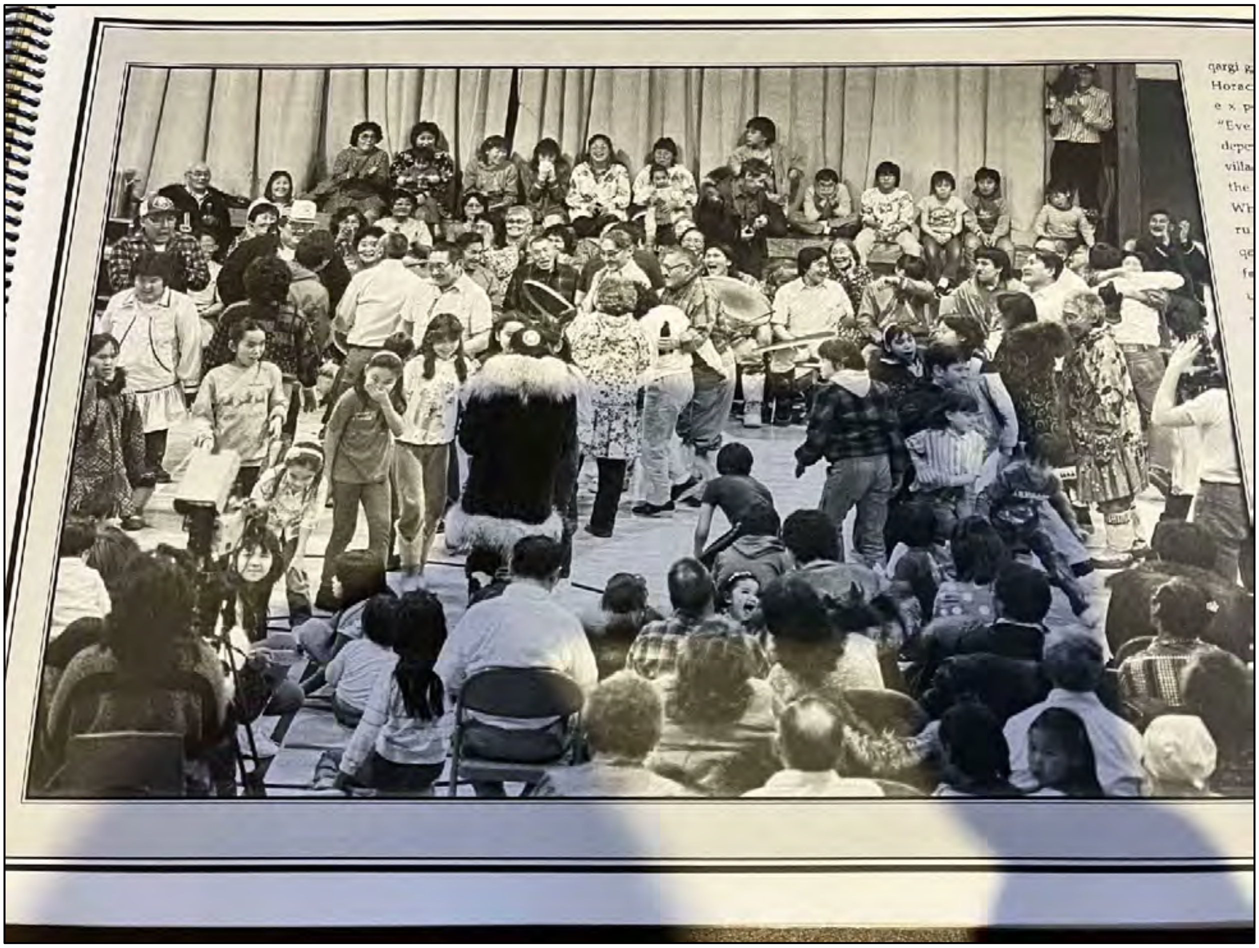

Figure 4.6. Kivgiq- all smiling faces (Hess, 1994).

The most recent Kivgiq was held February 1st-4th, 2023, after a four-year lull since 2019 due to the coronavirus pandemic. Modern-day Kivgiqs are all held with a theme that is intended to strengthen and affirm Iñupiaq culture (Hess, 1994). The 2023 theme was “It is time to speak Iñupiaq Iñupiuraaġnaqsiruq” (NSB). The next scheduled Kivgiq is set to be held in 2025 with the theme being: “IÑULLAAM SAVAAĠIKPAUŊ, NUNAAQQIM SUAŊŊATIGIGAA. Community strength through individual action” (NSB).

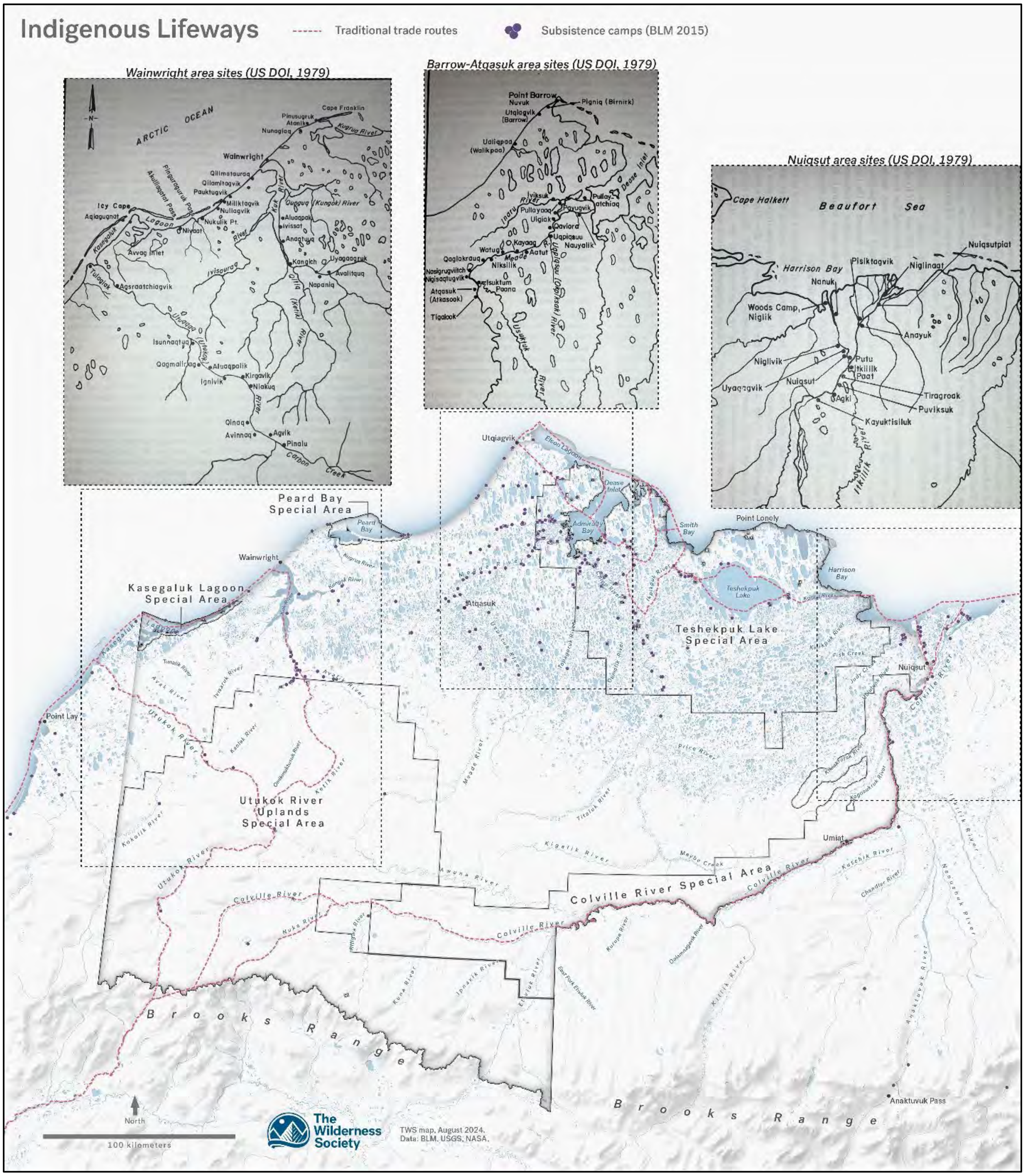

Figure 4.7. Indigenous lifeways, depicting traditional trade routes with historic and recent subsistence camps. Please see Appendix B for a higher resolution version of this figure.

Bowhead Whale / Agvik

Subsistence

The Iñupiat have hunted whales since time immemorial, bowhead whale being the most culturally significant harvest on the north slope (Brower, 2010).

The umiaq is a traditional skin boat used for hunting, traveling, and trading. It is a large open boat made of driftwood and covered in animal skin. It is used with sails, paddles, and today, outboard motors (Alaska State Libraries Archives and Museum). The umiaq is not seen as an object, but rather as a living being viewed as a hunting partner who shares the same fate as its hunter (Robert-Lamblin, 1980; Spencer, 1959).

Preparation for whaling happens throughout the year, with the preparation of the umiaq beginning in the summer. All whale hunting gear was remade or refurbished each year because no whale would approach gear used to kill another whale (Crowell, 2009; Spencer, 1959). Bearded seals, caribou, and sometimes walrus are hunted, and women prepare the seal skin, or walrus hide, to be used to cover the boat's wooden frame (Brower, 2010; Crowell, 2009). To sew the skin or hide onto the frame, women use sinew, a thread-like tool made out of dried and braided caribou tendon (Burch, 2006).

Men prepared for the hunt throughout the year in the qargi (ceremonial house). They built the umiaq frame, harpoons, and tools needed for the hunt.

The umialiq would seek spiritual guidance in preparation for the hunt. There were certain rituals that were followed, such as cleaning out the previous year's whale meat from the cellar to prepare for the new harvest (Crowell, 2009). Umialiq’s often had a whaling charm that was kept in a safe place and brought out for the whale hunt. Once the charm was in the umiaq, the umiaq became a living being (Spencer, 1959).

Whale hunting is a very dangerous activity, making all of the generational knowledge that much more important. Present-day whale hunting follows very similarly to traditional whale hunting.

The crew is composed of 9-10 people (Brower, 2009). Umialiqs paddle out with the crew, usually not using a motor due to the noise. The crew tries to follow the whale from behind and slightly to one side so they will be prepared to harpoon it when it comes up for air (Burch, 2006). The harpoon has a line with drag floats attached to it, usually made of seal skin, so when the harpooned whale dives back down, the drag floats will slow it down and tire it out (Burch, 2006; Crowell, 2009).

All the other boats in the water will come to assist in this whale hunt. The main goal is to attach more harpoons and drag floats to the whale (Burch, 2006). If everything goes well, the whale tires itself out and comes to rest at the surface, allowing the hunters to make cuts to render the whale immobile and tie lines to the tail to tow it into shore (Burch, 2006).

“I came upon a whale near the edge [of the ice] suspended in the clear water. I was in awe,” Iñupiaq Elder Robert Thompson recalled. “I decided to return to the camp and participate in the whaling hunt. Two hours later, I was in the umiat when we caught a whale. We saw it coming and intercepted it. The [whale] slid up on its back then they harpooned it. It was killed instantly and started to sink. There were 9 people in the umiat, 3 people held on to the rope to try to arrest the sinking. The rest of us paddled to the people on the ice. We almost came to the end of our rope. Another boat came to us and gave us their rope. We got to the ice edge where there were many people. We threw the remaining rope to the people and the whale was pulled up. Very exciting!”

As part of tradition, harvested sea mammals were offered a drink of fresh water upon their arrival on land, in the belief that sea creatures craved the fresh water they had never had access to (Crowell, 2009).

Pulling the, on average, 140,000-pound whale out of the water was a difficult task. People from the village gathered to help rig a system to pull the whale out of the water. Inch by inch, they cut meat and blubber as they went, being quick to remove the outer layer of skin and blubber to release body heat to prevent rot (Burch, 2006).

Sharing food is one of the most prominent aspects of Iñupiaq culture. The sharing of the whale is a great example.

In Utqiaġvik, the whale is divided into three sections: niniq (60%), tavsi (10%), and uati (30%) (Brower, 2010). The uati and tavsi are given to the whaling captain and then distributed throughout the community amongst different festivals. The niniq is set aside for the butchering crew to divvy up amongst their own communities and families (Brower, 2010).

Festival - Nalukataq

In June, the greater whaling festival occurs: Nalukataq, also known as Qagruġvik. People from all over the north slope gather to celebrate a successful whaling season, feast, sing, dance, and participate in the traditional blanket toss, Nalukataq, from which the festival gets its name.

Nalukataq is a game where two walrus hides are sewn together in the shape of an oval or circle with holes cut into the perimeter for hand holds. The participant would get on the trampoline-like invention and be thrown seven plus feet into the air, with the goal being to land back on their feet and be thrown again (Burch, 2006). It was not uncommon for this game to result in broken bones (Rasmussen, 1927).

The Umialiqs host Nalukataq, wear their traditional clothing, and hand out whale meat, including tail fluke, mikigaq, fermented whale meat, quaq, and maktak (Burch, 2006).

The Use of Indigenous Knowledge

Sense of hearing

In the 1980’s, umialiqs *(*whaling captains) voiced concerns to the North Slope Borough that the noise from the airguns, used during seismic testing, were affecting the behavior of the Bowhead whales and deterring them, making them more difficult to hunt (NSB TEK, 2022). Scientists, at the time, could not prove that what the umialiqs were saying was true, but the Iñupiat people had to travel much further out into the sea to find whales, which was increasing the danger and difficulty of the hunt (NSB TEK, 2022).

According to a report done on Traditional Knowledge regarding Bowhead Whales in the Chukchi Sea near Wainwright, Alaska, in 1969, there was seismic testing offshore of Wainwright, and not a single whale was seen. The people of Wainwright caught no whales that year and the people of Utqiaġvik provided them with whale meat and Maktak during the winter (Quakenbush and Huntington, 2010). The people of Wainwright were promised reimbursement for the loss of whaling, but the reimbursement never came (Quakenbush and Huntington, 2010).

A research project in 1996 confirmed what the Umialiqs had been saying. Bowhead whales would alter their dive patterns and avoid areas near seismic testing (NSB TEK, 2022). This has led to an abundance of research on the increased levels of industrial noise in the Arctic waters and the effects on Bowheads.

Sense of smell

In a similar example of Indigenous Knowledge, Iñupiat people have believed that Bowhead whales have the ability to smell. Scientists at the time did not believe this as they assumed Bowhead whales were like other whales, such as belugas, who did not have the ability to smell (NSB Sensory, 2022). Iñupiat prohibited burning anything on the ice during a whale hunt because they believe the smoke deters the whales (NSB Sensory, 2022).

In 2008, Dr. Hans Thewissen was in Utqiaġvik continuing research on the Bowhead whale’s ability to hear. To further investigate, Dr. Thewissen cut out a Bowhead’s brain. While doing this, Dr. Thewissen found olfactory bulbs (NSB Sensory, 2022). Olfactory bulbs allow both humans and Bowhead whales to smell (Purves, 1970). This, again, confirmed the Indigenous Knowledge of the Iñupiaq umialiqs.

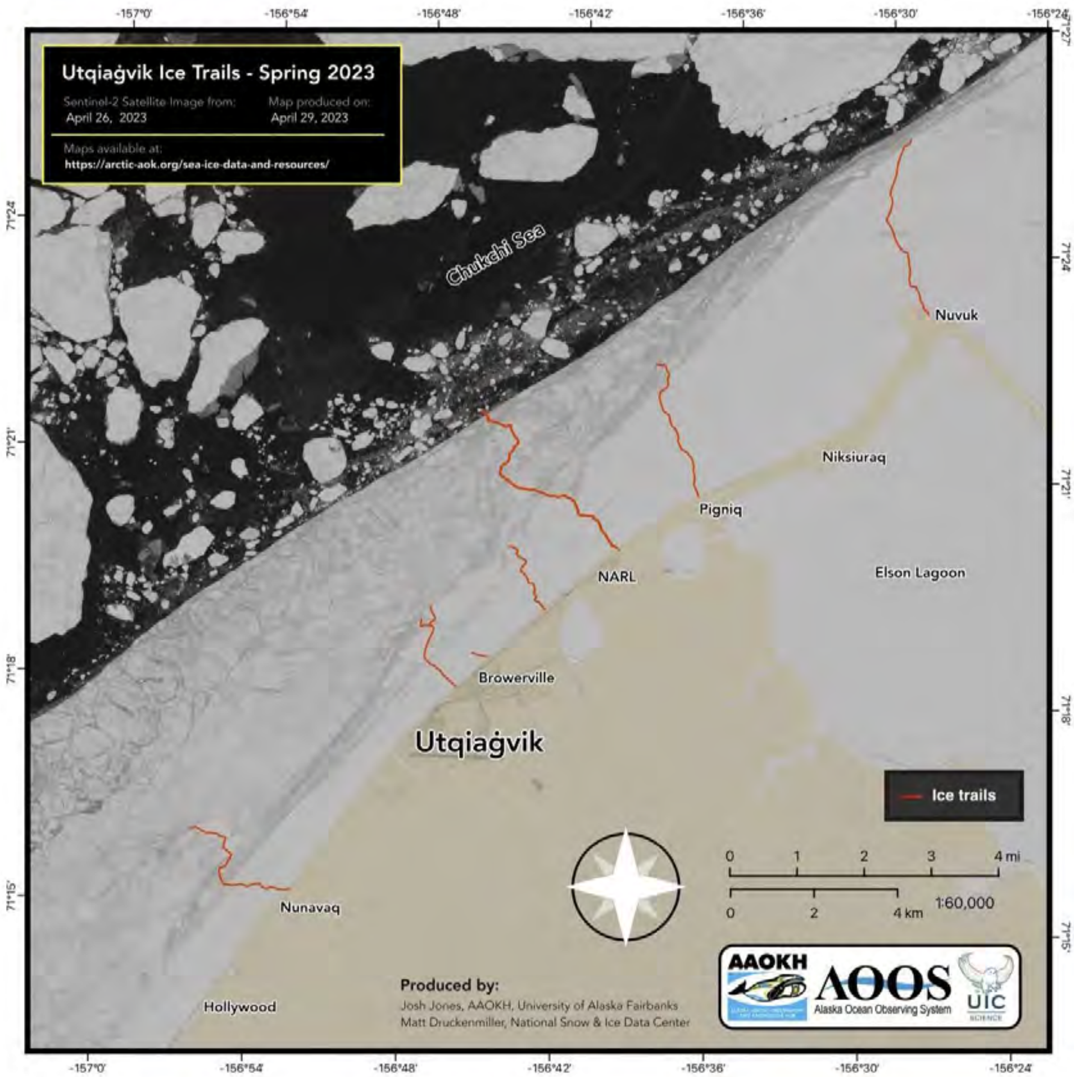

Figure 4.8. Map of the Ice Trails used during Utqiaġvik Whaling, 2023. For the Iñupiaq People the year round and seasonal ice are territorial terrane. Ice has shaped the worldview and culture and is the basis of an entire knowledge set based on Ice.

These ice trails lead to bowhead whale hunting sites. Every year hunters, the whaling community, scientists, and NSB personnel work together to analyze the ice and create trail maps to ensure safety when traveling across the otherwise unpredictable ice (Whaling, 2023). These maps are shared throughout the community.

The people of Wainwright often travel north along the coast to Point Belcher for whaling in the Spring (Whaling). The people of Nuiqsut travel to Cross Island in the fall for whaling (Whaling).

Nannut - Polar Bear

More than 15 years ago, the polar bear was listed as threatened under the Endangered Species Act.

There are 19 different subpopulations of polar bears in the Arctic. Those living within the Reserve are the Southern Beaufort Sea Polar Bear. Iñupiat and polar bears have been living together since time immemorial and are considered the Arctic's top predators. Iñupiat and polar bears are adapting to the devastating effects of the Arctic warming four times faster than the rest of the world, dramatically affecting sea ice, affecting their food, and the distance necessary to travel to reach their food.

"I have seen polar bears do things that demonstrate thinking," Iñupiaq Elder Robert Thompson said. Thompson lives in Kaktovik and has spent his life living and working around polar bears.

A study on Iñupiat Knowledge of Polar Bears highlighted some important data on the Southern Beaufort Polar Bear, a subspecies whose population status is "likely decreasing" (Status).

The study was done by conducting interviews with Iñupiat Elders and hunters in Wainwright, Utqiaġvik, Nuiqsut, and Kaktovik. Out of the four communities, Wainwright and Utqiaġvik rely more on polar bears for subsistence, while Nuiqsut and Kaktovik residents reported a stronger reliance on whale and caribou, and most of the polar bear kills in the community are due to safety reasons. For example, from 2007 to 2016, 161 polar bears were harvested in Wainwright and Utqiaġvik, while less than 20 per village were harvested in Nuiqsut and Kaktovik (Rode, Voorhees, Huntington, Durner, 2021).

Seven out of 10 of the Wainwright participants indicated they have a strong interest in subsistence hunting polar bears, and in Utqiaġvik, 10 of 13 participants had harvested a polar bear in their lives (Rode, Voorhees, Huntington, Durner, 2021).

Polar Bear hunting is often described throughout these interviews as opportunistic, meaning that it is dependent on encountering a polar bear while doing something else rather than targeted hunting (Rode, Voorhees, Huntington, Durner, 2021). Elders are taught to be very humble, especially during polar bear hunting (Voorhees, Sparks, Huntington, Rode, 2014).

Hunters often encounter or locate polar bears by their tracks while they are on the ice seal hunting. Traditionally, polar bears were hunted with bow and arrow. The best time to approach a polar bear is after it has just feasted, but it is unusual to have the choice of when you encounter a bear (Burch, 2006).

Some experienced hunters say that polar bears are left-handed and tell young hunters it is safer to approach from the right side (Voorhees, Sparks, Huntington, Rode, 2014). It can also be dangerous to shoot at a bear who has just emerged from the water, as their frozen fur can create a bulletproof coating around them (Voorhees, Sparks, Huntington, Rode, 2014).

During whale harvest, polar bears do not react to the normal deterrents. A Wainwright interview participant reported that if a polar bear approaches, the whaling captain will usually speak to the bear in Iñupiaq and ask it to leave. If it does not, the captain will often throw firecrackers toward it (Rode, Voorhees, Huntington, Durner, 2021).

The meat of harvested bears is shared among the community, and all pieces of the bear are used. The hunter usually keeps one of the hind legs and disperses the rest of the meat amongst the community (Spencer 1959). The internal organs, besides the liver, which contains hypervitaminosis A, are cooked for a long time and then eaten. The teeth and claws are used for tools and fish hooks, and the skin is made into clothing, mattresses, blankets, and door covers (Burch, 2006). Interview participants in all four communities reported that all pieces of the bear are used, and Elders, in particular, enjoy eating the meat (Rode, Voorhees, Huntington, Durner, 2021).

Elder Robert Thompson shared one experience: He saw, through the fog, a dead polar bear on the horizon being pecked at by seagulls. After a while, about ten bears surrounded it.

“I thought they were eating it,” Thompson said. No. They hung around it for several days. When they left, we went to check it out. They had not eaten it. They had pawed a circle around it like they were having a wake, like old Grand Paw Bear.”

Some Iñupiat hunters report polar bears sensing human emotions, specifically fear, with some hunters reporting that polar bears have the ability to read human thoughts (Voorhees, Sparks, Huntington, Rode, 2014).

“Polar bear hunting is very important,” one of the interview participants from Kaktovik said. “It’s one of our nourishments, that makes us Iñupiat. When we’re eating Western foods, we stay hungry; when we eat Eskimo foods, we stay full.”

The biggest threat to the polar bear is the decline of their sea ice habitat. Polar Bears spend 50% of their time hunting on the ice, and with climate change impacting the movement, thickness and consistency of the sea ice, polar bears are feeling the effects within their denning, food and interactions with humans. (Polar Bear, WWF).

Hunters first noticed changes in the sea ice in the 1970s, but they have observed the most change since the 1990s (Voorhees, Sparks, Huntington, Rode, 2014).

Out of the 47 people interviewed in the four Arctic communities, 46 people commented on the changes in sea ice conditions, including thinner ice, earlier retreat, later return, younger ice, slushier ice, weaker ice, lack of summer ice, less ice, and warmer ocean temperatures (Rode, Voorhees, Huntington, Durner, 2021).

“Their hunting grounds are dwindling down; I think that’s why they come to the land,” said an interviewee from Wainwright. “I usually don’t see them inland when I’m hunting caribou. [But one time in July a couple years ago] I was hunting caribou and thought, what the heck is a [polar] bear doing [out] there?”

In January 2019, a polar bear encounter occurred in Arctic Village, resulting in the death of the bear that was attempting to break into a resident’s home (Koenig, 2019). This polar bear was over 100 miles out of its normal range.

Thompson also reports a polar bear who came out of the ocean and lay down in the middle of Kaktovik to rest. He stayed there for about a month, resting and occasionally eating, and Kaktovik residents referred to him as “Old Skinny.”

A prominent observation made by Iñupiat hunters regards “blue icebergs” (Voorhees, Sparks, Huntington, Rode, 2014). Hunters report that these blue icebergs used to float from the north in the fall and bring polar bears and other animals along with them. In recent years, the blue icebergs have failed to arrive, and hunters attribute the late arrival of polar bears to it (Voorhees, Sparks, Huntington, Rode, 2014).

“The great respect that people hold for polar bears grows in part out of the species’ ability to find clever ways of adapting and surviving amidst very difficult conditions. It is this respect for polar bears that leaves hunters with a degree of optimism about the polar bears’ future.” (Voorhees, Sparks, Huntington, Rode, 2014).

Caribou

Caribou are the single most important terrestrial animal to Iñupiaq subsistence users (U.S. DOI, 1979). In 2019, 98% of people in Nuiqsut participated in caribou hunting activities (U.S. DOI, 2023).

Three different herds utilize the Reserve: the Western Arctic Caribou Herd, the Teshekpuk Lake Caribou Herd, and the Central Arctic Caribou Herd.

The Gwich’in people, who live east of the NPR-A in the Arctic National Wildlife Refuge and rely on the neighboring Porcupine Caribou Herd, believe that there is a piece of caribou heart in every Gwich’in and a piece of Gwich’in heart in every caribou. What happens to the caribou, in turn, happens to those who depend on it.

One of the most proficient techniques was known as the drive fence (Burch, 2006). Hunters would pick a specific spot that was directly on the caribou migration route to build the drive fence (Rasmussen, 1927). The drive fence was constructed with iñuksuit, either rock stacks (cairns) or bundles of shrubs often wrapped in caribou skin. Iñupiat would erect hundreds of iñuksuit in two rows, sometimes miles long, creating a V-shaped isle (Burch, 2006; Rasmussen, 1927). Hunters would then find caribou and stalk them into the opening of the V, and once they were in the V, hunters would shout and run at the caribou, corralling them towards the end of the V where there was either a trap, a lake, or other hunters waited with bow and arrows or spears (Burch, 2006; Rasmussen 1927; Alaska, 1986).

During spring hunts, when the snow still covered the tundra, "pitfall" traps were used (Alaska, 1986). Pitfall traps were dug into the snowbank and covered with a light layer of snow or brush (Burch, 2006). Often, hunters would line the bottom of the pitfall with erected sharp caribou antlers or sharpened bones to kill the caribou upon its fall (Burch, 2006). They would lay bait across the top of the pitfall traps, often lichen and sometimes human urine (Alaska, 1986; Burch, 2006).

With the use of firearms, hunting techniques have changed, as it is no longer necessary to get in such proximity as was needed for bow and arrow, spear, or snare hunting.

When the herds of caribou started arriving, Iñupiaq Elders taught that the first group of caribou should pass and not interrupt the migration (Gray, 2015). It is believed that the first caribou are the scouts, and if it is not safe, the rest of the herd will know and choose an alternate route (Gray, 2015). The significance of these caribou goes beyond their role as scouts; they also serve as leaders who are intimately familiar with historical migration routes. When these key individuals are removed from the herd due to hunting, it can result in disarray and fundamental changes to established migration patterns. These leaders, often larger male bulls, play a critical role in the survival of the herd. For instance, they protect the female cows and younger caribou from predators, and during adverse conditions such as ice on snow events, these robust bulls can break through the ice layers to access food, thereby creating breakthrough points that facilitate feeding for the rest of the herd.

All parts of the caribou and valued. Caribou meat for nutrition; hide for clothing, bedding, and sleeping bags; sinew for thread; antlers and bones for tools; bows and weapons; and tallow for medicine, cooking, or lamp light (U.S DOI 1979; Kuhnlein, H. V., & Humphries).

"Our Elders told us not to waste. Not to throw anything out," said Minnie Gray, a Kobuk River Elder, when sharing her knowledge on caribou.

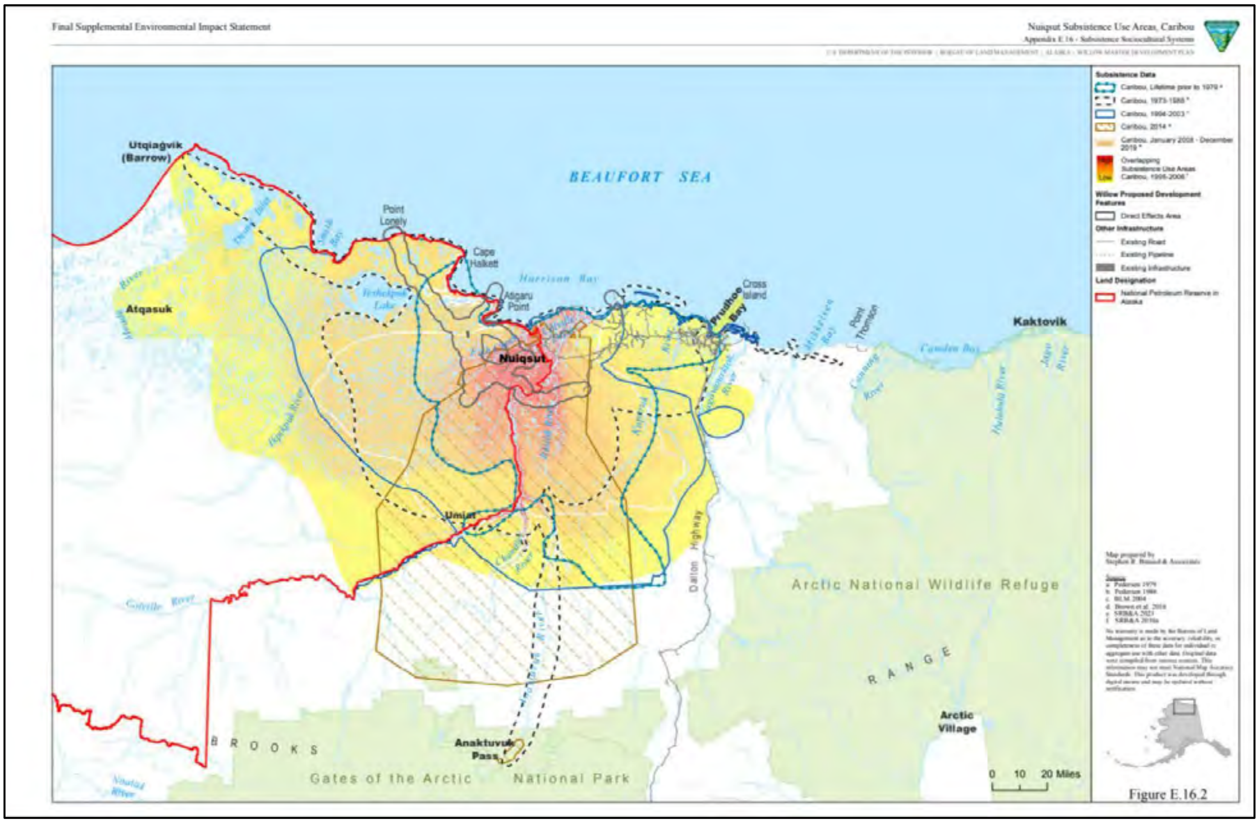

Figure 4.9. This subsistence use area map shows the areas in which the people of Nuiqsut hunt caribou. The brown line indicates the use areas in recent years, bordering Fish Creek and heading south past the Colville River, including Anaktuvuk Pass and back north to the Colville Delta (U.S. DOI, 2023).

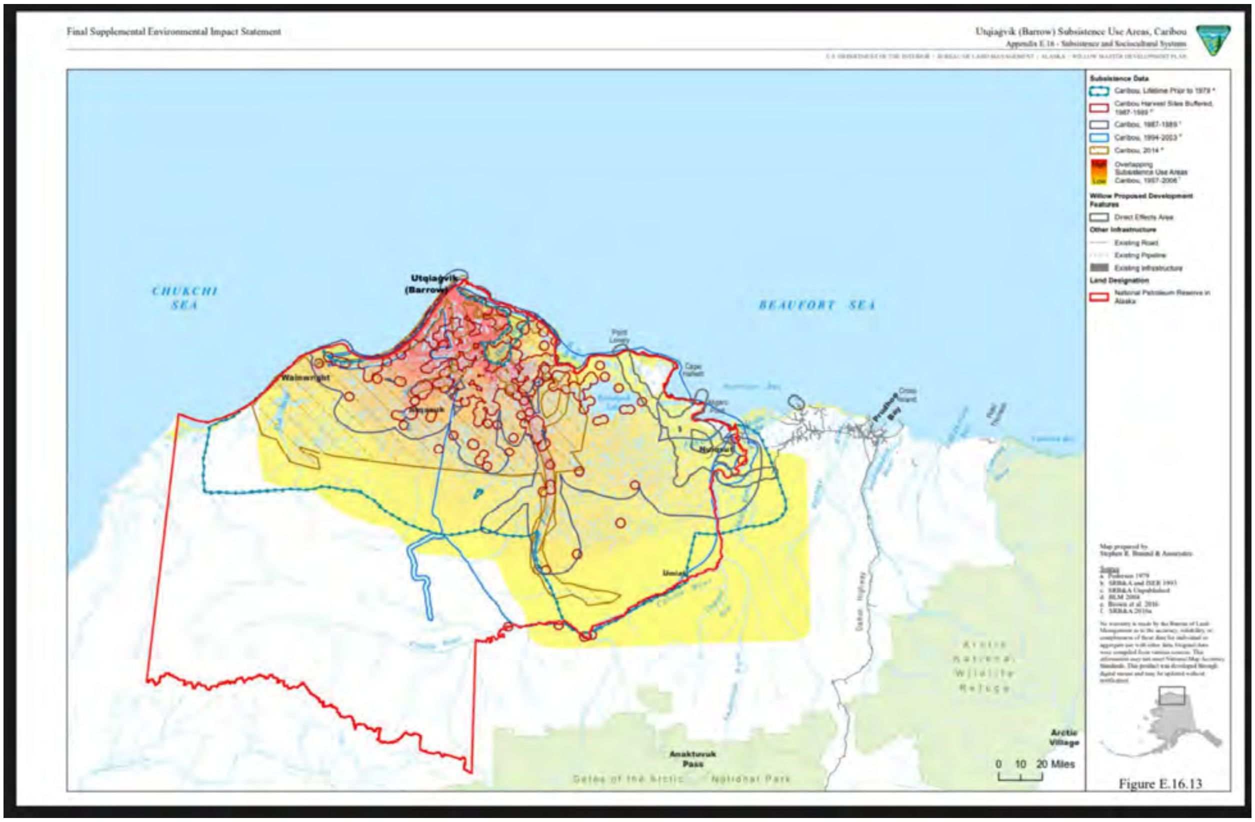

Figure 4.10. Utqiaġvik's caribou subsistence use area spans a very wide range (U.S. DOI, 2023).

The Effects of Climate Change and Industrial Development on the Reserve

The Arctic is warming four times faster than the rest of the planet, with noticeable effects since 1979 (Rantanen, 2022). This makes the Arctic, and those who live there, the frontline communities who are facing the brutal impacts of climate change at an expedited rate.

The Arctic sees the effects of pollution from both on-the-ground oil and gas extraction and from global distillation (Miller, 2023). Global distillation is the process where pollutants, such as mercury or persistent organic pollutants (POPs), are evaporated from a warm environment and transported with the wind, oceanic current, or rivers to a cooler environment (Riǵet, 2010). POPs have the ability to travel far distances due to their long-life span (Riǵet, 2010).

Although much of the NPR-A is still considered an intact ecosystem, the Arctic's greatest threat comes from places quite distant from it (Miller, 2023).

These transported pollutants bio-accumulate throughout the Arctic food web, including fish, polar bears, caribou, whales, and seals (ACACAP, 2020; Miller, 2023) POPs are lipophilic and bio-accumulate in fatty tissues of animals and humans (Schæbel, Bonefeld-Jørgensen, Vestergaard, & Andersen, 2017). As Iñupiaq people rely heavily on animal fat in their traditional diet, this has a direct impact on them (Miller, Karlsson, Medina, Waghiyi, 2024; Schæbel, Bonefeld-Jørgensen, Vestergaard, & Andersen, 2017).

High concentrations of POPs are reported amongst many Inuit Arctic communities; adverse effects of POPs in humans include immune system disruption and cardiovascular disease (Schæbel, Bonefeld-Jørgensen, Vestergaard, & Andersen, 2017).

A study done in St. Lawrence Island found that the Yupik people who live there have between 4-10 times higher concentrations of PCBs in their blood than the average person in the lower 48 (Carpenter et al. 2005; Miller, Karlsson, Medina, Waghiyi, 2024).

PCBs are a man-made chemical that was banned due to their adverse side effects in 1979. PCBs, among many other negative health effects, are known to cause cancer (EPA, Polychlorinated Biphenyls).

“We are overwhelmed with concern about the health harms associated with climate change, the loss of sea ice and melting permafrost, and the mobilization of chemicals and plastics—these are all interconnected,” Delbert Pungowiyi, Yupik Elder and Arctic Indigenous Leader, said. “We are running out of time!”

The Iñupiat village of Nuiqsut is located between the Colville Special Area and the Teshekpuk Lake Special Area. There are around 500 residents who live in Nuiqsut (Bureau, 2020). Nuiqsut means “something beautiful over the horizon” (Harball, 2019).

Nuiqsut was first surrounded by oil operations in 2000, and over the next decade, there was an abrupt spike in children’s leukemia and asthma, which was reported to Alaska Community Action on Toxins (ACAT) in 2012 (Stepanyan, 2019). Due to a lack of research on the effects of oil and gas, not just on the environment, but also on human health, ACAT set out to conduct its own research.

In the North Slope Borough, from 2008 to 2014, the leading pollutant was Nitrogen Oxide, emitting over 200,000,000 pounds into the atmosphere (Stepanyan, 2019). Nitrogen Oxide has very negative effects on humans, such as asthma, reduced pulmonary function, risk of stroke, lower logical memory, chronic cough, and more (Stepanyan, 2019).

The entire list of pollutants being emitted on the North Slope is quite long, including Sulfur Dioxide, PM10, PM2.5, Formaldehyde, Toluene, Xylenes, Acetaldehyde, Ethyl Benzene, Benzene, Phenol, and Hexane (Stepanyan, 2019). PM2.5 describes fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller

(EPA, 2023). Nuiqsut continues to be the frontline community for how these chemicals affect humans.

“What if there was an oil spill? The Alpine that is opening now, they made their ice road right on top of where they fish a lot. I have had my net there for many years,” a concerned Nuiqsut resident voiced to Heartbeat Alaska news station in 1996. “It scares me that it's never been done anywhere in the Arctic, and this would be the first, that’s scary.”

Black carbon (PM2.5,) is a result of flaring (NASA). Black carbon warms the atmosphere as it is extremely good at absorbing light, and therefore expeditiously warms its surrounding environment, and in the Arctic specifically, black carbon expedites the melting of snow. Not only is black carbon a threat to climate, but it also has extremely adverse effects on human health, including heart and lung disease, strokes, heart attacks, chronic respiratory diseases such as bronchitis, aggravated asthma, and other cardio-respiratory symptoms (Black Carbon, n.d.).

Approximately 4 million deaths are associated with air pollution made of PM2.5 particulate size a year (Black Carbon, n.d.).

Satellite mapping has shown recent images of natural gas flaring plumes across the north slope (Bachmeier, 2022). The images were of the North Slope on 02/08/2022, and the temperature was around -50°F that day. The infrared image indicates the gas flaring point source infrared brightness temperatures as warm as +70°F (Bachmeier, 2022). While the state of Alaska has “strictly limited” oil and gas flaring since the 1970s, loopholes have been created, such as special permits that allow long-term uses of flaring.

The presence of black carbon (PM2.5), is associated with emissions from flaring, poses significant threats not only to climate, but also to traditional plant material and berry-picking practices within Indigenous communities. As black carbon absorbs light efficiently, it leads to accelerated warming of the Arctic atmosphere, resulting in the rapid melting of snow and altering seasonal patterns essential for plant growth. This disruption can adversely affect the timing and availability of traditional plants and berries, which are critical for cultural practices and subsistence. Additionally, black carbon (PM2.5) has severe implications for human health, linking to various diseases such as heart and lung conditions, which can further diminish the capacity of communities to engage in traditional harvesting practices. While Alaska has implemented limitations on flaring, the existence of loopholes for special permits continues to pose risks to both the environment and community health, threatening the interconnectedness of Indigenous traditions and sustainable practices.

Industrial development also poses a risk to traditional gathering of plants as food and medicine due to dust from dirt or gravel roads and presents significant health risks to humans, animals, and the pants themselves, particularly regarding edible berries and other vegetation. This dust often harbors contaminants such as heavy metals such as lead, platinum-group elements (platinum, rhodium, and bohrium), aluminum, zinc, vanadium, and polycyclic aromatic hydrocarbons, along with pesticides, and pathogens, which can settle on the surfaces of plants (Kahn, 2018.) When these harmful substances are absorbed or come into contact with the fruits and leaves, they can compromise the safety and quality of the produce. Dust accumulation can obstruct photosynthesis by covering plant surfaces, reducing their growth and vitality. The consumption of contaminated berries and plants poses health risks for humans and animals, potentially leading to gastrointestinal issues and exposure to toxic chemicals. Monitoring and managing dust exposure is essential to safeguard the health of both plants and those who rely on them for sustenance.

Despite these sometimes-deadly health impacts, Nuiqsut has continued to be surrounded by a growing number of oil wells and proposed new drilling sites, such as the Willow Project, just 35 miles away from town.

In an interview with Alaska Public Media in 2019, tribal government administrator Martha Itta spoke on the oil industry's effects on the basic needs of the village, from the subsistence hunting of animals to the air they breathe (Harball, 2019).

“We are having to travel farther away to hunt for our animals. To even be able to see the animals,” Itta said in the published interview. “We do not get free oil and gas like people think we do. We pay $5-a-gallon for our gas. Gas that’s coming right underneath us. Coming from right underneath our feet. Taking out all our resources. Changing our way of life.”

A caribou land use study found that female caribou reduce their habitat use near infrastructure, especially during calving season along the coastal range (Johnson, Golden, Adams, Gustine, & Lenart (2020).

Climate change has negative effects on Indigenous Knowledge. The knowledge passed down from generations holds all the vital information on how to survive in the harsh Arctic environment. From animal migration patterns, long-used fishing sites, and methods of hunting whales to traditional beliefs and celebrations, food storage, and so much more, some of this knowledge is becoming less reliable due to the fast-paced effects of climate change on the Arctic environment (Otokiak, 2023).

Indigenous people have adapted to the environment since time immemorial (Glenn, 2023). Alaska Arctic Observatory Knowledge Hub, or AAOKH, is an observation platform for sharing Indigenous observations from the Arctic coastal communities. They do this by supporting and working with observers in five different communities: Kotzebue, Point Hope, Wainwright, Utqiaġvik, and Kaktovik.

Community-based monitoring is embedded in the Iñupiat way of life, as Iñupiat have been living, monitoring, and observing their environment since time immemorial. In recent years, community-based monitoring has been integrated into Western science to observe climate change in rural villages (Glenn, 2023).

Roberta Glenn, from Utqiaġvik, conducted her master's thesis on creating an interactive story map of the key and consistent takeaways from the 2,000-plus observations made through AAOKH.

Warmer temperatures were one of the most noted observations, particularly in 2019 (Genn, 2023).

"It has rained so much that the roads are falling apart, and we may have broken a temperature record," Billy Adams, an observer in Utqiaġvik, noted on 10/1/2019. "Everyone is waiting for snow. People are still camping inland by boat when we should be on our snow machines by last week. It's rainwater from on top that is eroding the road on this bridge."

Another consistent observation was in changes in the wind (Glenn, 2023). The change in winds affects both travel on the land and sea. The winds transporting snow leave the tundra bare and difficult to travel on.

"No new snow. The constant wind has blown the tundra clear of snow," Bobby Shaeffer, an observer from Kotzebue, noted on 1/29/2020. "There are a lot of snow drifts on the ice with glare ice between them. Makes for rough riding on our trails. Aarg! Need a storm with snow to straighten out the trails and to make riding on the tundra bearable."

The winds affect the formation of sea ice, making the ice rougher and more dangerous to travel on (Glenn, 2023).

"The ice conditions look low and rough as this is not great for hunting. We call it "siqummitngaruq" meaning it is broken up in many places which poses danger," Adams observed on 12/13/2020 in Utqiaġvik. "Currents and tides can also break this type of ice condition even when there is no wind."

These impacts of climate change directly impact the Iñupiat peoples, way of life, food security, and health and violate the rights of Indigenous people.

Future

“The Bureau of Land Management's mission is to sustain the health, diversity, and productivity of public lands for the use and enjoyment of present and future generations.” (BLM)

The National Petroleum Reserve of Alaska, or as Thompson would like to call it, Iñupiat Homelands, is one of the world’s most diverse, delicate, and pristine areas. Its health is vital to our collective future.

“We really have to take a good hard look at what kind of future you want for the people who come after us,” Hykes-Steere said. “You have to imagine the future with hope and joy. That's the thing about our culture, is everything you make has to be made as beautifully as you could make it at that point in time.”

“That's something all of us are supposed to do; we are supposed to do the best we can in the moment we are in. A lot of humanity has forgotten that, and our earth is paying for that,” Hykes-Steere said. “The waters are changing, and there are plastics in everything, but there is still hope. I really think that's important for people to understand.”

Indigenous Science and Lifeways literature cited

96th Congress. (1980, December 2). *Alaska National Interest Land Conservation Act*. Public Law 96-487. Available from: https://dnr.alaska.gov/commis/opmp/anilca/pdf/PublicLaw-96-487.pdf.

Alaska Department of Fish and Game/Habitat Division, 1986, Alaska Habitat Management Guide, Arctic Region, Vol.II; Distribution, Abundance and Human Use of Fish and Wildlife, Juneau, Alaska. Available from: https://www.arlis.org/docs/vol1/C/AHMG/17297209v2.pdf.

“Alaska Native Language Center.” *Alaska Native Language Center | Alaska Native Languages | Alaska Native Language Center*, www.uaf.edu/anlc/. Accessed 9 May 2024.

Alaska State Libraries Archives and Museum. Native Alaska, Time Immemorial - Present. Juneau, AK.

Arctic Council’s Arctic Contaminants Action Program (ACACAP). (2020, October 23). *Mercury and Toxins Cocktails Affect the Arctic Ecosystems, Wildlife and Human Health - How to Take Action*. The Arctic Council. https://arctic-council.org/

Bachmeier, S. • 8 F. (2022, February 8). Natural gas flaring cloud plumes across the north slope of Alaska. CIMSS Satellite Blog. https://cimss.ssec.wisc.edu/satellite-blog/archives/44587

Black Carbon. Climate & Clean Air Coalition. (n.d.). https://www.ccacoalition.org/short-lived-climate-pollutants/black-carbon

Brower Jr., H. (2010, March 26). *Subsistence Hunting Activities and the Iñupiat Eskimo*. Cultural Survival. https://www.culturalsurvival.org/publications/cultural-survival-quarterly/subsistence-hunting-activities-and-inupiat-eskimo.

Brower, T Sr. (Paniattaaq), Ahgeak, K. I., Arundale, W., Pederson, S., Libbey, D., & Schneider, W. (1983). Chipp-Ikpikpuk and Meade Rivers . *Project Jukebox*. Other. Available from: https://jukebox.uaf.edu/chipp.

Burch, E. S. (2006). *Social Life in Northwest Alaska: the Structure of Inupiaq Eskimo Nations*. University of Alaska Press. Available from: https://www.amazon.com/Social-Life-Northwest-Alaska-Structure/dp/1889963925.

Bureau, U. S. C. (2020). *Nuiqsut, Alaska*. United States Census Bureau. https://data.census.gov/profile/Nuiqsut_city,_Alaska?g=160XX00US0256320

Carpenter, D. O., DeCaprio, A. P., O'Hehir, D., Akhtar, F., Johnson, G., Scrudato, R. J., Apatiki, L., Kava, J., Gologergen, J., Miller, P. K., & Eckstein, L. (2005). Polychlorinated biphenyls in serum of the Siberian Yupik people from St. Lawrence Island, Alaska. *International Journal of Circumpolar Health*, *64*(4), 322–335. https://doi.org/10.3402/ijch.v64i4.18010

Crowell, A. L. (2009). The Art of Iñupiaq Whaling: Elders' Interpretations of International Polar Year Ethnological Collections. *Smithsonian at the Poles : Contributions to International Polar Year Science*, 99–113. https://doi.org/10.5479/si.097884601x.0.

Edwardsen, C Sr. (Aaluk), Ahgeak, K. I., Arundale, W., Pederson, S., Libbey, D., & Schneider, W. (1982). Chipp-Ikpikpuk and Meade Rivers. *Project Jukebox*. Other. Available from: https://jukebox.uaf.edu/chipp.

Edwardsen, M. (Amayun), Ahgeak, K. I., Arundale, W., Pederson, S., Libbey, D., & Schneider, W. (1983, January). Chipp-Ikpikpuk and Meade Rivers. *Project Jukebox*. Other. Available from: https://jukebox.uaf.edu/chipp.

Environmental Protection Agency. (2023). *Learn about Polychlorinated Biphenyls*. Environmental Protection Agency.https://www.epa.gov/air-trends/particulate-matter-pm25-trends

Glenn, R. (2023). *Insights from Coastal Arctic Indigenous Observers* (thesis). Available from: https://arctic-aok.org/wp-content/uploads/2022/05/AAOKH_Storymap_Transcript_2022-05-03-1245.pdf.

Gray, M. (2015, Summer). *New caribou hunting rules in effect - Listening to our Elders*. Caribou Trails. https://westernarcticcaribou.net/wp-content/uploads/2016/09/caribou-trails-2015.pdf

Harball, E. (2019, May 8). *How a small Arctic village found itself in the middle of Alaska's new oil boom*. Alaska Public Media. https://alaskapublic.org/

Hayes, E. (2018, March 10). *What Shall We Do With Our Heroes?* Alaska Historical Society. https://alaskahistoricalsociety.org/about-ahs/special-projects/150treaty/150th-resource-library/new-articles/what-shall-we-do-with-our-heroes/

Hess, Bill. *A Photographic Celebration of Kivgiq, the Messenger Feast*. North Slope Borough, 1994.

Ikuta, Hiroko. “Iñupiaq Pride: Kivgiq (Messenger Feast) on the Alaskan North Slope – Études/Inuit/Studies.” *Érudit*, Association Inuksiutiit Katimajiit Inc., 20 Jan. 2009, www.erudit.org/en/journals/etudinuit/2007-v31-n1-2-etudinuit2570/019736ar/abstract/.

Indigenous Knowledge. Inuit Circumpolar Council Canada | United Voice of the Arctic. (n.d.). https://www.inuitcircumpolar.com/icc-activities/environment-sustainable-development/indigenous-knowledge/#:~:text=Indigenous%20knowledge%20is%20a%20systematic,multigenerational%20observations%2C%20lessons%20and%20skills.

Johnson, H. E., Golden, T. S., Adams, L. G., Gustine, D. D., & Lenart, E. A. (2020). Caribou use of habitat near energy development in Arctic Alaska. *The Journal of Wildlife Management*, *84*(3), 401–412. https://doi.org/10.1002/jwmg.21809

Khan, R. K., & Strand, M. A. (2018). Road dust and its effect on human health: a literature review. *Epidemiology and health*, *40*, e2018013. https://doi.org/10.4178/epih.e2018013.

Kingston, D. M., Mayac, E. A., & Koyuk, L. T. (2001). The Story of the King Island Wolf Dance, Then and Now. *Western Folklore*,*60*(4), 263–278. Available from: https://www.jstor.org/stable/1500408.

“Kivgiq 2023 Mayor’s Office Official.” *YouTube*, YouTube, 1 Feb. 2023, www.youtube.com/@Kivgiq2023.

Koenig, R. (2019, January 15). *Polar Bear Encounter reported in Arctic village, many miles south of normal range*. Alaska Public Media. https://alaskapublic.org/2019/01/15/polar-bear-encounter-reported-in-arctic-village-many-miles-south-of-normal-range/

Kuhnlein, H. V., & Humphries, M. M. (n.d.). *Traditional Animal Foods of Indigenous Peoples of Northern North America*. Caribou | Traditional Animal Foods of Indigenous Peoples of Northern North America - Animals - Mammals - Hoofed Mammals. http://traditionalanimalfoods.org/mammals/hoofed/page.aspx

Leavitt, A. (Qapqan), Ahgeak, K. I., Arundale, W., Pederson, S., Libbey, D., & Schneider, W. (1983). Chipp-Ikpikpuk and Meade Rivers . *Project Jukebox*. Other. Available from: https://jukebox.uaf.edu/chipp.

Miller, P. (2023, January 2). *Protecting the health of future generations in the arctic through community-based participatory research and action*. Alaska Community Action on Toxins. https://www.akaction.org/

Miller, P., Karlsson, T., Medina, S. S., & Waghiyi, V. (2024, April). *(PDF) the Arctic’s plastic crisis: Toxic threats to health, human rights, and indigenous lands from the petrochemical industry*. Alaska Community Action on Toxins. https://www.researchgate.net/publication/379864260_The_Arctic%27s_Plastic_Crisis_Toxic_Threats_to_Health_Human_Rights_and_Indigenous_Lands_From_the_Petrochemical_Industry

NASA Science Editorial Team. (n.d.). Scientists scrutinize Arctic gas flaring pollution - NASA science. NASA. https://climate.nasa.gov/news/2437/scientists-scrutinize-arctic-gas-flaring-pollution/.

North Slope Borough. (2022, April 6). *TEK & Sense of Hearing and Smelling in Bowhead Whales*. The Official Website of the North Slope Borough. Available from: https://www.north-slope.org/departments/wildlife-management/studies-research-projects/bowhead-whales/traditional-ecological-knowledge-of-bowhead-whales/tek-sense-of-hearing-and-smelling-in-bowhead-whales/.

North Slope Borough. (2022, March 31). *Sensory research*. The Official Website of the North Slope Borough. Available from: https://www.north-slope.org/departments/wildlife-management/studies-research-projects/bowhead-whales/bowhead-whale-anatomy-physiology-studies/sensory-research/.

Nusunginya, F. (Kimmialuk), Ahgeak, K. I., Arundale, W., Pederson, S., Libbey, D., & Schneider, W. (1982). Chipp-Ikpikpuk and Meade Rivers . *Project Jukebox*. Other. Available from: https://jukebox.uaf.edu/chipp.

Observers of coastal Arctic Alaska. 2022. Local Observations from the Seasonal Ice Zone Observing Network (SIZONet) and Alaska Arctic Observatory and Knowledge Hub (AAOKH), Version 2. Edited by AAOKH Team. Boulder, Colorado USA: National Snow and Ice Data Center. https://doi.org/10.7265/jhws-b380.

Otokiak, M. (2023, March 23). *Indigenous knowledge in a Melting Arctic*. Arctic Circle. https://www.youtube.com/watch?v=WveTT4eSQYc

Petersen, V. (2022, August 3). *Alaska's Willow Project promises huge amounts of oil - and huge environmental impacts*. High Country News. https://www.hcn.org/

Polar Bear. World Wildlife Fund. (n.d.). https://www.worldwildlife.org/species/polar-bear

Purves, D. (1970, January 1). *The Olfactory Bulb*. Neuroscience. 2nd edition. https://www.ncbi.nlm.nih.gov/books/NBK11158/.

Quakenbush, L. T., & Huntington, H. P. (2010). (rep.). *Traditional Knowledge Regarding Bowhead Whales in the Chukchi Sea near Wainwright, Alaska*. Available from: https://www.boem.gov/newsroom/2009063.

Rantanen, M., Karpechko, A.Y., Lipponen, A. *et al.* The Arctic has warmed nearly four times faster than the globe since 1979. *Commun Earth Environ* 3, 168 (2022). Available from: https://www.nature.com/articles/s43247-022-00498-3.

Rasmussen, Knud. *Across Arctic America*. Putnam, 1927. Available from: https://upcolorado.com/university-of-alaska-press/item/5610-across-arctic-america.

Riǵet FA Bignert, Braune B, Stow J, Wilson S. Temporal trends of legacy POPs in Arctic biota, an update. *Sci Total Environ*. 2010;408:2874–2884. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0048969709007062?via%3Dihub

Robert-Lamblin, J. (1980). *The Aleut Kayak - As Seen by its Builder and User - and The Sea Otter Hunt*. Available from: https://www.arctickayaks.com/PDF/Robert-Lamblin1980/robert-lamblin1980.pdf.

Rode, K. D., Voorhees, H., Huntington, H. P., & Durner, G. M. (2021). Inupiaq Knowledge of Polar Bears (Ursus maritimus) in the Southern Beaufort Sea. *Arctic*, *74*(3), 239–257. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/73030.

Schæbel, L. K., Bonefeld-Jørgensen, E. C., Vestergaard, H., & Andersen, S. (2017). The influence of persistent organic pollutants in the traditional Inuit diet on markers of inflammation. *PLOS ONE*, *12*(5). https://doi.org/10.1371/journal.pone.0177781

Spencer, R. F. (1959). The North Alaskan Eskimo. In *The North Alaskan Eskimo A Study in Ecology and Society* essay, Smithsonian Institution Press. Available from: https://repository.si.edu/handle/10088/15465.

Status. Polar Bears International. (n.d.). https://polarbearsinternational.org/

Stepanyan, V. (2019, February). *Air pollution in Alaska's North Slope and its implications for the community of Nuiqsut*. Alaska Community Action on Toxins. https://www.akaction.org/

The North Slope Borough. (NSB) (n.d.). https://www.north-slope.org/

The United States Government. (2022, December 1). *White House releases first-of-a-kind Indigenous Knowledge Guidance for federal agencies*. The White House. https://www.whitehouse.gov/ceq/news-updates/2022/12/01/white-house-releases-first-of-a-kind-indigenous-knowledge-guidance-for-federal-agencies/

U.S. Department of the Interior, Bureau of Land Management, 1 Willow Master Development Plan: Subsistence and Sociocultural Systems Technical Appendix (2023). Anchorage, AK.

U.S. Department of the Interior, National Petroleum Reserve in Alaska, 105(c) Land Use Study, National Petroleum Reserve in Alaska, Native Livelihood and Dependence: A study of land use values through time (1979). Anchorage, AK. Available from: https://www.arlis.org/docs/vol1/N/NPRA/5974397.pdf.

Voorhees, H., Sparks, R., Huntington, H. P., & Rode, K. D. (2014). Traditional Knowledge About Polar Bears in Northwestern Alaska. *Arctic*, *67*(4), 523–536. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/67469.

Waugh, D. A., Sensor, J. D., George, J. C., & Thewissen, J. G. M. (2023, July). *Auditory Health of Bowhead Whales of the Bering-Chukchi-Beaufort Stock Based on Inner Ear Neuron Counts*. Aquatic Mammals. Available from: https://www.aquaticmammalsjournal.org/article/auditory-health-of-bowhead-whales-balaena-mysticetus-of-the-bering-chukchi-beaufort-stock-based-on-inner-ear-neuron-counts/.

Webster, D. H., & Zibell, W. (1970). Inupiat Eskimo Dictionary. Available from: https://library.alaska.gov/hist/hist_docs/docs/anlm/200078.pdf.

Whaling Trail Mapping: AAOKH. Alaska Arctic Observatory & Knowledge Hub. (2023, December 7). https://arctic-aok.org/data-sources/whaling-trail-mapping/.

Whaling. International Whaling Commission. (n.d.). https://iwc.int/management-and-conservation/whaling/aboriginal/usa/alaska.

5: NPR-A Landscape Benefits

5a: Intactness

A primary goal of conservation is to protect the most intact lands left on Earth, within every country, and locally. Remote sensing and other spatial data have allowed scientists the ability to map and monitor human land use in the last two decades. We can now assess the footprint and expansion of industrial development including roads; transmission lines; agricultural, residential, and commercial land use; mining; logging; dam-building, and other forms of human modification (Riggio et al. 2020). Mapping human modification (Theobald et al. 2020) or the human footprint (Venter et al. 2016) allows us to assess what is left of the Earth's remaining natural area (or "wildlands"), and track their decline and the associated impacts on species habitat (Di Marco et al. 2018) and ecosystem services (Costanza et al. 1997). Lands that are relatively unfragmented and free of modification from industrial activity have been described as intact landscapes (Potapov et al. 2017, Watson et al. 2018). Additionally, evidence of historical ranges combined with spatial modeling tools allow scientists the ability to map the historical distributions of some taxonomic groups (e.g., mammals, Faurby and Svenning 2015). Scientists have combined these historical and current distributions of mammals to map compositional or biotic intactness (Newbold et al. 2016), an index describing the degree to which species composition remains 'whole' compared to an historical baseline (Belote et al. 2020) (Figures 5a.1 and 5a.2). These efforts and others provide new insights into the scarcity of the remaining wildlands and their recent rapid decline (Watson et al. 2016). From these mapping efforts, we know that Indigenous people steward a disproportionate amount of the remaining intact landscapes around the planet (Garnett et al. 2018). Based on several assessments of human modification and compositional intactness, Alaska's Arctic landscape is among the most intact places left on Earth (Figures 5a.1 and 5a.2). Care should be taken to ensure that this globally significant value is not overlooked.

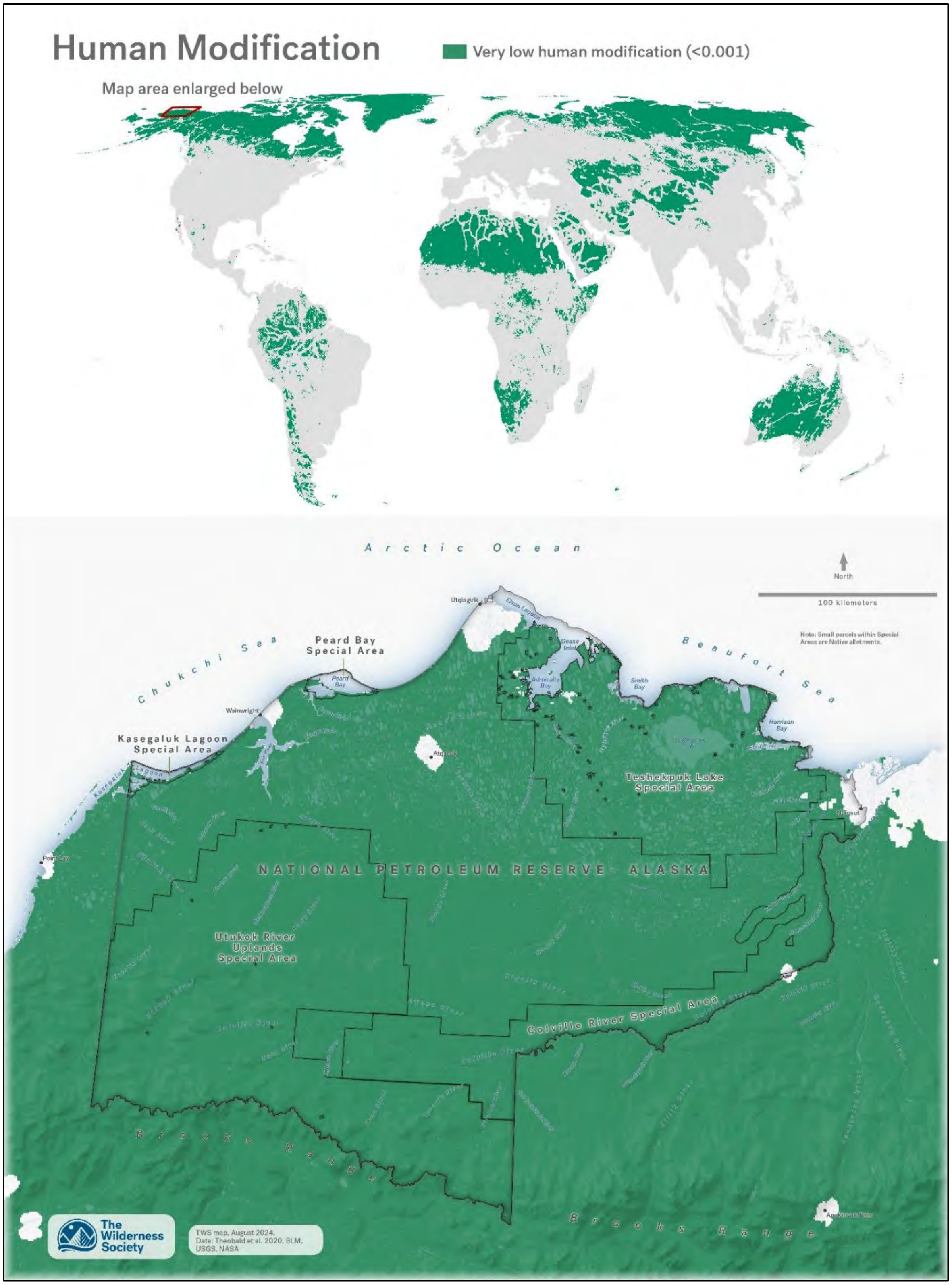

Figure 5a.1. Maps of intact lands based on Theobald et al. (2020) global human modification within the NPR-A. Please see Appendix B for a higher resolution version of this figure.

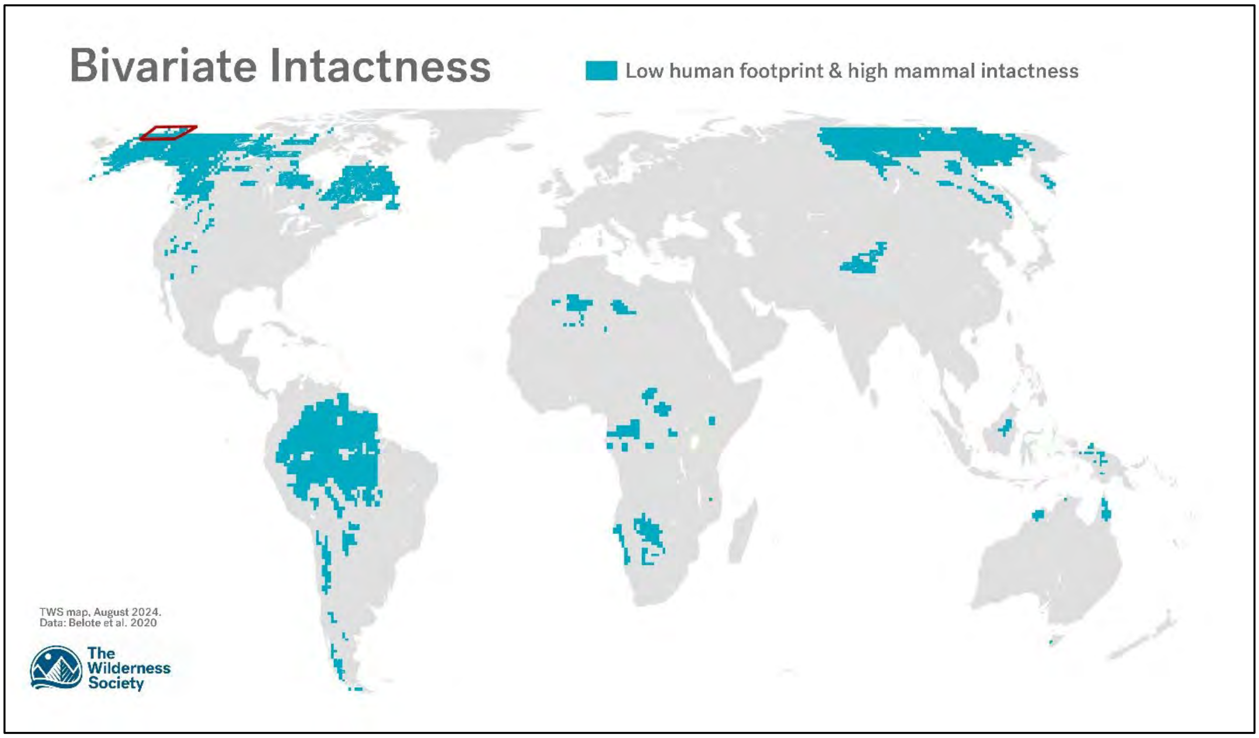

Figure 5a.2. Map of intact lands based on combined assessment of the human footprint and mammal intactness, with green areas characterized by low human footprint and high mammal intactness (Belote et al. 2020). Please see Appendix B for a higher resolution version of this figure.

Intactness literature cited

Belote, R. T., S. Faurby, A. Brennan, N. H. Carter, M. S. Dietz, B. Hahn, W. J. McShea, and J. Gage. 2020. Mammal species composition reveals new insights into Earth's remaining wilderness. Frontiers in Ecology and the Environment 18:376–383. Available from: https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/fee.2192.

Costanza, R., R. de Groot, S. Farberk, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O, J. Paruelo, R. G. Raskin, P. Sutton, and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253–260. Available from: https://www.nature.com/articles/387253a0.

Di Marco, M., O. Venter, H. P. Possingham, and J. E. M. Watson. 2018. Changes in human footprint drive changes in species extinction risk. Nature Communications 9:4621. Available from: https://www.nature.com/articles/s41467-018-07049-5.

Faurby, S., and J. C. Svenning. 2015. Historic and prehistoric human-driven extinctions have reshaped global mammal diversity patterns. Diversity and Distributions 21:1155–1166. Available from: https://onlinelibrary.wiley.com/doi/full/10.1111/ddi.12369.

Garnett, S. T., N. D. Burgess, J. E. Fa, Á. Fernández-Llamazares, Z. Molnár, C. J. Robinson, J. E. M. Watson, K. K. Zander, B. Austin, E. S. Brondizio, N. F. Collier, T. Duncan, E. Ellis, H. Geyle, M. V. Jackson, H. Jonas, P. Malmer, B. McGowan, A. Sivongxay, and I. Leiper. 2018. A spatial overview of the global importance of Indigenous lands for conservation. Nature Sustainability 1:369–374. Available from: https://www.nature.com/articles/s41893-018-0100-6.

Newbold, T., L. N. Hudson, A. P. Arnell, S. Contu, A. D. Palma, S. Ferrier, S. L. L. Hill, A. J. Hoskins, I. Lysenko, H. R. P. Phillips, V. J. Burton, C. W. T. Chng, S. Emerson, D. Gao, G. Pask-hale, J. Hutton, M. Jung, K. Sanchez-ortiz, B. I. Simmons, S. Whitmee, and H. Zhang. 2016. Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. Science 353:288–291. Available from: https://www.science.org/doi/abs/10.1126/science.aaf2201.

Potapov, P., M. C. Hansen, L. Laestadius, S. Turubanova, A. Yaroshenko, C. Thies, W. Smith, I. Zhuravleva, A. Komarova, S. Minnemeyer, and E. Esipova. 2017. The last frontiers of wilderness: Tracking loss of intact forest landscapes from 2000 to 2013. Science Advances 3:e1600821. Available from: https://www.science.org/doi/full/10.1126/sciadv.1600821.

Riggio, J., J. E. M. Baillie, S. Brumby, E. Ellis, C. M. Kennedy, J. R. Oakleaf, A. Tait, T. Tepe, D. M. Theobald, O. Venter, J. E. M. Watson, and A. P. Jacobson. 2020. Global human influence maps reveal clear opportunities in conserving Earth's remaining intact terrestrial ecosystems. Global Change Biology 26:4344–4356. Available from: https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15109.

Theobald, D. M., C. Kennedy, B. Chen, J. Oakleaf, S. Baruch-Mordo, and J. Kiesecker. 2020. Earth transformed: Detailed mapping of global human modification from 1990 to 2017. Earth System Science Data 12:1953–1972. Available from: https://essd.copernicus.org/articles/12/1953/2020/essd-12-1953-2020.html.

Venter, O., E. W. Sanderson, A. Magrach, J. R. Allan, J. Beher, K. R. Jones, H. P. Possingham, W. F. Laurance, P. Wood, B. M. Fekete, M. A. Levy, and J. E. M. Watson. 2016. Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. Nature Communications 7:1–11. Available from: https://www.nature.com/articles/ncomms12558.

Watson, J. E. M., T. Evans, O. Venter, B. Williams, A. Tulloch, C. Stewart, I. Thompson, J. C. Ray, K. Murray, A. Salazar, C. McAlpine, P. Potapov, J. Walston, J. G. Robinson, M. Painter, D. Wilkie, C. Filardi, W. F. Laurance, R. A. Houghton, S. Maxwell, H. Grantham, C. Samper, S. Wang, L. Laestadius, R. K. Runting, G. A. Silva-Chávez, J. Ervin, and D. Lindenmayer. 2018. The exceptional value of intact forest ecosystems. Nature Ecology and Evolution 2:599–610. Available from: https://www.nature.com/articles/s41559-018-0490-x.

Watson, J. E. M., D. F. Shanahan, M. D. Marco, J. Allan, W. F. Laurance, E. W. Sanderson, B. Mackey, and O. Venter. 2016. Catastrophic declines in wilderness areas undermine global environment targets. Current Biology 26:1–6. Available from: https://www.cell.com/current-biology/fulltext/S0960-9822(16)30993-9.

5b: Wildness

Highlights:

- Wildness represents the ecological condition and freedom from human control of natural systems and can be mapped by overlaying a variety of anthropogenic factors.
- The NPR-A features overall high wildness values, especially within many of its existing Special Areas.
- Wildness values are inversely correlated with human development, with the least wild areas occurring around the Prudhoe Bay and Kuparuk oilfields and the Dalton Highway corridor. Additional development in the lands lying between the Teshekpuk Lake and Colville River Special Areas would likely further degrade NPR-A wildness values.

Overview

People have long valued wild places for the multitude of benefits they contain and convey to the natural world and to humans. The United States has a complicated relationship with the concept of the wild, which played an important role in development of an American identity of rugged frontier expansion and recreation while also diminishing the value and established presence of Native American groups who occupied many “wild” areas long before European settlers arrived and who, in many cases, were forcibly removed to “protect” wild places. Recognizing these detrimental effects and their ongoing legacy, there have been efforts to redefine the way wilderness is conceptualized and discussed by recognizing the connections of people to these places and encouraging a sense of belonging for all people in wild lands (e.g., Lindholm 2023).

In its more formal sense, designated Wilderness areas that are part of the U.S. National Wilderness Preservation System play an important role in protecting lands, waters, and natural processes. This has been recognized to benefit certain wildlife species, though there is a need for greater coordinated study of these effects (Schwartz et al. 2016).

There is value in spatially representing the degree of ecological integrity of the natural world to aid conservation planning, given the well-documented detrimental effects that human modification of natural systems has on many species and the rapid speed with which people continue to modify the planet. In light of this, there have been calls to protect the remaining intact “wild” places (e.g., Watson et al. 2018), including 30 x 30 initiatives (seeking to set aside 30% of lands and waters for nature by 2030; e.g., Dinerstein et al. 2019), and calls for protecting half of the planet for nature (Wilson 2017). Many efforts have been undertaken to represent wildness, intact ecosystems, and human modifications at local, national, and global scales (e.g., Aplet et al. 2000; Theobald 2013; Venter et al. 2016; Williams et al. 2020). However, their coverage in Alaska is inadequate, including inaccurate data or omitting important covariates. As a result, The Wilderness Society created a new wildness layer based on the conceptualization of wildness described in Aplet (1999), which is presented here.

Methods

Wildness was represented as a compilation of two primary components, following the approach of Aplet (1999): freedom from human control and ecological condition (“naturalness” in Aplet 1999).

Freedom from control

Freedom from control was further subdivided into remoteness, which we defined as ease of access to an area, and solitude, which we defined as the likelihood of encountering people. These two concepts are clearly related but provide a useful way to divide different input data.

Remoteness was represented by the distance to the Dalton Highway, other gravel roads, navigable waters, and airstrips. Linear distance from these features was calculated out to 15 km, representing the distance a person can walk in one day in difficult terrain/land cover (Sanderson et al. 2002). Values were rescaled linearly between 1.0 to 0.0, with a different maximum for each layer to reflect relative intensity of use and impact (higher values = higher impact, Table 5b.1). All pixels beyond the maximum distance received a value of zero. Shapefiles for the Dalton Highway and other gravel roads in the study area were obtained from Trammell et al. (2015). The Dalton Highway is the most heavily used major transportation route within the study area. Consequently, it was assigned a maximum impact value of one (Table 5b.1). Other gravel roads in the study area show variable levels of use and were assigned a maximum impact value of 0.8 based on Table F-2 in Trammell (2015).

Table 5b.1. Input variables and parameters used to evaluate wildness across Alaska's North Slope.

Wildness feature	Variable	Maximum impact	Maximum distance (km)
Freedom from control			
Remoteness	Distance to Dalton Highway	1.0	15.0
	Distance to other gravel roads	0.8	15.0
	Distance to navigable waters	0.5 (coastline, Teshekpuk Lake, Strahler order 8 rivers) 0.4 (Strahler order 7 rivers) 0.3 (Strahler order 6 rivers) 0.2 (Strahler order 5 rivers)	15.0
	Distance to airstrips	1.0	15.0
Solitude	Distance to communities	1.0	no limit
	Distance to oil and gas facilities	1.0	no limit
	Distance to subsistence cabins	0.25	no limit
Ecological condition			
Environmental degradation	Contaminated sites	1.0	0.5
	Invasive species	1.0	0.2
	Light at night	1.0	no limit
	Altered viewshed	1.0	no limit
	Aircraft noise	1.0	no limit

Navigable waters were considered those of Strahler order 5 and higher as well as coastlines, and Teshekpuk Lake, the largest lake in the study area. Strahler order was calculated using National Hydrography Dataset flow line data from the United States Geological Survey (USGS). Venter et al. (2016) used a distance of 80 km from human settlements as the approximate distance a vessel can travel and return during daylight hours. In our study area, multi-day trips are common for hunting or recreation and daylight never ends during the summer months, so we used a buffer distance of 125 km around communities and the airstrip facilities at Umiat along the southeastern NPR-A border (Figure 2.1) to define navigable waters. Linear distance decay up to 15 km from navigable waters was calculated as for roads. The maximum impact value for navigable waters was weighted by their Strahler order with higher impact values assigned to higher order (larger) rivers (Table 5b.1). Coastal areas and Teshekpuk Lake were also assigned the highest impact value (Table 5b.1). Impact rasters for each Strahler-order river, coastlines, and Teshekpuk Lake were overlaid and the maximum value per cell was used to represent the likelihood of encountering people due to navigable waters.

Air travel is a major way that people and goods are moved across the generally roadless North Slope (Figure 2.1). Airstrip locations were obtained from Trammell et al. (2015) and linear distance decay was applied up to 15 km away from airstrips, as with roads. The maximum impact value for airstrips was set to 1.0 (Table 5b.1).

Solitude was related to distance from sites occupied by humans, including communities, oil and gas facilities, and subsistence camps. For each of these sources a logistic distance decay function was used to decrease likelihood of encountering people the farther one is from the source. For communities, the maximum impact value (i.e., maximum likelihood of encountering people) was 1.0 at communities and decayed at different rates based on the population of each community, with larger communities experiencing a longer distance to decay (Table 5b.1). Oil and gas facilities also experience high levels of human use but facility workers are unlikely to travel far from such facilities away from the road network (which was already accounted for in the remoteness metric above). Thus, distance decay started at 1.0 but decayed quickly. Subsistence cabins are used by fewer people, with sporadic use depending on harvest patterns across seasons and other factors. Because of this lower intensity of use the maximum impact value for cabins was set to 0.25 (Table 5b.1). For each of these solitude inputs there was no pre-specified maximum distance beyond which values were set to zero, but the various distance decay functions essentially made this happen at population-scaled distances.

Remoteness and solitude measures each ranged from zero to one and were summed together to yield a combined Freedom from Control layer (Figure 5b.1).

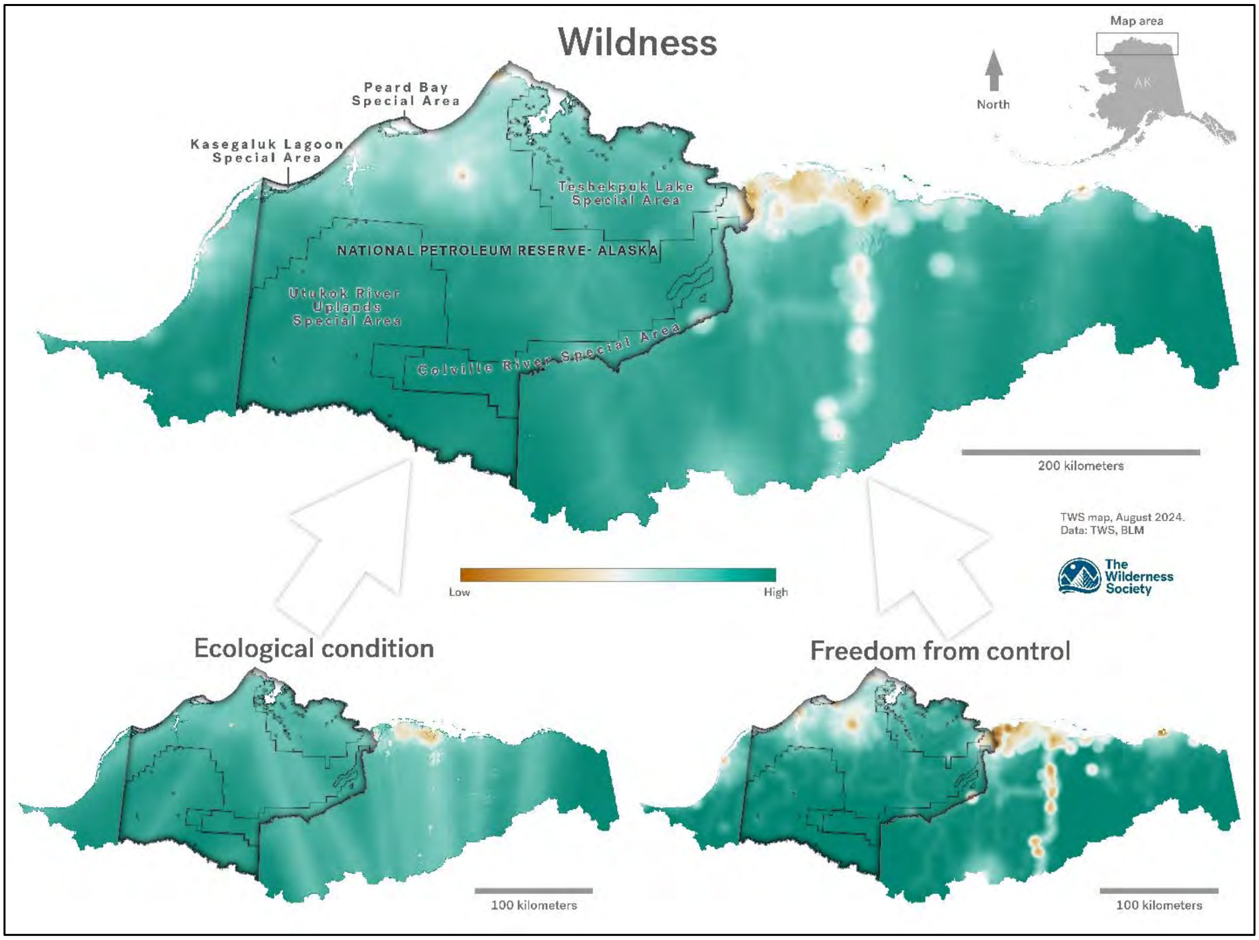

Figure 5b.1. Wildness across the North Slope of Alaska, defined here as areas north of the crest of the Brooks Range mountains. Wildness was a composite metric reflecting both ecological condition and freedom from control (see text for details). Note that wildness is a relative metric so many of the areas indicated here to have moderate wildness with respect to the North Slope may still rank highly for wildness if compared with other areas in the contiguous United States or elsewhere. Please see Appendix B for a higher resolution version of this figure.

Ecological condition

Ecological condition reflects the degree to which the environment has been degraded, especially due to human impacts. Five variables were combined to reflect ecological condition: contaminated sites, invasive plants, light at night, altered viewshed, and aircraft noise. Locations of contaminated sites and known invasive plant occurrences were identified from the Trammell et al. (2015) dataset. For both variables, linear distance decay was used with impact values of 1.0 at the source of the contaminated site or invasive plant location, decreasing down to a score of 0 at 500 m and 200 m, respectively (Table 5b.1).

There is a growing awareness of the many detrimental effects that artificial light at night has on species and ecosystems (e.g., van Langevelde et al. 2017; Owens et al. 2020; Schligler et al. 2021; Sanders et al. 2023). We used a NASA light at night dataset to represent this across the North Slope study area. Similarly, visual cues can play an important role in affecting animal behavior, leading to calls for more investigation of viewsheds (Aben et al. 2017). A viewshed analysis was conducted in ArcGIS using approximate heights of oil and gas production facilities combined with infrastructure locations from Trammell et al. (2015). This resulted in a raster layer indicating the number of structures visible from every point across the North Slope. This reflected magnitude of viewshed impact, with more structures that are in view leading to a greater viewshed impact score. This was affected both by facility height and topography. Both light at night and viewshed scores were rescaled to range between 1.0 – 0.0; because they were calculated for the entire North Slope no maximum distance threshold was applied (Table 5b.1).

As is mentioned above, aircraft are a primary means of travel between communities on Alaska's North Slope, given the lack of year-round road access between communities. Despite the importance of aircraft, many in local communities express negative reactions to aircraft, especially due to perceptions that aircraft noise interferes with subsistence harvest opportunities (Georgette and Loon 1988; Jacobson 2008; Halas 2015; Stichcomb et al. 2019,2020). We modeled aircraft sound across the North Slope of Alaska using a commercially available dataset from Flight Aware (www.flightaware.com). We note that this dataset was an imperfect representation of aircraft sound as it primarily incorporated large commercial and industrial aircraft and thus likely missed many of the small private aircraft that may fly lower and lead to greater impacts on subsistence harvest. Nonetheless, it represented the best available information and was used as a proof of concept to represent inclusion of aircraft effects in a way that has not been done in other modeling of ecological condition in the U.S.

Point locations for aircraft in flight were provided along with attributes like aircraft type, altitude, and airspeed. These data were input into the Sound Mapping Tools (SMT) ArcGIS toolbox (Keyel et al. 2017), which includes three sound propagation models that reflect how sound is heard across landscapes. We used the NMSIMGIS model, which is more suitable for high-flying sources such as aircraft as it takes into account spherical spreading loss and atmospheric absorption of sound, relevant for sound sources in flight. We used A-weighting of sound levels, as this is analogous to what a human ear would hear. NMSIMGIS produced modeled estimates of sound decibels from aircraft, heard at ground-level around each point location in the dataset, incorporating aircraft characteristics, sound decay over space, and effects of weather conditions and terrain shielding (Keyel et al. 2017). These were mosaicked together into one flight line, representing the sound levels for a single aircraft flight. Aircraft sound does not occur in spatially separated points but as a continuous process, so to account for the discrete nature of the input data and for gaps due to missing information, we ran linear mixed effects models (Zuur et al. 2009) to approximate the sound propagation process. We used SMT-modeled sound levels as the response variable and input parameters for SMT as covariates along with a quadratic function of Euclidean distance from the flight line. Random intercepts were included for data from the same point observation and aircraft flight. We trained the model on 1000 pixels from each of the 132 points of 34 flights in July 2014 and used the model to predict sound levels on flight lines for the same week in July 2014. The resulting aircraft sound layer was highly correlated with the point-based estimates derived from SMT (r = 0.972) and better reflected continuous sound propagation from each aircraft. We validated the model by running the regression model built in July 2014, one of the busiest aircraft traffic months to model sound in March 2014, one of the lowest aircraft traffic months in that year and a period of very different seasonal environmental conditions. Comparison with SMT-modeled sound for the March 2014 week again showed a very high correlation (r = 0.965), increasing our confidence in the ability of the model to predict sound across different conditions. We thus applied the regression model to aircraft sound data for one week from each month of 2014 and averaged the monthly results to represent relative sound level across the year. This was rescaled to range from 1.0 – 0.0 and integrated into the ecological condition layer. As with the viewshed and light at night layers, aircraft sound was modeled across the entire North Slope and did not have an *a priori* maximum distance threshold (Table 5b.1).

With each input scaled to range from zero to one, contaminated sites, invasive plants, altered viewshed, light at night, and aircraft sound were summed together to yield a combined Ecological Condition layer (Figure 5b.1). This and the Freedom from Control layer were, in turn, each rescaled to range from 0-1 and summed to create a single combined representation of wildness across the North Slope of Alaska (Figure 5b.1).

Findings

Wildness values strongly correlate with human development, with the least wild areas occurring around the Prudhoe Bay and Kuparuk oilfields and the Dalton Highway corridor (Figure 5b.1). The NPR-A features overall high wildness values (Figure 5b.1), especially within many of its existing Special Areas (Figure 5b.2). Notable exceptions include the northeastern corner of the NPR-A, where infrastructure in the Kuparuk Development Area, Colville Delta Unit, and Greater Mooses Tooth Units combine to reduce wildness. Effects of these are strongest in the lands between the Teshekpuk Lake Special Area and Colville River Special Area but extend into each Special Area (Figure 5b.2). The Umiat development site also reduces wildness within the Colville River Special Area. For the most part, the Utukok River Uplands Special Area has high wildness values, occurring far from permanent human communities and industrial development. Based on these observed patterns, additional development in the lands lying between the Teshekpuk Lake and Colville River Special Areas, or within these Special Area Boundaries, would be expected to continue to degrade wildness values.

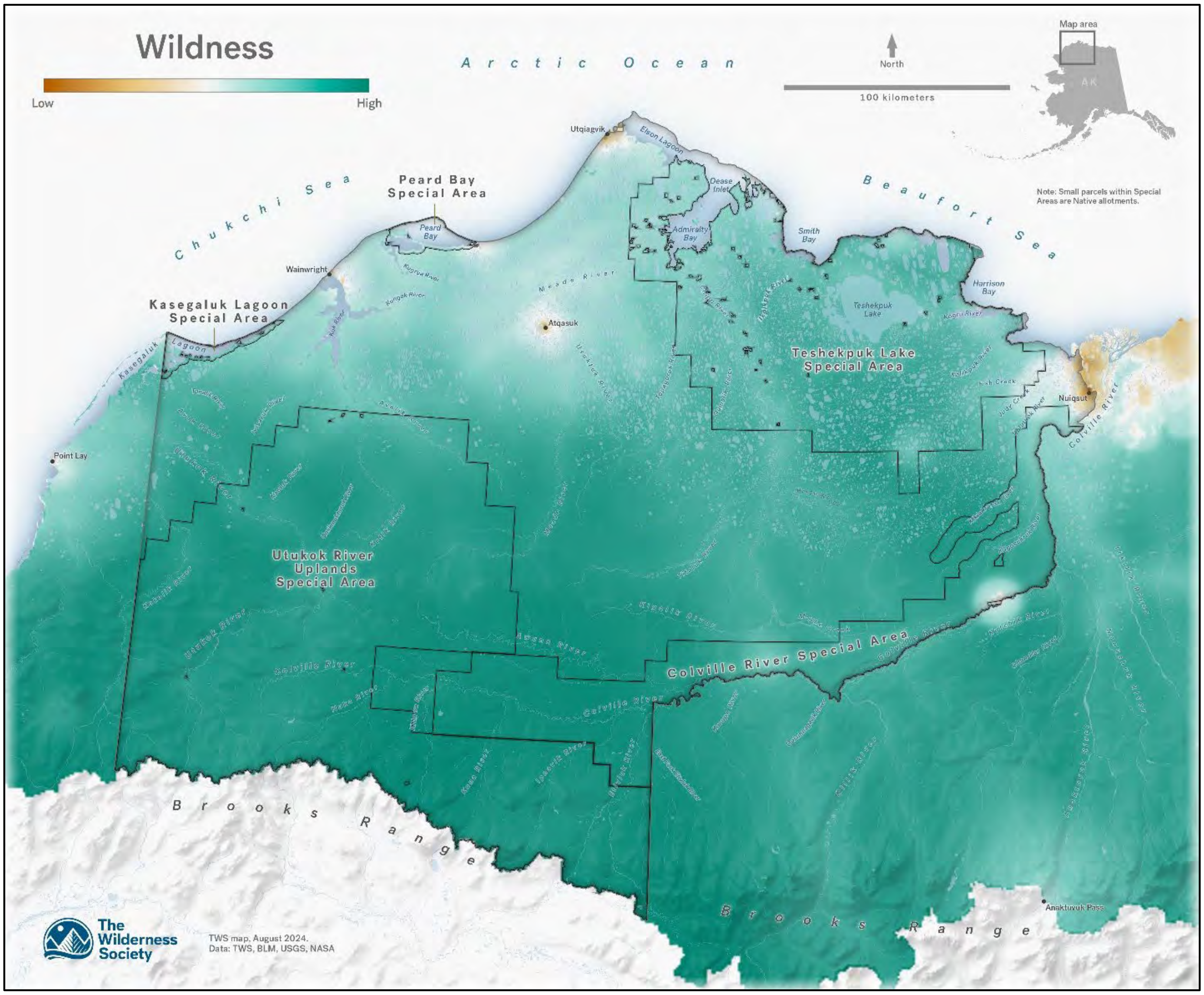

Figure 5b.2. Wildness within the National Petroleum Reserve – Alaska. Wildness is clearly reduced around development areas in the northeastern NPR-A and Umiat, and to a lesser degree around communities. Wildness is a relative metric so many of the areas indicated here to have moderate wildness with respect to the North Slope may still rank highly for wildness if compared with other areas in the contiguous United States or elsewhere. Please see Appendix B for a higher resolution version of this figure.

Wildness literature cited

Aben J, Pellikka P, Travis JMJ. 2018. A call for viewshed ecology: advancing our understanding of the ecology of information through viewshed analysis. Methods in Ecology and Evolution 9(3), 447-798. Available from: https://besjournals.onlinelibrary.wiley.com/doi/10.1111/2041-210X.12902.

Aplet GH. 1999. On the nature of wildness: exploring what wilderness really protects. Denver University Law Review 76(2), 347-367. Available from: https://digitalcommons.du.edu/dlr/vol76/iss2/4/.

Aplet G, Thomson J, Wilbert M. 2000. Indicators of wildness: using attributes of the land to assess the context of wilderness. In: SF McCool, DN Cole, WT Borrie, J O'Loughlin (Comps.) *Wilderness science in a time of change conference—Volume 2: Wilderness within the context of larger systems*; 1999 May 23-27; Missoula, MT. Proceedings RMRS-P-15-VOL-2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Available from: https://research.fs.usda.gov/treesearch/21931.

Dinerstein E, Vynne C, Sala E, Joshi AR, Fernando S, Lovejoy TE, Mayorga J, Olson D, Asner GP, Baillie JEM, Burgess ND, Burkart K, Noss RF, Zhang YP, Baccini A, Birch T, Hahn N, Joppa LN, Wikramanayake E. 2019. A global deal for nature: guiding principles, milestones, and targets. Science Advances 5, eaaw2869. Available from: https://www.science.org/doi/10.1126/sciadv.aaw2869.

Georgette S, Loon H. 1988. The Noatak River: Fall Caribou Hunting and Airplane Use. Technical Paper No. 162. Alaska Department of Fish and Game, Division of Subsistence, Kotzebue, AK, USA. Available from: https://www.adfg.alaska.gov/techpap/tp162.pdf.

Halas G. 2015. Caribou migration, subsistence hunting, and user group conflicts in northwest Alaska: a traditional knowledge perspective. MS Thesis. University of Alaska Fairbanks, Fairbanks, AK, USA. Available from: https://scholarworks.alaska.edu/handle/11122/6090.

Jacobson C. 2008. Fall Hunting in Game Management Unit 23: Assessment of Issues and Proposal for a Planning Process. Alaska Department of Fish and Game, Division of Wildlife Conservation, Juneau, AK, USA. Available from: https://www.adfg.alaska.gov/static/research/plans/pdfs/unit23.pdf.

Keyel AC, Reed SE, McKenna MF, Wittemyer G. 2017. Modeling anthropogenic noise propagation using the Sound Mapping Tools ArcGIS toolbox. Environmental Modelling & Software 97, 56-60. Available from: https://www.sciencedirect.com/science/article/abs/pii/S1364815217301500?via%3Dihub.

Lindholm A. 2023. Reimagining the wilderness concept for a diverse America: a case study of inclusive wilderness stewardship in Glacier Bay National Park, Alaska. International Journal of Wilderness 29(2). Available from: https://ijw.org/reimagining-the-wilderness-concept-for-a-diverse-america/.

Owens ACS, Cochard P, Durrant J, Farnworth B, Perkin EK, Seymoure B. 2020. Light pollution is a driver of insect declines. Biological Conservation 241, 108259. Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3378835.

Sanders D, Hirt MR, Brose U, Evans DM, Gaston KJ, Gauzens B, Ryser R. 2023. How artificial light at night may rewire ecological networks: concepts and models. Philosophical Transactions of the Royal Society B 378, 20220368. Available from: https://royalsocietypublishing.org/doi/10.1098/rstb.2022.0368.

Sanderson EW, Jaiteh M, Levy MA, Redford KH, Wannebo AV, Wollmer G. 2002. The human footprint and the last of the wild. BioScience 52(10), 891-904. Available from: https://academic.oup.com/bioscience/article/52/10/891/354831?login=false.

Schligler J, Cortese D, Beldade R, Swearer SE, Mills SC. 2021. Long-term exposure to artificial light at night in the wild decreases survival and growth of a coral reef fish. Proceedings of the Royal Society B 288(1952), 20210454. Available from: https://royalsocietypublishing.org/doi/10.1098/rspb.2021.0454.
Schwartz MK, Hahn BA, Hossack BR. 2016. Where the wild things are: a research agenda for studying the wildlife-wilderness relationship. Journal of Forestry 114(3), 311-319. Available from: https://academic.oup.com/jof/article/114/3/311/4599813.
Stinchcomb TR, Brinkman TJ, Fritz SA. 2019. A review of aircraft-subsistence harvester conflict in Arctic Alaska. Arctic 72(2), 131-150. Available from: https://journalhosting.ucalgary.ca/index.php/arctic/article/view/68228.
Stinchcomb TR, Brinkman TJ, Betchkal D. 2020. Extensive aircraft activity impacts subsistence areas: acoustic evidence from Arctic Alaska. Environmental Research Letters 15, 115005. Available from: https://iopscience.iop.org/article/10.1088/1748-9326/abb7af.
Theobald DM. 2013. A general model to quantify ecological integrity for landscape assessments and US application. Landscape Ecology 28, 1859-1874. https://link.springer.com/article/10.1007/s10980-013-9941-6.
Trammell EJ, Carlson ML, Fresco N, Gotthardt T, McTeague ML, Vadapalli D, eds. 2015. *North Slope Rapid Ecoregional Assessment*. Prepared for the Bureau of Land Management, U.S. Department of the Interior. Anchorage, Alaska, USA. Available from: https://accscatalog.uaa.alaska.edu/sites/default/files/REA_NorthSlope_Report.pdf.
van Langevelde F, van Grunsven RHA, Veenendaal EM, Fijen TPM. 2017. Artificial night lighting inhibits feeding in moths. Biology Letters 13, 20160874. Available from: https://royalsocietypublishing.org/doi/10.1098/rsbl.2016.0874.
Venter O, Sanderson EW, Magrach A, Allan JR, Beher J, Jones KR, Possingham HP, Laurance WF, Wood P, Fekete BM, Levy MA, Watson JEM. 2016. Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. Nature Communications 7, 12558. https://www.nature.com/articles/ncomms12558.
Watson JEM, Venter O, Lee J, Jones KR, Robinson JG, Possibgham HP, Allan JR. 2018. Protect the last of the wild. Nature 563, 27-30. Available from: https://www.nature.com/articles/d41586-018-07183-6.
Williams BA, Venter O, Allan JR, Atkinson SC, Rehbein JA, Ward M, Di Marco M, Grantham HS, Ervin J, Goetz SJ, Hansen AJ, Jantz P, Pillay R, Rodríguez-Buriticá S, Supples C, Virnig ALS, Watson JEM. 2020. Change in terrestrial human footprint drives continued loss of intact ecosystems. One Earth 3, 371-382. Available from: https://www.cell.com/one-earth/fulltext/S2590-3322(20)30418-8?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS2590332220304188%3Fshowall%3Dtrue.
Wilson EO. 2017. *Half-Earth: Our Planet's Fight for Life*. Liveright, New York, NY, USA.
Zuur AF, Ieno EN, Walker NJ, Saveliev AA, Smith GM. 2009. *Mixed Effects Models and Extensions in Ecology with R*. Springer Science+Business Media, LLC, New York, NY, USA. Available from: https://link.springer.com/book/10.1007/978-0-387-87458-6.

5c: Soil Carbon

The carbon cycle includes exchanges of carbon between the atmosphere (air), biosphere (life), lithosphere (rock), and hydrosphere (water). Concentrations of carbon in the atmosphere partially govern the Earth's climate, based on the ability of carbon dioxide and methane to absorb and retain heat. Since the Industrial Revolution, carbon dioxide in the atmosphere has been increasing from a pre-industrial level of around 280 parts per million (ppm) to current (and increasing) concentrations of over 420 ppm (Tierney et al. 2020). To avoid the worst of human-driven climate change, most scientists recommend transitioning from energy produced by burning fossil fuels - which releases into the atmosphere carbon stored in the lithosphere for millions of years - to renewable energy sources. In addition to reducing the burning of fossil fuels, scientists also recommend protecting lands that store and sequester large amounts of carbon (Goldstein et al. 2020). In fact, land use - including deforestation and agricultural practices - partially explain increasing atmospheric carbon dioxide concentrations (Ryan et al. 2010). Lands that historically maintained forests or grasslands once absorbed and retained carbon in living and dead biomass and soil organic matter. Disturbing and converting natural ecosystems to other land uses can release large amounts of carbon to the atmosphere as vegetation and soil organic matter decomposes and releases carbon dioxide, or in some cases methane (Friedlingstein et al. 2020, Liu et al. 2020). While old-growth forests are widely celebrated for the carbon stored in living and dead trees (Luyssaert et al. 2008), large amounts of carbon are also stored in soils, especially permafrost soils in northern latitudes (Miner et al. 2022). In some cases, this permafrost carbon has been slowly accumulating for over 10,000 years (Shi et al. 2020). The soil carbon stored in Alaska's Arctic represents some of the most carbon-dense areas on Earth (Hengl et al. 2014). See Figures 5c.1 and 5c.2 with data from the Food and Agriculture Organization of the United Nation and the Intergovernmental Technical Panel on Soils (FAO and ITPS 2018) and Hengl and Wheeler (2018). Care should be taken to avoid both direct disturbance to permafrost soils and accelerating their decomposition through climate-warming fossil fuel emissions (Plaza et al. 2019).

Figure 5c.1. Top 20% highest soil carbon locations down to 30-cm depth on Earth based on the Food and Agriculture Organization of the United Nation and the Intergovernmental Technical Panel on Soils. Permafrost soils located in high latitudes store large amounts of carbon, which is often very old. Please see Appendix B for a higher resolution version of this figure.

Figure 5c.2. Top 10% global areas for soil carbon down to 200-cm depth from Hengl and Wheeler (2018). Permafrost soils located in high latitudes store large amounts of carbon, which is often very old. Please see Appendix B for a higher resolution version of this figure.

Food and Agriculture Organization of the United Nation and the Intergovernmental Technical Panel on Soils. 2018. Global soil organic carbon map. Technical report. Page 162. Food and Agriculture Organization of the United Nations, Rome. Available from: https://openknowledge.fao.org/server/api/core/bitstreams/c3ccec0d-fe75-49b7-9a4c-ee0a8777fed9/content.

Friedlingstein, P., M. O'Sullivan, M. W. Jones, R. M. Andrew, J. Hauck, A. Olsen, G. P. Peters, W. Peters, J. Pongratz, S. Sitch, C. Le Quéré, J. G. Canadell, P. Ciais, R. B. Jackson, S. Alin, L. E. O. C. Aragão, A. Arneth, V. Arora, N. R. Bates, M. Becker, A. Benoit-Cattin, H. C. Bittig, L. Bopp, S. Bultan, N. Chandra, F. Chevallier, L. P. Chini, W. Evans, L. Florentie, P. M. Forster, T. Gasser, M. Gehlen, D. Gilfillan, T. Gkritzalis, L. Gregor, N. Gruber, I. Harris, K. Hartung, V. Haverd, R. A. Houghton, T. Ilyina, A. K. Jain, E. Joetzjer, K. Kadono, E. Kato, V. Kitidis, J. I. Korsbakken, P. Landschützer, N. Lefèvre, A. Lenton, S. Lienert, Z. Liu, D. Lombardozzi, G. Marland, N. Metzl, D. R. Munro, J. E. M. S. Nabel, S. I. Nakaoka, Y. Niwa, K. O'Brien, T. Ono, P. I. Palmer, D. Pierrot, B. Poulter, L. Resplandy, E. Robertson, C. Rödenbeck, J. Schwinger, R. Séférian, I. Skjelvan, A. J. P. Smith, A. J. Sutton, T. Tanhua, P. P. Tans, H. Tian, B. Tilbrook, G. Van Der Werf, N. Vuichard, A. P. Walker, R. Wanninkhof, A. J. Watson, D. Willis, A. J. Wiltshire, W. Yuan, X. Yue, and S. Zaehle. 2020. Global Carbon Budget 2020. Earth System Science Data 12:3269–3340. Available from: https://essd.copernicus.org/articles/12/3269/2020/.

Goldstein, A., W. R. Turner, S. A. Spawn, K. J. Anderson-teixeira, S. Cook-patton, J. Fargione, H. K. Gibbs, B. Griscom, J. H. Hewson, J. F. Howard, J. C. Ledezma, S. Page, L. P. Koh, J. Rockström, J. Sanderman, and D. G. Hole. 2020. Protecting irrecoverable carbon in Earth's ecosystems. Nature Climate Change 10:287–295. Available from: https://www.nature.com/articles/s41558-020-0738-8.

Hengl, T., J. M. de Jesus, R. A. MacMillan, N. H. Batjes, G. B. M. Heuvelink, E. Ribeiro, A. Samuel-Rosa, B. Kempen, J. G. B. Leenaars, M. G. Walsh, and M. R. Gonzalez. 2014. SoilGrids1km — Global Soil Information Based on Automated Mapping. PLoS ONE 9:e105992. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0105992.

Hengl, T., and I. Wheeler. 2018, December 24. Soil organic carbon stock in kg/m2 for 5 standard depth intervals (0–10, 10–30, 30–60, 60–100 and 100–200 cm) at 250 m resolution. Zenodo. Available from: https://zenodo.org/records/2529721.

Liu, J., B. M. Sleeter, Z. Zhu, T. R. Loveland, T. Sohl, S. M. Howard, C. H. Key, T. Hawbaker, S. Liu, B. Reed, M. A. Cochrane, L. S. Heath, H. Jiang, D. T. Price, J. M. Chen, D. Zhou, N. B. Bliss, T. Wilson, J. Sherba, Q. Zhu, Y. Luo, and B. Poulter. 2020. Critical land change information enhances the understanding of carbon balance in the United States. Global Change Biology 26:3920–3929. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.15079.

Luyssaert, S., E. D. Schulze, A. Börner, A. Knohl, D. Hessenmöller, B. E. Law, P. Ciais, and J. Grace. 2008. Old-growth forests as global carbon sinks. Nature 455:213–215. Available from: https://www.nature.com/articles/nature07276.

Miner, K. R., M. R. Turetsky, E. Malina, A. Bartsch, J. Tamminen, A. D. McGuire, A. Fix, C. Sweeney, C. D. Elder, and C. E. Miller. 2022. Permafrost carbon emissions in a changing Arctic. Nature Reviews Earth & Environment 3:55–67. Available from: https://www.nature.com/articles/s43017-021-00230-3.

Plaza, C., E. Pegoraro, R. Bracho, G. Celis, K. G. Crummer, J. A. Hutchings, C. E. Hicks Pries, M. Mauritz, S. M. Natali, V. G. Salmon, C. Schädel, E. E. Webb, and E. A. G. Schuur. 2019. Direct observation of permafrost degradation and rapid soil carbon loss in tundra. Nature Geoscience 12:627–631. Available from: https://www.nature.com/articles/s41561-019-0387-6.

Ryan, M. G., M. E. Harmon, R. a Birdsey, C. P. Giardina, L. S. Heath, R. a Houghton, R. B. Jackson, D. C. Mckinley, J. F. Morrison, B. C. Murray, D. E. Pataki, and K. E. Skog. 2010. A synthesis of the science on forests and carbon for U.S. forests. Issues in Ecology 13:1–16. Available from: https://www.fs.usda.gov/rm/pubs_other/rmrs_2010_ryan_m002.pdf.

Shi, Z., S. D. Allison, Y. He, P. A. Levine, A. M. Hoyt, J. Beem-Miller, Q. Zhu, W. R. Wieder, S. Trumbore, and J. T. Randerson. 2020. The age distribution of global soil carbon inferred from radiocarbon measurements. Nature Geoscience 13:555–559. Available from: https://www.nature.com/articles/s41561-020-0596-z.

Tierney, J. E., C. J. Poulsen, I. P. Montañez, T. Bhattacharya, R. Feng, H. L. Ford, B. Hönisch, G. N. Inglis, S. V. Petersen, N. Sagoo, C. R. Tabor, K. Thirumalai, J. Zhu, N. J. Burls, G. L. Foster, Y. Goddéris, B. T. Huber, L. C. Ivany, S. K. Turner, D. J. Lunt, J. C. McElwain, B. J. W. Mills, B. L. Otto-Bliesner, A. Ridgwell, and Y. G. Zhang. 2020. Past climates inform our future. Science 370. Available from: https://www.science.org/doi/full/10.1126/science.aay3701.

5d: Terrestrial Ecosystem Representation

Highlights:

- Ecosystem representation indicates how well various ecosystem types are included in an existing protected area network and emphasizes where underrepresented ecosystems occur that may be prioritized for future protection.
- Terrestrial ecosystem representation within GAP 1 and 2 protected areas of the North Slope is generally high. Falling outside GAP 1 and 2 lands, the NPR-A contains lower representation scores for many of its ecosystems, especially along the northern coastal plain, including much of the Teshekpuk Lake and Colville River Special Areas.
- Lands within the NPR-A, both within and outside of Special Areas, contain terrestrial ecosystem types currently under-represented in the existing North Slope protected area system, suggesting need for additional protections.

Overview

Ecosystem representation indicates how well various ecosystem types are included in an existing protected area network and emphasizes where underrepresented ecosystems occur that may be prioritized for future protection (Aycrigg et al. 2013; Dietz et al. 2015). This is based on the idea that protected areas more fully conserve genetic, species, and community diversity when they encompass the full variety of ecosystem types across their geographic range (Olson and Dinerstein 1998; Margules and Pressey 2000). Indeed, one of the primary approaches to conservation planning is to try to "represent, in a system of protected areas, all native ecosystem types…across their natural range of variation" (Noss and Cooperrider 1994 p.89). Ecosystem representation assessment allows an evaluation of how well this is being achieved.

Areas with strong protections, such as designated Wilderness and other protected lands, can also serve as conservation references, setting a benchmark to compare against conditions in more heavily managed or modified lands (Belote et al. 2015). Their value as reference points, however, depends in part on how well they represent existing ecosystem diversity (Belote et al. 2015). Based on the concept of complementarity, understanding of ecosystem representation can help identify priorities for future management and conservation action, suggesting areas where ecosystem types currently underrepresented in a protected area network might be added to improve the overall diversity of the network.

Representation has been evaluated in multiple contexts, including for protected areas broadly in the United States (Aycrigg et al. 2013) and internationally (Mancheno et al. 2017; Ye et al. 2017), for specific U.S. federal land management categories (Dietz et al. 2015; Talty et al 2020), for private lands (Graves et al. 2019; Ivanova and Cook 2020), and for wildlife habitat and diversity (Campos et al. 2017; Dietz et al. 2020; McCarley and Aycrigg 2020). Such efforts identify areas where ecological systems were already well represented and those for which gaps remained. They also enable evaluation of what other federal lands could be added to the current protected area system to improve representation (e.g., Aycrigg et al. 2016b) and serve as a building block for more comprehensive evaluation of where wild, connected, and diverse areas exist that may support creation of a more resilient network of protected areas (Aycrigg et al. 2016a; Belote et al. 2017a). Such efforts can help inform the application of different conservation strategies, including under a changing climate (Belote et al. 2017b), though care must be taken in their interpretation and application (Dreiss et al. 2024).

Despite the progress that has been made in evaluating ecological representation, there remain many areas in which such assessments have yet to be conducted. For example, ecosystem representation analyses in the US typically have been constrained to the contiguous US (e.g., Aycrigg et al. 2013; Dietz et al. 2015), leaving Alaska and Hawaii excluded. To begin to address this gap, The Wilderness Society conducted an evaluation of terrestrial ecosystem representation for the North Slope of Alaska.

Methods

In this analysis we focused on terrestrial ecosystem representation. Freshwater and marine habitats offer a tremendous array of diversity that supports a correspondingly rich assemblage of species, however sufficient high-quality data were not available for our study area to adequately represent such habitats. Analyses were conducted for the North Slope of Alaska (hereafter, North Slope), which we define as all areas north of the crest of the Brooks Range of mountains (NRC 2003; Figure 5d.1). The North Slope comprises about 203,700 km^2 and features a gradient of topography stretching from the peaks of the Brooks Range at 2736 m elevation along the southern boundary to the coast of the Arctic Ocean, with the Chukchi Sea to the northwest and the Beaufort Sea to the northeast. Beyond the mountains and foothills of the Brooks Range, much of the North Slope consists of coastal plain tundra, featuring an internationally renowned complex of wetlands and lakes.

Terrestrial ecosystems were depicted using a land cover map for the North Slope of Alaska produced by the North Slope Science Initiative (NSSI; Ducks Unlimited 2013). Where gaps existed between this map and the North Slope study area extent, they were filled by crosswalking fine-scale land cover data from the Alaska Natural Heritage Program (Boggs et al. 2014) to the classes in the NSSI dataset. Representation of these land cover classes (hereafter, ecosystems) was evaluated compared to ecosystems within lands classified as GAP status 1 or 2 (Belote et al. 2017a) in the Protected Areas Database of the US Gap Analysis Program (USGS 2016). GAP status 1 and 2 lands are characterized by having permanent protection from conversion of natural land cover, using an established management plan (USGS 2016). Terrestrial ecosystem representation in our study thus reflects the area of each ecosystem type within GAP 1 and 2 protected areas divided by the total area of that ecosystem type

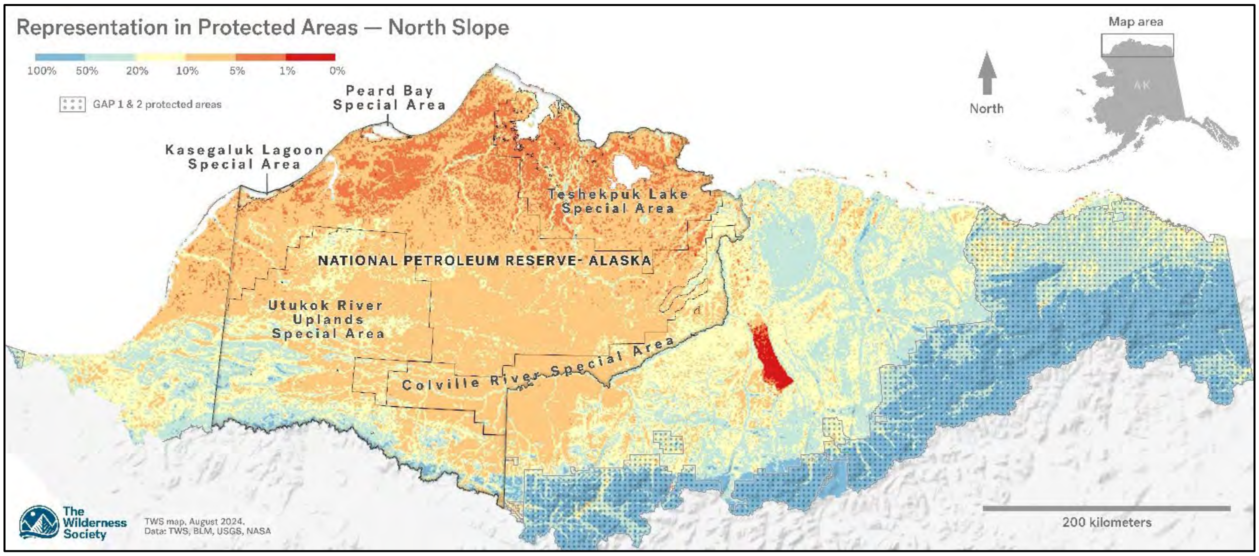

Figure 5d.1. Terrestrial ecosystem representation across the North Slope of Alaska, defined here as areas north of the crest of the Brooks Range mountains. Higher representation scores indicate terrestrial ecosystem types that are well-represented in the current GAP 1 & 2 protected areas on the North Slope while those with lower scores are underrepresented in the existing protected area network on the North Slope. Please see Appendix B for a higher resolution version of this figure.

across the North Slope. Higher values indicate greater representation within the existing conservation system while lower values indicate gaps in coverage.

Findings

The National Petroleum Reserve – Alaska (NPR-A) falls outside of GAP 1 and 2 lands, which occur primarily in the eastern and southern portions of the North Slope (Figure 5d.1). Terrestrial ecosystem representation within those GAP 1 and 2 protected areas is generally high. The NPR-A, in contrast, stands out as containing much lower representation scores for many of its ecosystems, especially along the northern coastal plain (Figure 5d.1). This includes much of the land within the Teshekpuk Lake Special Area and portions of the Colville River Special Area (Figure 5d.2). Many of the ecosystems in these areas have less than 10% of their North Slope extent contained within GAP 1 and 2 protected areas, leaving them more vulnerable to disturbance and development. The Utukok River Uplands Special Area has slightly higher representation scores across much of its extent, though most ecosystems still have less than 20% of their North Slope extent in GAP 1 and 2 protections (Figure 5d.2). These results emphasize the important role that lands within the NPR-A, both within and outside of Special Areas, play in housing terrestrial ecosystem types currently under-represented in the existing North Slope protected area system.

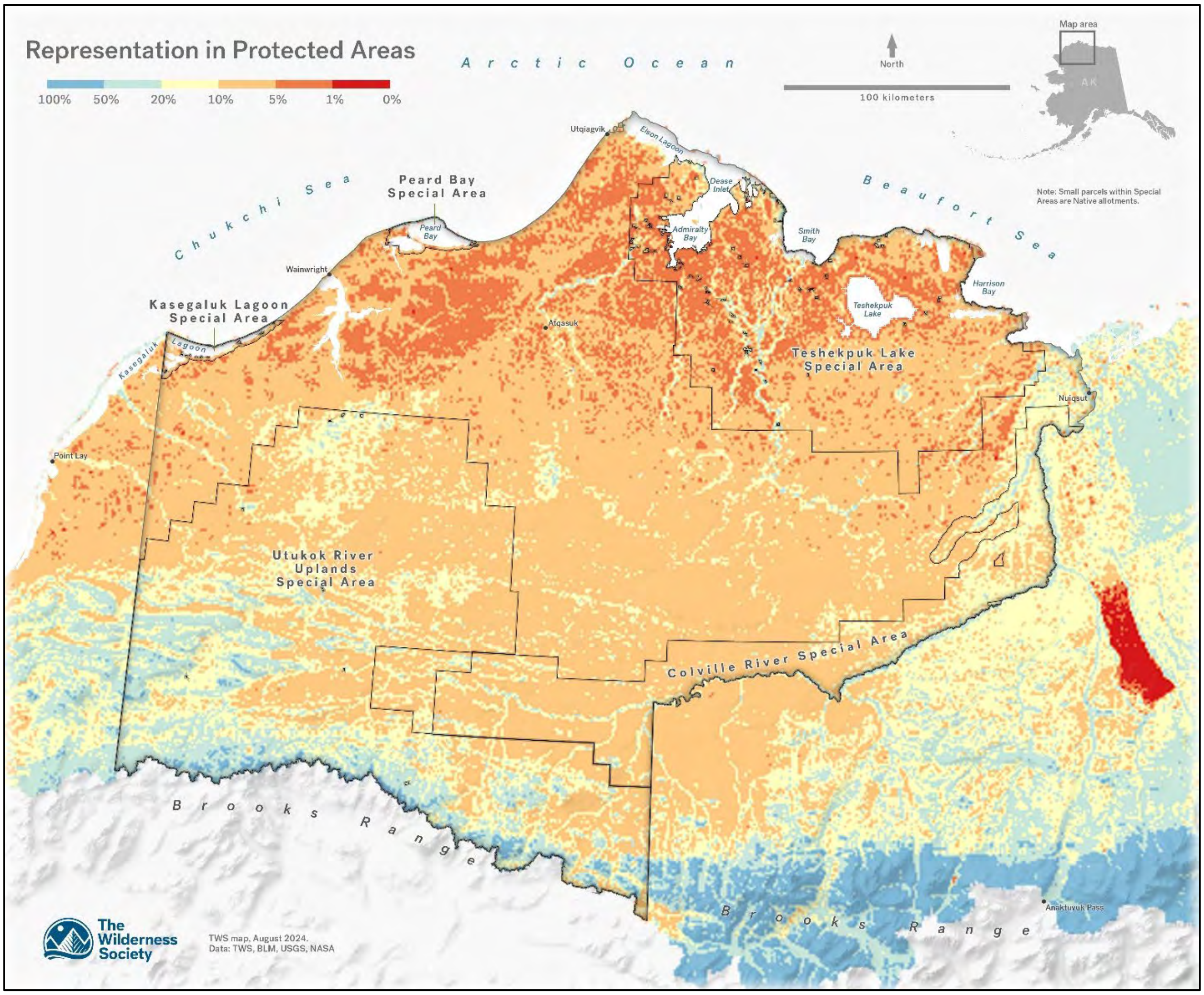

Figure 5d.2. Terrestrial ecosystem representation within the National Petroleum Reserve – Alaska. Higher representation scores indicate terrestrial ecosystem types that are well-represented in the current GAP 1 & 2 protected areas on the North Slope while those with lower scores are underrepresented in the existing protected area network on the North Slope. Please see Appendix B for a higher resolution version of this figure.

Terrestrial ecosystems representation literature cited

Aycrigg JL, Davidson A, Svancara LK, Gergely KJ, McKerrow A, Scott JM. 2013. Representation of ecological systems within the protected areas network of the continental United States. PLoS ONE 8(1), e54689. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0054689.

Aycrigg JL, Groves C, Hilty JA, Scott JM, Beier P, Boyce Jr DA, Figg D, Hamilton H, Machlis G, Muller K, Rosenberg KV, Sauvajot RM, Shaffer M, Wentworth R. 2016a. Completing the system: opportunities and challenges for a national habitat conservation system. BioScience 66(9), 774-784. Available from: https://academic.oup.com/bioscience/article/66/9/774/1753772.

Aycrigg JL, Tricker J, Belote RT, Dietz MS, Duarte L, Aplet GH. 2016b. The next 50 years: opportunities for diversifying the ecological representation of the National Wilderness Preservation System within the contiguous United States. Journal of Forestry 114(3), 396-404. Available from: https://academic.oup.com/jof/article/114/3/396/4599832?login=false.

Belote RT, Dietz MS, Aplet GH. 2015. Allocating untreated “controls” in the National Wilderness Preservation System as a climate adaptation strategy: A case study from the Flathead National Forest, Montana. Northwest Science 89:239-254. Available from: https://bioone.org/journals/northwest-science/volume-89/issue-3/046.089.0311/Allocating-Untreated-Controls-in-the-National-Wilderness-Preservation-System-as/10.3955/046.089.0311.short.

Belote RT, Dietz MS, Jenkins CN, McKinley PS, Irwin GH, Fullman TJ, Leppi JC, Aplet GH. 2017a. Wild, connected, and diverse: building a more resilient system of protected areas. Ecological Applications 27, 1050-1056. Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1002/eap.1527.

Belote RT, Dietz MS, McKinley PS, Carlson AA, Carroll C, Jenkins CN, Urban DL, Fullman TJ, Leppi JC, Aplet GH. 2017b. Mapping conservation strategies under a changing climate. BioScience 67, 494-497. Available from: https://academic.oup.com/bioscience/article/67/6/494/3102936?login=false.

Boggs K, Boucher TV, Kuo TT, Fehringer D, Guyer S. 2014. Vegetation map and classification: Northern, Western and Interior Alaska, 2014 update. Alaska Natural Heritage Program, University of Alaska Anchorage, Anchorage, Alaska, USA. Available from: https://accscatalog.uaa.alaska.edu/node/41/revisions/85/view.

Campos FS, Lourenço-de-Moraes, Llorente GA, Solé M. 2017. Cost-effective conservation of amphibian ecology and evolution. Science Advances 3, e1602929. Available from: https://www.science.org/doi/10.1126/sciadv.1602929.

Dietz MS, Belote RT, Aplet GH, Aycrigg JL. 2015. The world’s largest wilderness protection system after 50 years: An assessment of ecological system representation in the U.S. National Wilderness Preservation System. Biological Conservation 184:431-438. Available from: https://www.sciencedirect.com/science/article/pii/S0006320715000944?via%3Dihub.

Dietz MS, Belote RT, Gage J, Hahn BA. 2020. An assessment of vulnerable wildlife, their habitats, and protected areas in the contiguous United States. Biological Conservation 248, 108646. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0006320720307047?via%3Dihub.

Dreiss LM, Anderson MG, Bateman BL, Belote RT, Michalak JL, Rice MB. 2024. Agreeing that maps can disagree: moving away from map confusion in conservation. BioScience 74(4), 281-289. Available from: https://academic.oup.com/bioscience/article-abstract/74/4/281/7617360?redirectedFrom=fulltext&login=false.

Ducks Unlimited, Inc. 2013. North Slope Science Initiative landcover mapping summary report. Rancho Cordova, CA. Available from: https://catalog.northslopescience.org/gl/dataset/2450.

Graves RA, Williamson MA, Belote RT, Brandt JS. 2019. Quantifying the contribution of conservation easements to large-landscape conservation. Biological Conservation 232, 83-96. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0006320718311984?via%3Dihub.

Ivanova IM, Cook CN. 2020. The role of privately protected areas in achieving biodiversity representation within a national protected area network. Conservation Science and Practice 2(12), e307. Available from: https://conbio.onlinelibrary.wiley.com/doi/10.1111/csp2.307.

Mancheno CSM, Zazanashvili N, Beruchashvili G. 2017. Effectiveness of the network of protected areas of the South Caucasus at representing terrestrial ecosystems after the dissolution of the Soviet Union. Environmental Conservation 44(2), 158-165. Available from: https://www.cambridge.org/core/journals/environmental-conservation/article/abs/effectiveness-of-the-network-of-protected-areas-of-the-south-caucasus-at-representing-terrestrial-ecosystems-after-the-dissolution-of-the-soviet-union/A67AB300C78F7CFFDACCCC6DB4254931.

Margules CR, RL Pressey. 2000. Systematic conservation planning. Nature 405:243-253. Available from: https://www.nature.com/articles/35012251.

McCarley TR, Aycrigg JL. 2020. Biodiversity within the National Wilderness Preservation System: how well do Wilderness areas represent species richness across the contiguous United States? International Journal of Wilderness 26, 3. Available from: https://ijw.org/biodiversity-national-wilderness-preservation-system/.

Noss RF, Cooperrider AY. 1994. Saving nature’s legacy. Island Press, Washington DC, USA. Available from: https://islandpress.org/books/saving-natures-legacy#desc.

Olson DM, Dinerstein E. 1998. The global 200: a representation approach to conserving the earths most biologically valuable ecoregions. Conservation Biology 12:502-515. Available from: https://conbio.onlinelibrary.wiley.com/doi/10.1046/j.1523-1739.1998.012003502.x.

Talty MJ, Lacroix KM, Aplet GH, Belote RT. 2020. Conservation value of national forest roadless areas. Conservation Science and Practice 2(11), e288. Available from: https://conbio.onlinelibrary.wiley.com/doi/10.1111/csp2.288.

USGS. 2016. Protected Areas Database of the United States (PAD-US), version 1.4. United States Geological Survey Gap Analysis Program. Available from: https://www.sciencebase.gov/catalog/item/56bba648e4b08d617f657960.

Ye X, Liu G, Li Z, Gong L, Wang M, Wang H. 2017. Evaluation of ecological effectiveness of protected areas in northwest China. Chinese Geographical Science 27, 259-272. Available from: https://link.springer.com/article/10.1007/s11769-017-0854-1.

Map Data Sources

The sources below were used in the maps created by The Wilderness Society (TWS), which are also featured with higher resolution in Appendix B.

Bivariate intactness:

Belote, R. T., S. Faurby, A. Brennan, N. H. Carter, M. S. Dietz, B. Hahn, W. J. McShea, and J. Gage. 2020. Mammal species composition reveals new insights into Earth's remaining wilderness. Frontiers in Ecology and the Environment 18:376–383. Available from: https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/fee.2192.

Elevation data:

ASTER GDEM created by NASA, METI, AIST, Japan:Spacesystems and U.S./Japan ASTER Science Team. Accessed via Google Earth Engine. Earth Engine Resource: https://gee-community-catalog.org/projects/aster/. ASTER product: https://doi.org/10.5067/ASTER/ASTGTM.003.

Existing BLM Alaska oil and gas leases:

State of Alaska Geoportal. Available from: https://gis.data.alaska.gov/datasets/BLM-EGIS::blm-ak-oil-and-gas-lease-tract-npra/explore?location=70.239728%2C-152.764404%2C7.00.

Existing pipelines, roads, well pads:

North Slope Science Initiative. Available from: https://catalog.northslopescience.org/dataset/2663.

Existing State of Alaska oil and gas leases:

Alaska Department of Natural Resources. "Current State Oil and Gas Leases." Available from: https://dog.dnr.alaska.gov/Information/MapsAndGis.

Generalized caribou ranges:

Trammell EJ, Carlson ML, Fresco N, Gotthardt T, McTeague ML, Vadapalli D, eds. 2015. *North Slope Rapid Ecoregional Assessment*. Prepared for the Bureau of Land Management, U.S. Department of the Interior. Anchorage, Alaska, USA. Available from: https://accscatalog.uaa.alaska.edu/sites/default/files/REA_NorthSlope_Report.pdf.

Generalized major rivers:

Government of Canada; Natural Resources Canada; Canada Centre for Mapping and Earth Observation. Available from: http://www.cec.org/north-american-environmental-atlas/lakes-and-rivers-2023/.

Geology & ecological landscapes:

Jorgenson, M. T., and J. Grunblatt. 2013. Landscape-Level Ecological Mapping of Northern Alaska and Field Site Photography Report. Arctic Landscape Conservation Cooperative. Available from: https://catalog.northslopescience.org/dataset/8e2d5a71-7808-4ea2-b60b-c2b615fceaa8/resource/7aead4d6-4fe9-4914-bc38-a1e072ff6030/download/n-alaska-landscape-mapping-and-field-site-photography-2013.pdf.

Human modification:

Theobald, D. M., C. Kennedy, B. Chen, J. Oakleaf, S. Baruch-Mordo, and J. Kiesecker. 2020. Earth transformed: Detailed mapping of global human modification from 1990 to 2017. Earth System Science Data 12:1953–1972. Available from: https://essd.copernicus.org/articles/12/1953/2020/essd-12-1953-2020.html.

Indigenous trade routes & sites:

U.S. Department of the Interior. 1979. National Petroleum Reserve in Alaska, 105(c) Land Use Study, National Petroleum Reserve in Alaska, Native Livelihood and Dependence: A study of land use values through time. Anchorage, AK. Available from: https://www.arlis.org/docs/vol1/N/NPRA/5974397.pdf.

Land cover:

TWS adaptation of data (see Section 5d for details) from:

North Slope Science Initiative: Ducks Unlimited, Inc. 2013. North Slope Science Initiative landcover mapping summary report. Rancho Cordova, CA. Available from: https://catalog.northslopescience.org/gl/dataset/2450.

Boggs K, Boucher TV, Kuo TT, Fehringer D, Guyer S. 2014. Vegetation map and classification: Northern, Western and Interior Alaska, 2014 update. Alaska Natural Heritage Program, University of Alaska Anchorage, Anchorage, Alaska, USA. Available from: https://accscatalog.uaa.alaska.edu/node/41/revisions/85/view.

Land ownership:

BLM National Surface Management Agency Area Polygons. Available from: https://gbp-blm-egis.hub.arcgis.com/datasets/6bf2e737c59d4111be92420ee5ab0b46/about.

Leasing & infrastructure restrictions within NPR-A Special Areas:

BLM. 2022. Integrated Activity Plan Record of Decision geospatial data. Available from: https://eplanning.blm.gov/eplanning-ui/project/117408/590.

NPR-A boundary:

BLM Integrated Activity Plan Introduction geodatabase. Available from: https://eplanning.blm.gov/eplanning-ui/project/117408/590.

Soil carbon 30cm:
Food and Agriculture Organization of the United Nation and the Intergovernmental Technical Panel on Soils. 2018. Global soil organic carbon map. Technical report. Page 162. Food and Agriculture Organization of the United Nations, Rome. Available from: https://openknowledge.fao.org/server/api/core/bitstreams/c3ccec0d-fe75-49b7-9a4c-ee0a8777fed9/content.
Data from: https://openknowledge.fao.org/items/c0b7c9bc-d8e9-4d45-8ef2-969f58f01247.

Soil carbon 200cm:
Hengl, T., J. M. de Jesus, R. A. MacMillan, N. H. Batjes, G. B. M. Heuvelink, E. Ribeiro, A. Samuel-Rosa, B. Kempen, J. G. B. Leenaars, M. G. Walsh, and M. R. Gonzalez. 2014. SoilGrids1km — Global Soil Information Based on Automated Mapping. PLoS ONE 9:e105992. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0105992.
Data from: https://zenodo.org/records/2536040.

Special Area boundaries:
BLM. 2022. Integrated Activity Plan Record of Decision geospatial data. Available from: https://eplanning.blm.gov/eplanning-ui/project/117408/590.

Subsistence camps:
Trammell EJ, Carlson ML, Fresco N, Gotthardt T, McTeague ML, Vadapalli D, eds. 2015. *North Slope Rapid Ecoregional Assessment*. Prepared for the Bureau of Land Management, U.S. Department of the Interior. Anchorage, Alaska, USA. Available from: https://accscatalog.uaa.alaska.edu/sites/default/files/REA_NorthSlope_Report.pdf.

Terrestrial Ecosystem Representation on the North Slope of Alaska:
TWS unpublished data. See Section 5d for description.

Water data:
United States Geological Survey National Hydrography Dataset. Available from: https://prd-tnm.s3.amazonaws.com/index.html?prefix=StagedProducts/Hydrography/NHD/State/GPKG/.

Western Arctic Herd calving overlap:
Cameron MD, Joly K, Breed GA, Mulder CPH, Kielland K. 2020. Pronounced fidelity and selection for average conditions of calving area suggestive of spatial memory in a highly migratory ungulate. Frontiers in Ecology and Evolution 8, 564567. Available from: https://www.frontiersin.org/journals/ecology-and-evolution/articles/10.3389/fevo.2020.564567/full. Data received directly from authors.

Wildness on the North Slope of Alaska:
TWS unpublished data. See Section 5b for description.