4. Affected Environment

This chapter describes the physical, biological, social, cultural, and economic components of the environment of Arctic National Wildlife Refuge (Arctic Refuge, Refuge) that could be affected by the management alternatives described in this Comprehensive Conservation Plan (Plan). The chapter also describes land status, special designations, and infrastructure for and staffing of the Refuge. Appendix F lists the scientific names of the plants and animals of the Refuge.

4.1 Geographic Setting

4.1.1 Refuge History

The Refuge has a long history. During World War II, a public land order (PLO 82; January 22, 1943) withdrew much of the land in northern Alaska for "use in connection with the prosecution of the war." This 49-million-acre[1] withdrawal included the entire Arctic coastal plain, including lands previously reserved as the National Petroleum Reserve No. 4 (Executive Order 3797-A; February 23, 1923). When land is "withdrawn," it is closed to some or all of the public land laws and/or mineral laws and reserved for a particular purpose or program administered by a Federal agency.

During the 1950s, the wilderness movement was gaining momentum. Two National Park Service (NPS) employees, George Collins and Lowell Sumner, were convinced that the northeastern corner of Alaska was one of the best remaining examples of true wilderness. Together with the help of nationally prominent conservationists, they sought its protection. While there was considerable support for the idea, there was also strong opposition from those concerned about future industrial development of the Alaska territory. The political struggle ended on December 6, 1960, when Secretary of the Interior Fred A. Seaton signed PLO 2214, creating the Arctic National Wildlife Range (Range, Arctic Range), and PLO 2215, revoking the existing withdrawal (PLO 82). The 8.83-million-acre Arctic Range was established for the "purpose of preserving unique wildlife, wilderness and recreational values" and was withdrawn from all forms of appropriation under the public land laws, including mining but not mineral leasing laws.

The action represented both a victory and a compromise for conservationists. In exchange for designating the Arctic Range, the national conservation community quietly withdrew its opposition to the revocation of PLO 82, which had effectively protected most of Arctic Alaska from State and corporate appropriation. Interior Secretary Seaton signed PLO 2215 immediately after signing PLO 2214, enabling the State to acquire and develop lands beyond the Range's western boundary, including what became the Prudhoe Bay oil field.

PLO 2214 had two clauses. The first outlined the purposes for the Arctic Range ("preserving unique wildlife, wilderness and recreational values"). The second stated that the Secretary of the Interior was authorized to permit "the hunting, and the taking of game animals, birds, and

[1] Acreages in this Plan are derived from many sources and may not agree with previously published values, including the draft Revised Plan. For more information, please refer to "A Note about Acreages" in the front pages of this volume.

fish in the wildlife range…as well as the trapping of fur animals." The clause went on to say, "State law shall govern all hunting and taking of wildlife which the Secretary of the Interior permits under the terms of this order."

On December 2, 1980, the Alaska National Interests Lands Conservation Act (ANILCA, Public Law 96-487) established the Arctic National Wildlife Refuge. Section 303(2) of ANILCA specified the Refuge include the existing Arctic National Wildlife Range[2], including "lands, waters, interests, and whatever submerged lands, if any, were retained in Federal ownership at the time of statehood," plus an additional 11.04 million acres of public lands.

ANILCA Section 303(2)(B), identified four purposes for managing the Refuge. Chapter 1 (Section 1.4.2.1) of this Plan describes these purposes (ANILCA purposes). Under the provisions of ANILCA Section 305, the three 1960 purposes are to remain in force and effect on the original Range lands to the extent they are consistent with ANILCA; however, the ANILCA purposes apply to the entire Refuge. ANILCA also designated the Ivishak, Sheenjek, and Wind rivers within the Refuge boundary as national wild rivers (Section 603) and about 7.16 million acres as the Arctic Wildlife Refuge Wilderness (Section 702(3)).

The newly created Wilderness included most of the original Range, except for approximately 1.57 million acres of the Arctic coastal plain. This area of the coastal plain (the "1002 Area"), was opened to limited oil and gas exploratory activity pursuant to ANILCA Section 1002. Section 1002 also directed the Secretary of the Interior to prepare a report to Congress on biological resources, the oil and gas potential of the coastal plain, and the impacts of development, and provide recommendations as to whether further oil and gas exploration and development should be permitted. In 1987, the Department of the Interior (DOI) published the Arctic National Wildlife Refuge, Alaska, Coastal Plain Resource Assessment report, which found that the coastal plain met criteria of the Wilderness Act for designation. While the Secretary of the Interior recommended to Congress that the entire 1002 Area should be open to oil and gas leasing programs at such a pace and in such circumstances so as to avoid unnecessary adverse effects on the environment, Congress has not acted on this recommendation.

ANILCA Section 1003 prohibits production of oil and gas on Arctic Refuge and requires congressional authorization before undertaking any leasing or other development leading to production of oil and gas from the original Range. In 1988, Congress amended ANILCA Section 1302 through Public Law 100-395, which requires congressional authorization before the Secretary can exchange or otherwise convey lands or interests in lands in the coastal plain of Arctic Refuge. The amendment addressed congressional concerns that exchanges could ultimately preempt the authority of Congress to make the decision whether to lease and develop oil and gas resources of the coastal plain.

The last major additions to the Refuge occurred in the mid-1980s. About 1.3 million acres of land, originally selected by the State of Alaska under the Alaska Statehood Act (Public Law 85-508) but later relinquished, was added to the Refuge in two actions occurring in 1983 and 1985. This State selected land was located 40 miles east of Arctic Village on the southern slopes of the Brooks Range and was surrounded on three sides by Refuge land. On August 16, 1988, the President signed the Alaska Submerged Lands Act (Public Law 100-395), which

[2] On February 29, 1980, about nine months before passage of ANILCA, the Arctic National Wildlife Range was renamed the William O. Douglas Arctic Wildlife Range by Presidential Proclamation 4729.

amended ANILCA. Section 301 of the Submerged Lands Act added 325,000 acres to Arctic Refuge. These acres were a former proposed utility and transportation corridor managed by the Bureau of Land Management (BLM). Both these additions were of lands already within the boundaries of the Refuge as established by ANILCA.

In 1996, Public Law 104-167 officially renamed the "Arctic National Wildlife Refuge Wilderness" the "Mollie Beattie Wilderness." The name change posthumously honors conservationist Mollie Beattie, the first female director of the U.S. Fish and Wildlife Service (Service).

4.1.2 Land Status

The exterior boundary of Arctic Refuge encompasses nearly 19.86 million acres, of which about 19.64 acres (99 percent) are administered by the Refuge. Table 4-1 shows, by general ownership, the approximate area of non-Refuge lands within the Refuge boundary.

The Alaska Native Claims Settlement Act of 1971 (ANCSA) and ANILCA determined the current land ownership patterns in and surrounding Arctic Refuge. ANCSA authorized the formation of Alaska Native village and regional corporations, enabling northeast Alaska's Native Iñupiat and Athabascan peoples to select and gain title to Federal lands that were originally part of their ancestral homelands.

Nine years later, ANILCA established the current Refuge boundaries. For the most part, boundary lines roughly followed major ecological features, such as rivers or watersheds, regardless of existing land ownership. Consequently, the Refuge surrounds non-Refuge land in a variety of ownerships, including Alaska Native allotments, Alaska Native corporation lands (regional and village), a town site, and other Federal agency withdrawals (Table 4-1, Map 4-1).

Complete conveyances of Native corporation land selections, and thus changes in land ownership, were scheduled to be finished in 2009 under the provisions of the Alaska Land Transfer Acceleration Act of 2004 (Public Law 108-452). However, it is likely that there will be continued but minor land ownership changes as selected lands are conveyed, relinquished, or rejected, and land conveyed by interim conveyances is surveyed prior to patent.

Table 4-1. Surface land status as of March 21, 2012

Land Status	Arctic Refuge (acres) [a]		
Federal (U. S. Fish and Wildlife Service)	19,660,000		
	Selected [b]	Conveyed [b, c]	Other
Arctic Slope Regional Corporation	0	11,088.00	
Doyon Limited	1,200	85,994.61	
Kaktovik Iñupiat Corporation	4,400	90,108.20	
Native Allotments	319.97	11,470.25	
Town Site (Canyon Village)	0	29.86	
Other Federal Agency	0	0	669
Total	5,919.97	198,690.92	669

[a] Official Service acreage from the "Annual Report of Lands Under Control of the U.S. Fish and Wildlife Service as of September 30, 2009" states Arctic Refuge is 19,286,722 acres, which includes 5,822 acres of Native selected land. Official Service acreage differs from the GIS-derived acreage of 19,660,000 acres cited in Table 4-1. The GIS-derived acreage includes the Refuge's coastal lagoons. For more information about acreage values, see "A Note about Acreages" in the front matter of this volume.

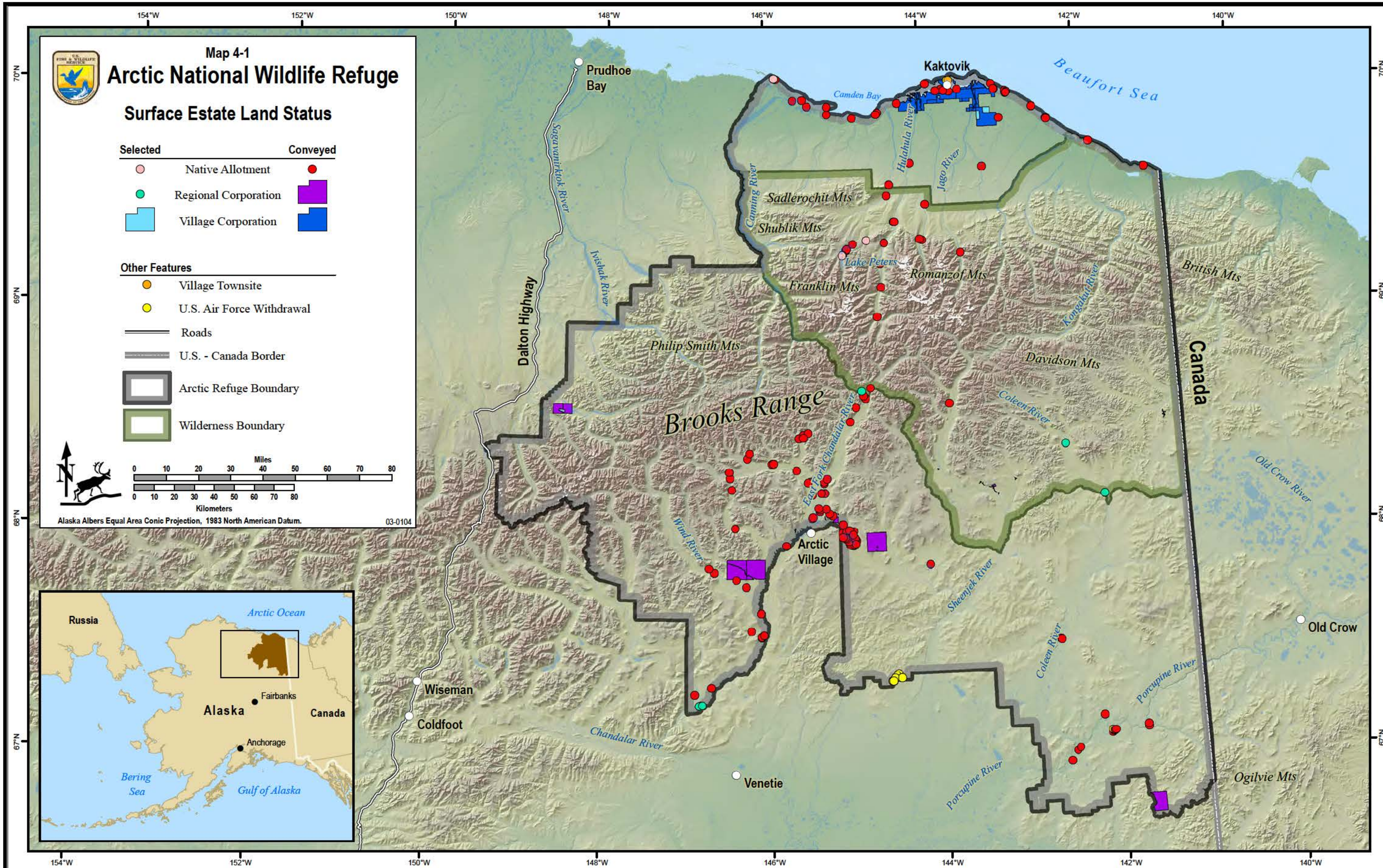
[b] Acreages of Native conveyed lands are from legal documents (deeds, patents, interim conveyance documents). Acreages of selected lands are GIS-calculated approximations and may differ from acreage figures reported elsewhere. The source for the GIS data is the Master Title Plats maintained by the Bureau of Land Management. Acreage figures exclude submerged beds of meandered water bodies (rivers of 198 feet or more in width and lakes of 50 acres or more), within interim conveyed and patented Native corporation lands. Ownership of the submerged lands beneath water bodies outside of Native corporation ownership depends on the navigability status and is yet to be determined for most water bodies. No ownership of the land beneath these water bodies is implied in this table.

[c] Includes patented and interim conveyed lands. Only land claims within the Refuge boundary are reported.

4.1.2.1 Regional Native Corporation Lands

Section 7 of ANCSA authorized the Secretary of the Interior to divide the State into 12 geographic regions, each composed of Alaska Natives sharing a common heritage. The regions were to be based upon existing Native associations. Arctic Refuge spans portions of two geographic regions represented by the Arctic Slope Regional Corporation (ASRC) and Doyon Limited (Doyon). The provisions of ANCSA Sections 12 and 14 determined the land entitlements for each regional corporation. Regional corporations were prevented from selecting the subsurface estate in refuges (such as the former Arctic Range) but were authorized to select an equivalent acreage elsewhere.

Doyon owns 123,204.47 acres of land in the southern part of the Refuge and ASRC owns 11,088.00 acres surrounding Elusive Lake in the western Brooks Range. ANCSA conveyance rules prevented ASRC from obtaining subsurface estate in the former Arctic Range; however, the corporation received a large tract of subsurface through a land exchange. In the Chandler Lake Land Exchange, ASRC exchanged 101,272 acres of surface lands in Gates of the Arctic National Park for the subsurface estate beneath the Kaktovik Iñupiat Corporation (KIC) lands on the coastal plain (more than 90,000 acres). The acquired subsurface estate is in an area considered to have oil and gas potential; however, the commercial development of oil and



Map 4-1
Arctic National Wildlife Refuge
Surface Estate Land Status
Selected
Conveyed
Native Allotment
Regional Corporation
Village Corporation
Other Features
Village Townsite
U.S. Air Force Withdrawal
Roads
U.S. - Canada Border
Arctic Refuge Boundary
Wilderness Boundary
Miles
0 10 20 30 40 50 60 70 80
0 10 20 30 40 50 60 70 80
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
03-0104
Prudhoe Bay
Kaktovik
Beaufort Sea
Camden Bay
Hulahula River
Jago River
Canning River
Sagavanirktok River
Ivishak River
Dalton Highway
Sadlerochit Mts
Shublik Mts
Lake Peters
Romanzof Mts
Franklin Mts
Kongakut River
British Mts
Philip Smith Mts
Davidson Mts
Canada
Brooks Range
East Fork Chandalar River
Coleen River
Old Crow River
Wind River
Arctic Village
Sheenjek River
Old Crow
Porcupine River
Wiseman
Coldfoot
Chandalar River
Venetie
Ogilvie Mts
Russia
Arctic Ocean
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska
154°W
152°W
150°W
148°W
146°W
144°W
142°W
140°W
70°N
69°N
68°N
67°N

gas from ASRC's acquired subsurface in the Refuge is contingent upon an act of Congress, as provided in ANILCA Section 1002 and 1003. ASRC may remove sand and gravel from these lands, provided they follow provisions in the Chandler Lake Exchange agreement that specify how and where sand and gravel pits are located and developed. The exchange included land use stipulations to ensure the conveyance of the subsurface to ASRC would not "undermine the essential integrity of the Arctic National Wildlife Refuge and will not frustrate the purposes of the Refuge." The stipulations remain with the land even if it is sold or exchanged.

In the late 1980s, a review by the General Accounting Office concluded that the Chandler Lake Land Exchange and other proposed exchanges in Arctic Refuge were not in the public interest. In 1988, Congress legislated to prevent more land exchanges within the Arctic coastal plain without congressional approval (P.L. 100-395, amending ANILCA 1302(h)(2).

4.1.2.2 Village Native Corporation Lands

Section 8 of ANCSA provided that the Native residents of each Native village entitled to receive lands under ANCSA "shall organize as a business for profit or nonprofit corporation under the laws of the State of Alaska…." Section 11 of ANCSA created the framework and made certain public lands available for selection by village corporations. Section 11(B)(b)(1) lists the villages subject to ANCSA, including those in the ASRC and Doyon regions. Of these, only unoccupied Canyon Village is within the boundaries of the Refuge. The communities of Venetie and Arctic Village in the Doyon region and Kaktovik in the ASRC region are outside the Refuge boundary but in close proximity.

ANCSA Section 12(a) established rules guiding village corporation land selections. Selections were to include all of the townships in which the village was located. Any additional selections necessary to meet the village's entitlement were to be made from adjacent townships. However, selections of a village corporation located in a national wildlife refuge were limited to 69,120 acres within the refuge boundaries; any remaining land entitlement had to be selected from land outside refuge boundaries.

Because of its location in the former Arctic Range, KIC was subject to this stipulation. However, a provision included in a subsequent land exchange agreement, ratified by ANILCA Section 1431, authorized KIC to acquire its full ANCSA land entitlement in the Refuge. The village site itself is located just outside of the Refuge boundary (as established by ANILCA).

The communities of Venetie and Arctic Village own land adjacent to the Refuge. These villages chose to opt out of the ANCSA land claims settlement. In 1943, the Secretary of the Interior had created the Venetie Indian Reservation for the Neets'aii Gwich'in on approximately 1.8 million acres of their traditional lands. Among other things, ANCSA revoked the Venetie Reservation and all but one other reservation in Alaska. The two Native corporations established for the Neets'aii Gwich'in elected to make use of an ANCSA provision allowing them to take title to former reservation lands in return for giving up the cash and land settlement provided by ANCSA. The United States conveyed fee simple title to the former reservation lands to the Native corporations as "tenants in common." The two corporations then transferred the title for all of the land to the Native Village of Venetie Tribal Government.

Canyon Village's situation is also unusual. At the passage of ANCSA, its population was below the minimum requirement for an ANCSA village. In such cases, Section 14(h)(2) authorized conveyance of up to 23,040 acres to a Native group not qualifying as a Native village, provided that it is incorporated under the laws of the State of Alaska. In 1976, Canyon Village filed a land selection for 5,760 acres of land under this ANCSA provision. At the time of this application, the area in which this selection was made was designated by PLO 3520 as a powersite withdrawal and was therefore unavailable for selection. Although PLO 3520 was later revoked (1990), the application to select the land remained invalid, as the selected land had been designated part of the Refuge by ANILCA in 1980. Canyon Village currently owns no ANCSA-conveyed land but does hold title to a Native town site (see Section 4.1.2.4) in the Refuge. The town site is currently unoccupied.

4.1.2.3 Native Allotments

Until its repeal in 1971, the Native Allotment Act of 1906 authorized individual Alaska Natives to claim up to 160 acres of land. In addition, a 1998 amendment to ANCSA (Section 432 of Public Law 105-276 [43 U.S.C. 1629g]) authorized qualified Alaska Native Vietnam veterans to apply for an allotment if they had not previously done so. The 1998 law addressed the concern that military service may have prevented some Native veterans from applying for an allotment under the 1906 act. The application period for these new allotments closed on January 31, 2002. To date, 123 allotments have been patented in Arctic Refuge.

4.1.2.4 Town Sites

Three Federal laws created the opportunity for Alaska Native villages to establish town sites and convey title to Alaska Native adults:

- The act of March 3, 1891 (26 Stat. 1095), opened Federal land in Alaska for the establishment of town sites.
- The Alaska Native Town Site Act of May 25, 1926 (44 Stat. 629), created the opportunity for Native villages to establish town sites, to survey lots and streets, and to convey lots by restricted deed to Alaska Natives.
- The act of February 26, 1948 (62 Stat. 35), included a provision that allowed the conveyance of town site lots to Alaska Natives by unrestricted deeds.

Kaktovik in 1967 and Canyon Village in 1981 received patent to Federal land (280.92 acres and 29.86 acres, respectively) for the establishment of town sites. Only the Canyon Village town site is within the Refuge boundary, as the Kaktovik site was excluded.

4.1.2.5 ANCSA 22(g)

All lands (including surface and subsurface estates) conveyed under ANCSA in pre-ANCSA national wildlife refuges are subject to section 22(g) of ANCSA. Under section 22(g), refuge lands conveyed under ANCSA remain subject to the laws and regulations governing use and development of the refuge. This means that the refuge manager evaluates the uses proposed by 22(g) landowners to determine whether they are compatible with refuge purposes. The evaluation considers only the effects of the use on the adjacent refuge lands and the ability of the refuge to meet its mandated purposes. The refuge manager can impose special conditions to ensure the compatibility of a proposed use. The evaluation does not consider the effects of the use on the 22(g) lands. Section 22(g) also reserves the right of first refusal to the United States if the lands are offered for sale.

4.1.2.6 ANCSA 14(h)(1)

Under the provisions of ANCSA Section 14(h)(1), regional corporations could apply for and receive conveyance to cemetery sites and historical places. A covenant in the conveyance document states that the corporation shall not authorize any use that is incompatible with or in "derogation of the values as a cemetery site/historical place," including mining or mineral activities of any type. The covenant remains with the land, and the United States reserves the right to seek enforcement of the covenant. Furthermore, 14(h)(1) sites in refuges are subject to the provisions of ANCSA Section 22(g).

Currently, 27 parcels totaling 3,284.34 acres have been conveyed as cemetery sites or historical places. Another five parcels (totaling 1,144.31 acres) are selected but not yet conveyed.

4.1.2.7 State of Alaska

The Alaska Statehood Act (Public Law 85-508) entitled the State to select 102,550,000 acres of vacant or unreserved lands, or lands not appropriated under the general grant, and to select an additional 400,000 acres to promote development and expansion of communities. The State was also granted title to most of the existing roads, airfields, and associated facilities under the Alaska Omnibus Act (Public Law 86-70) enacted on June 25, 1959. The Arctic Refuge boundary established by ANILCA was drawn to exclude a large tract of land east of Arctic Village that had been selected by the State of Alaska. However, the State later relinquished these lands and about 1,300,000 acres were added to the Refuge in 1983 and 1985. There are no other State conveyed or selected lands in the Refuge.

4.1.2.8 Submerged Lands

In general, the Equal Footing Doctrine, the Submerged Lands Act of 1953, and the Statehood Act of 1958 granted the lands beneath tidelands and inland navigable waters to the State of Alaska. Lands beneath water bodies that were reserved or withdrawn by the Federal government prior to statehood on January 3, 1959, may have been retained by the United States. If the United States did not reserve or withdraw submerged lands, then the ownership of inland submerged lands is determined on the basis of navigability. If an inland water body is navigable, the underlying bed of the river or lake belongs to the State; if non-navigable, the bed belongs to the adjacent upland landowner(s). The term navigable has a legal definition and does not simply refer to whether a boat can navigate the body of water.

After statehood, the ownership of coastal submerged lands within the original Arctic Range boundary was disputed by the State and Federal governments. The dispute was settled in 1997 when the Supreme Court ruled that submerged lands (including tidally influenced lands) within the Arctic Range boundary did not transfer to the State of Alaska at statehood (United States v. Alaska, No. 84 Original). The Court's decision recognized that the application to create the Arctic Range (which pre-dated statehood) clearly intended these submerged lands to be included as part of the Range. Arctic Refuge, therefore, contains navigable and non-navigable waters. Submerged lands within the boundaries of the original Arctic Range, including river beds, were retained in Federal ownership on the date Alaska was granted statehood. However, the status of many water bodies outside the former Arctic Range has not yet been determined. Any disagreements between the State and the Federal government over what waters are navigable or non-navigable that cannot be resolved, can only be finally resolved through the Federal courts.

4.1.2.9 Refuge Boundary Issues

In 2000, a court-ordered decree was jointly prepared by the State and Federal governments to address the location of the Refuge boundary bordering the Beaufort Sea. The decree defined the coastal boundary as following the line of extreme low water for offshore bars, reefs, and islands and lagoons. As such, the boundary is considered to be “ambulatory” and prone to migrate if relevant physical features change. The Supreme Court accepted the decree but retained jurisdiction to consider and accept future joint proposals from the State and the United States regarding the coastal boundary of the Refuge. Efforts to jointly define a non-ambulatory administrative boundary have thus far been unsuccessful.

The eastern boundary of Arctic Refuge abuts Canada. Lands adjacent to the boundary have been continuously reserved for 100 years. In 1912, President Taft reserved all public land “lying within sixty feet of the Boundary Line between the United States and the Dominion of Canada” from entry, settlement, or other forms of appropriation under the public land laws.

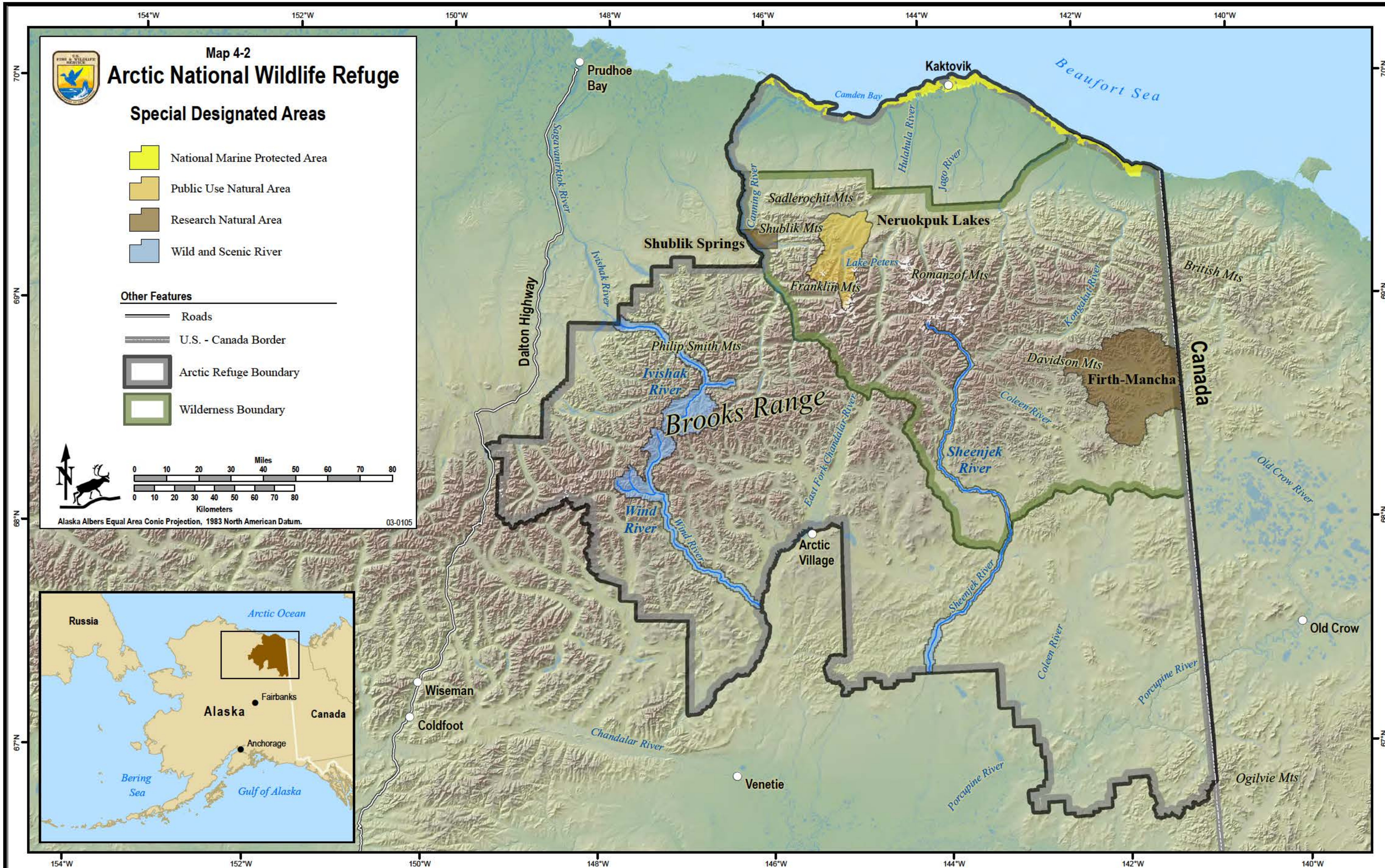
4.1.3 Special Designations

In addition to refuge status, the special status of lands in individual refuges may be recognized by additional designations, either legislatively or administratively. Special designation may also occur through the actions of other agencies or organizations. The influence that special designations have on the management of lands and waters in refuges may vary considerably. Arctic Refuge contains a number of special designated areas (Map 4-2).

4.1.3.1 Research Natural Areas

Two Research Natural Areas (RNAs), the Firth River-Mancha Creek (also known as Firth-Mancha) RNA and the Shublik Springs RNA, were established in the Refuge on August 5, 1975, as part of a national system of RNAs. This designation differs from other classifications, such as Wilderness, refuge, or preserve, in that the latter designations often have broader use and management objectives than the preservation and scientific applications of the RNA system (Federal Committee on Ecological Reserves 1977). RNAs receive no special legislative protection; additional protections, if any, are derived only from the individual agencies that manage them. Both of the Refuge’s RNAs occur entirely in designated Wilderness. The Firth-Mancha RNA is approximately 520,000 acres and is located in the northeastern portion of the Refuge. The Shublik Springs RNA is approximately 34,000 acres and is located in the northwestern portion of the Refuge.

The purpose of RNAs is to preserve examples of all major ecosystem types in the country, to provide opportunities for research and education, and to preserve a full range of genetic and behavioral diversity in native plants and animals (Service 1988a). The original RNA system received no special legislative protection; it was left to the administering agencies to provide additional protective measures. However, with the passing of ANILCA in 1980, Arctic Refuge’s two RNAs became a part of the Refuge’s designated Wilderness, granting additional protection.



Map 4-2
Arctic National Wildlife Refuge
Special Designated Areas
National Marine Protected Area
Public Use Natural Area
Research Natural Area
Wild and Scenic River
Other Features
Roads
U.S. - Canada Border
Arctic Refuge Boundary
Wilderness Boundary
Miles
0 10 20 30 40 50 60 70 80
0 10 20 30 40 50 60 70 80
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
03-0105
154°W
152°W
150°W
148°W
146°W
144°W
142°W
140°W
70°N
69°N
68°N
67°N
Prudhoe Bay
Kaktovik
Beaufort Sea
Camden Bay
Sagavanirktok River
Hulahula River
Jago River
Canning River
Sadlerochit Mts
Shublik Mts
Neruokpuk Lakes
Shublik Springs
Lake Peters
Romanzof Mts
Franklin Mts
British Mts
Ivishak River
Kongakut River
Dalton Highway
Philip Smith Mts
Davidson Mts
Firth-Mancha
Canada
Ivishak River
Brooks Range
Coleen River
East Fork Chandalar River
Sheenjek River
Old Crow River
Wind River
Wind River
Arctic Village
Sheenjek River
Old Crow
Coleen River
Porcupine River
Wiseman
Coldfoot
Chandalar River
Venetie
Porcupine River
Ogilvie Mts
Russia
Arctic Ocean
Fairbanks
Alaska
Canada
Anchorage
Bering Sea
Gulf of Alaska

Although no management plan or objectives have been developed for these RNAs, the description on which the Firth-Mancha RNA designation was based stated that "the area will be maintained in a natural condition permitting succession to advance to a climax without interference" (Service 1988a). A similar goal was stated for the Shublik Springs RNA in its area description: the area was to be dominated by natural processes of succession, with no improvement or disturbance of the habitat (Service 1988a). Both RNAs are managed as Wilderness, which ensures the integrity of these areas.

4.1.3.2 Public Use Natural Areas

The Neruokpuk Lakes Public Use Natural Area was established on May 2, 1977. It is approximately 212,000 acres and is the only Public Use Natural Area (PUNA) in the Refuge. It is located in the Brooks Range, entirely in the designated Wilderness area. It was chosen as a PUNA because of its relative ease of access, scenic beauty, and abundant wildlife.

The purposes of PUNAs are to preserve important natural areas for public use and to preserve these areas essentially unmodified by human activity for future use (Service 1988a). No management plan or objectives have been established for the Neruokpuk Lakes PUNA. However, it is managed as Wilderness, which ensures the integrity of this area.

4.1.3.3 Marine Protected Area

In 2005, all marine waters located within Refuge boundaries were nominated as part of the National Marine Protected Area System. Currently, approximately 91,000 acres of marine waters and lagoons located off the northern coast of the Refuge are a designated marine protected area (MPA). Given the uncertainty of shifting shorelines and the point at which to differentiate between freshwater and saltwater at river mouths, the acreage estimate for the MPA is plus or minus several hundred acres.

Executive Order 13158, issued in 2000, strengthened and expanded the nation's system of MPAs and defined them as "...any area of the marine environment that has been reserved by Federal, State, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein."

There are no special conditions for managing the MPA. Some parts of the MPA fall in designated Wilderness, while others are outside of the Wilderness boundary. The current management approach ensures the integrity of this area.

4.1.3.4 Wild Rivers

In 1980, ANILCA designated those portions of the Ivishak, Sheenjek, and Wind rivers within the boundaries of Arctic Refuge as wild rivers under the Wild and Scenic Rivers Act. The Service established corridor boundaries for each of the rivers through the 1988 Plan. All three rivers are part of the National Wild and Scenic Rivers System (NWSRS), and the Refuge manages the rivers under the Wild River Management category (see Chapter 2, Section 2.3.5). In this management category, water bodies are maintained in natural, free-flowing, and undisturbed conditions, where the evidence of human activities is minimized.

Each river in the NWSRS has particular values for which it was designated, and management of a wild river must protect those specific values. Congress did not specify values for the Ivishak, Sheenjek, and Wind rivers. The Refuge will use legislative records, historic reports, and current information to determine the values for each river through individual Comprehensive River Management Plans (see Chapter 2, Section 2.1.3, Objective 3.5).

The Ivishak River flows north through the Philip Smith Mountains and the northern foothills of Arctic Refuge to join the Sagavanirktok River on the Arctic coastal plain south of Prudhoe Bay. From its headwaters, the Ivishak develops an increasingly wide, braided floodplain typical of northern Alaska rivers. Bird life on the river likely exceeds 100 species. Sixty-one miles of the 95-mile-long Ivishak River lie in Arctic Refuge. The wild river corridor encompasses 200,000 acres and includes all of the river's headwaters.

The Sheenjek River originates from glaciers in the Romanzof Mountains. This river travels south 200 miles to join the Porcupine River near its junction with the Yukon River. The Sheenjek flows through a wide variety of Arctic habitats and scenery. Portions of the Porcupine caribou herd occasionally winter in the Sheenjek valley. The segment of the Sheenjek River classified as wild totals 191 miles. The river management corridor encompasses 150,000 acres.

The Wind River, also classified as wild, flows for 102 miles and is entirely within the boundary of Arctic Refuge. Beginning in the Philip Smith Mountains, this river offers a wide variety of vegetation, scenery, and wildlife characteristic of tundra-taiga transition on the South Slope of the Refuge. All of the river's headwaters are included in the river's corridor, which is 200,000 acres in size.

4.1.3.5 Wilderness Qualities

Section 304(g) of ANILCA requires the Service to identify and describe the special values of the Refuge, including wilderness values. Congressionally designated Wilderness is subject to the provisions of the Wilderness Act of 1964 and to the modifying provisions of ANILCA. Areas not designated as Wilderness may possess wilderness-associated values but may or may not have the same degree of natural and other qualities as designated Wilderness. In Arctic Refuge, 7.16 million acres were designated as Wilderness by ANILCA in 1980. The lands that were part of the original Range retain the 1960 establishing purpose to preserve the unique wilderness values of the area to the extent the establishing purpose is not inconsistent with ANILCA (see Chapter 1, Section 1.4.2). With only a few exceptions, the designated Wilderness and the non-designated areas (Minimal Management category) of the Refuge have been managed in the same manner.

The Wilderness Act describes four primary qualities of Wilderness. The following are descriptive of the Refuge's designated Wilderness and much of the non-designated areas of the Refuge, with the exception of certain tracts in the vicinity of Kaktovik and Arctic Village (see Appendix H).

Undeveloped

The undeveloped quality of Wilderness is defined as free from roads, structures, and other evidence of modern human occupation or improvements, where the land essentially retains its original character and ecological function (Landres et al. 2008). The undeveloped quality can influence opportunities to experience solitude and unconfined recreation.

Untrammeled

The Wilderness Act states that Wilderness is an area where the land and its biological communities are untrammeled by humans. In other words, Wilderness is essentially unrestricted and free from modern human control or manipulation (Landres et al. 2008). The untrammeled quality of the Wilderness resource can be diminished when ecological events or processes are constrained or manipulated.

Natural

In designated Wilderness, ecological systems are substantially free from the effects of modern civilization (Landres et al. 2008). Natural condition is the degree to which an area remains substantially free from the effects of modern civilization; it is affected primarily by the forces of nature and looks natural to the average visitor.

Opportunities for Solitude or Primitive and Unconfined Recreation

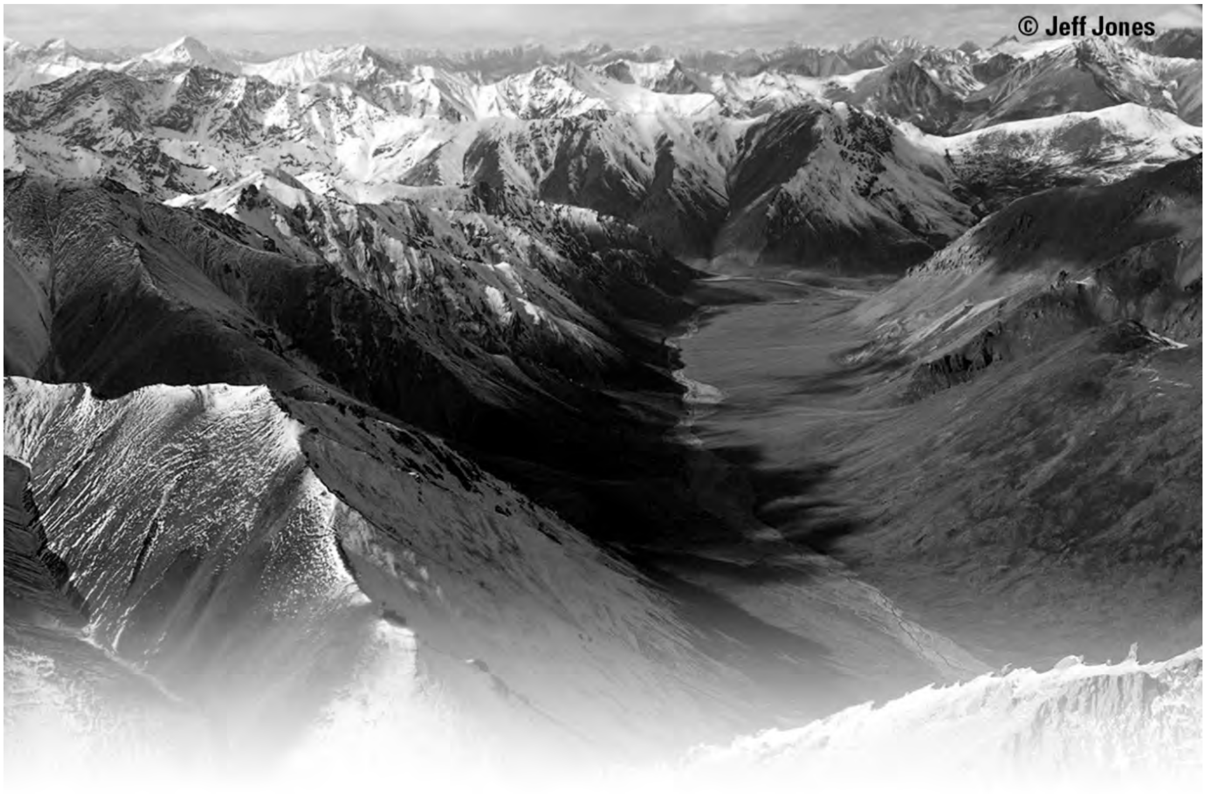
Primitive or unconfined recreation in wilderness settings is characterized by non-motorized methods of travel, no or minimal facilities, self-reliance, and a minimum of restrictions on the visitor’s travel and behavior. Privacy and isolation are important components, but solitude also is enhanced by the absence of distractions, such as large groups, mechanization, unnatural noise and light, unnecessary managerial presence (such as signs), and other modern artifacts.

Primitive or unconfined recreation in wilderness settings is characterized by freedom from management restrictions on visitor behavior (Landres et al. 2008). Travel in Wilderness usually is by non-motorized and non-mechanical means (e.g., walking or paddling). Wilderness recreation may often include the experiences of challenge, risk, self-reliance, and/or freedom. Facilities in Wilderness can decrease the challenges of self-reliant recreation. Dispersed travel and camping patterns, in an area with little or no facilities, can enhance opportunities for unconfined recreation.

4.1.3.6 Designated Wilderness

At 7.16 million acres, the Refuge’s designated Wilderness area is the largest, wildest, and most diverse Wilderness in the National Wildlife Refuge System (Refuge System). It includes five ecoregions, spanning 132 miles (mi) or 213 kilometers (km) north to south. The coastal marine system along the Beaufort Sea in the eastern quarter of the Refuge along the Canadian border is characterized by bays, inlets, and lagoons sheltered by barrier islands, and the Kongakut River delta. The coastal plain consists of a narrow band of relatively flat, wet, and moist tundra. The Brooks Range Foothills consists of a narrow swath of gently rolling hills and plateaus that ascend from the coastal plain to the mountains. The Brooks Range Mountains, reaching to 9,000 feet, dominate the unit, which contains the highest peaks and most glaciers in the Brooks Range. Rugged crags, deep-cleft valleys, knife-like ridges, and expansive vistas combine to make it dramatically scenic. The Davidson Mountains flank the southern Brooks Range. Dissected by broad, spruce-lined valleys, some of these lower-level mountains are steep and rugged, while others are rounded and gradual.

The variety of unaltered habitats supports a great diversity of high-interest arctic and subarctic wildlife, including whales, seals, polar and brown bears, wolves, wolverines,



muskoxen, moose, Dall's sheep, and wide-ranging caribou. Most species of birds, mammals, and fish in the Refuge use this Wilderness for at least some portion of their life cycles. The many animal and plant species that live there are integral components of the area's ecology.

The purposes of the Wilderness Act are additional purposes of the designated Wilderness portion of the Refuge, specifically:

> *"Secure an enduring resource of wilderness; protect and preserve the wilderness character of areas within the National Wilderness Preservation System (NWPS); administer the NWPS for the use and enjoyment of the American people in a way that will leave these areas unimpaired for future use and enjoyment as wilderness; and gather and disseminate information regarding the use and enjoyment of wilderness areas."*

The designated Wilderness is administered in accordance with the Wilderness Act, the special provisions of ANILCA, and other laws and regulations governing management of the Refuge System. A primary purpose is to maintain the area's Wilderness character: the natural and scenic condition of the land, natural numbers and interactions of wildlife, and the integrity and freedom of ecological processes. Consistent with protection of Wilderness character, the area provides for a wide range of uses. It is regularly used for subsistence hunting and fishing by residents of Kaktovik and occasionally by Arctic Villagers. Scientists conduct investigations related to biology, ecology, geology, and climate change. In 2010, an estimated 720 visitors came seeking adventure and solitude through a variety of activities—river floating, backpacking, camping, mountain climbing, wildlife observation, hunting, and fishing.

4.2 Physical Environment

4.2.1 Landforms and Geology

Arctic Refuge lies across the spine of the Brooks Range Mountains in the northeast corner of Alaska. It spans roughly 200 mi north to south from the Beaufort Sea coast of the Arctic Ocean to the Porcupine and Chandalar River tributaries of the Yukon River. From east to west, the Refuge is 180 mi across at its maximum width between the U.S.–Canada border and the Sagavanirktok River drainage near the Dalton Highway (Map 4-2). Five ecoregions (Nowacki et al. 2001) encompass the Refuge in a roughly north-south direction (Map 4-3). Those ecoregions include the Beaufort Sea coastal plain, the Brooks Range Foothills, the Brooks Range Mountains, the Davidson Mountains, the Yukon–Old Crow Basin, and the North Ogilvie Mountains. The following descriptions of these ecoregions are taken primarily from Gallant et.al. (1995), Nowacki et.al. (2001), and the Alaska Division of Geological and Geophysical Surveys (1987).

4.2.1.1 Beaufort Sea Coastal Plain

This ecoregion is a smooth tree-less plain rising very gradually (slope gradients generally less than 1°) from the Arctic Ocean to the foothills of the Brooks Range, 590 feet/foot (ft) (180 meters [m]) above sea level. Locally, permafrost-related features mark the terrain surface-ice related features, such as extensive networks of ice-wedge polygons, oriented lakes, peat ridges, frost boils, and pingos (ice-cored hills) are common. The coastal plain in Arctic Refuge is relatively narrow, ranging from 2.5–25 mi (4–40 km) in width. In contrast, this ecoregion is over 100 mi (160 km) wide south of Barrow.

The coastal plain sediments are late-Quaternary deposits of marine, glacial-fluvial, alluvial, and aeolian origin. Siltstone and sandstone underlay the unconsolidated materials at depths of several to tens of meters. Much of the coastal plain is dominated by a series of large alluvial fans.

4.2.1.2 Brooks Range Foothills

In Arctic Refuge, the Brooks Range Foothills ecoregion consists of a narrow swath of rolling hills and plateaus that rises from the coastal plain on the north to the Brooks Range on the south. The hills and valleys of the ecoregion have better defined drainage patterns than those found in the coastal plain to the north, and have fewer lakes. This ecoregion is underlain by thick permafrost, and many ice-related surface features are present. Like the coastal plain, the northern portion of the Brooks Range Foothills are built from unconsolidated Quaternary materials of glacial, alluvial, and aeolian origin with several small exposures of sandstone, siltstone, and shale (Imm et al. 1993). Elevations are generally less than 2,000 ft (600 m) above sea level.

This ecoregion was free from Pleistocene glaciation (except for some areas directly north of the Brooks Range) but is underlain by thick permafrost. Many ice-related features are present, such as gelifluction lobes, ice-wedge polygons, stone stripes, and beaded stream drainages. Regional slope gradients generally vary from 0° to 5°, but may be steeper in some areas.

4.2.1.3 Brooks Range Mountains

The Brooks Range ecoregion represents the northernmost extension of the Rocky Mountains. The Brooks Range consists of a wide belt of mountain ranges that arc gently east to west across the Refuge. The long, central, northeast-trending crest of the Philip Smith Mountains forms the continental drainage divide where the range enters the Refuge from the southwest. In the north central portion of the Refuge, where the range bends east and southeast, the highest peaks of the Franklin, Romanzof, and British Mountains project up abruptly at the north front of the range (Alaska Division of Geological and Geophysical Surveys 1987). North of the Franklin Mountains are the Shublik Mountains, lying between the Canning and Sadlerochit rivers. The isolated Sadlerochit Mountains lie to the north of the Shublik Mountains.

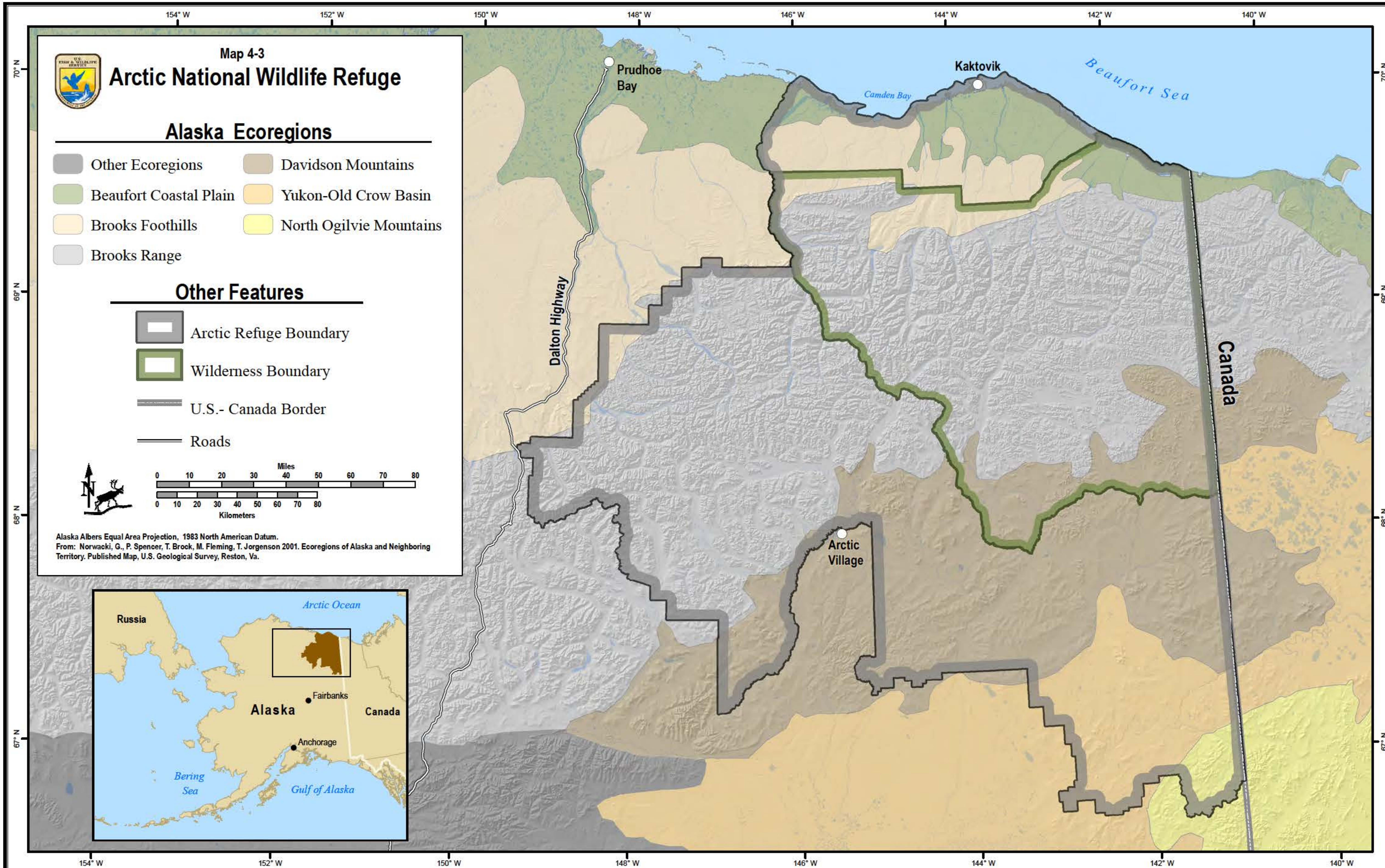
Topography throughout the Brooks Range is rugged, reflecting glaciation and differential erosion of tilted, folded, and faulted rock layers. Valleys are wide, steep sided and flat floored, cut by glaciers and then filled with alluvium. Mountain summits are generally from 4,000 to 6,000 ft (1,200 to 1,800 m) in the Philip Smith Mountains; 7,000 to 8,000 ft (2,100 to 2,400 m) in the Franklin Mountains; and 8,000 to 9,000 ft (2,400 to 2,700 m) in the Romanzof Mountains. The four highest peaks in the Brooks Range are in the Refuge in the Romanzof Mountains, the highest being 9,020-ft (2,760-m) Mount Chamberlin.

The bedrock underlying the Brooks Range consists of folded and faulted stratified Paleozoic and Mesozoic sedimentary deposits (including sandstone, shale, and limestone marine and nonmarine deposits, and some metamorphic rocks) that were uplifted during the Cretaceous period. Rubble and exposed bedrock cover the mountain slopes. The Sadlerochit and Shublik Mountains are mostly limestone, quartz, sandstone, dolomite, and a shale-quartz-chert sandstone conglomerate. In the Franklin and Romanzof Mountains, an east to west formation of schist lies to the north adjacent to a latitudinal chert and phillite formation. The oval Okpilak batholith spanning the Okpilak River on the north edge of the range is composed of course-grained granite. To the east, the British Mountains are latitudinal strips (north to south) of volcanic rock, calcareous siltstone and sandstone, and schist. Bathtub Ridge, south of British Mountains, is capped by lithic graywacke, and ringed with marine deposits of shale, siltstone, and sandstone. The remainder of the Brooks Range in the Refuge, including the Philip Smith Mountains, is primarily limestone with surface inclusions of quartzite, schist, sandstone, and shale (Imm et al. 1993).

This ecoregion was extensively glaciated during the Pleistocene epoch, but only small, scattered alpine glaciers persist above 6,000 ft (1,800 m) in the Franklin and Romanzof Mountains. Continuous, thick permafrost underlies the region.

4.2.1.4 Davidson Mountains

This ecoregion along the south flank of the Brooks Range consists of rugged mountains and steep, rounded ridges, dissected by broad floodplains of glacial origin. Elevations range from 1,600 ft (500 m) in the valleys to greater than 5,000 ft (1,500 m) on the peaks—with some peaks rising above 5,900 ft (1,800 m). Slope gradients are commonly within the range of 5° to 15°. Most of the ecoregion is overlain with unconsolidated (Quaternary) alluvial, colluvial, glacial and lacustrine deposits. Other geologic formations consists of volcanic rock (basalt), Lisburne Group Alapah limestone, Skagit limestone, a Kayak shale/Kanyut conglomerate/Noatak sandstone, Beaucoup formation of heterogeneous marine-deposited calcareous shale and



Map 4-3
Arctic National Wildlife Refuge
Alaska Ecoregions
Other Ecoregions
Davidson Mountains
Beaufort Coastal Plain
Yukon-Old Crow Basin
Brooks Foothills
North Ogilvie Mountains
Brooks Range
Other Features
Arctic Refuge Boundary
Wilderness Boundary
U.S.- Canada Border
Roads
Miles
0 10 20 30 40 50 60 70 80
0 10 20 30 40 50 60 70 80
Kilometers
Alaska Albers Equal Area Projection, 1983 North American Datum.
From: Norwacki, G., P. Spencer, T. Brock, M. Fleming, T. Jorgenson 2001. Ecoregions of Alaska and Neighboring Territory. Published Map, U.S. Geological Survey, Reston, Va.
Prudhoe Bay
Kaktovik
Camden Bay
Beaufort Sea
Dalton Highway
Canada
Arctic Village
Russia
Arctic Ocean
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska
154° W
152° W
150° W
148° W
146° W
144° W
142° W
140° W
70° N
69° N
68° N
67° N

sandstone, and exposed chert formations (Imm et al. 1993). Also in this ecoregion, close to the U.S.–Canada border, is the large Old Crow batholith composed of Balotite granite.

This ecoregion is underlain by continuous permafrost. Permafrost and frost-related ground features are evident, including low mounds, gelifluction lobes, frost boils, and stone stripes. Many of the peaks were glaciated during the Pleistocene epoch.

4.2.1.5 Yukon–Old Crow Basin

The Yukon–Old Crow Basin ecoregion abuts the Davidson Mountains in the southeast corner of the Refuge. This gently sloping basin along the Porcupine River is comprised of depositional fans, terraces, pediments, and mountain toeslopes that ring the Yukon and Old Crow Flats. The surfaces surrounding the flats are largely unglaciated and products of millions of years of weathering of the surrounding mountains. Here, deep deposits of colluvial, alluvial, and aeolian origin are underlain by continuous masses of permafrost. Active fluvial processes are etched throughout the topography featuring deltaic fans, terraces, and floodplains (Nowacki et al. 2001). Along with the unconsolidated deposits are inclusions of igneous rock (basalt and breccia) and formations of limestone, dolomite, and clay sedimentary and metamorphic rock (Imm et al. 1993).

4.2.1.6 North Ogilvie Mountains

The North Ogilvie Mountains primarily lie in the Yukon Territory but extend into the Southeast corner of the Refuge. This terrain consists of flat-topped hills and eroded remnants of a former plain (Nowacki et al. 2001). Sedimentary rocks of limestone and dolomite underlie most of the area along with small inclusions of basalt and quartzite sandstone (Imm et al. 1993). Unconsolidated deposits are only found in the narrow floodplains. Ridge tops and upper slopes are often barren with angular, frost-shattered rock outcrops surrounded by long scree slopes. These are characteristic of an unglaciated area that has undergone long periods of erosion (Nowacki et al. 2001).

4.2.1.7 Coastal Marine System

Although the coastal marine system was not designated separately by Nowacki et al. (2001), it deserves recognition here as a unique, functioning ecosystem because it holds important biological values for the Refuge. The coastal boundary of Arctic Refuge, defined as the line of extreme low water running along the coast and barrier islands from the U.S.–Canada border to Brownlow Point (Reed 2000), is 154 mi (247 km) in length and at a scale of 1:1000, there is approximately 593 mi (368 km) of inner shoreline (Brackney 2008). Sixteen bays and lagoons line Arctic Refuge coast and cover approximately 90,100 acres (ac) (365 km2) (Brackney 2008).

The Beaufort Sea coast is characterized by bays and inlets, lagoons with barrier islands, exposed peat bluffs, drained basins, and deltas. Jorgenson and Brown (2005) subdivided the Beaufort Sea coastline into segments by type and classified 266 mi (428 km) of Arctic Refuge shoreline, including spits and barrier islands, as follows:

- delta–72 mi (116 km), 27 percent
- exposed bluff–40 mi (64 km), 15 percent
- lagoon–154 mi (248 km), 58 percent

The lagoons are generally shallow with a maximum depth of 6.5–13 ft (2–4 m) and are wholly or partially sheltered by barrier islands. Bays and inlets may have spits across a portion of the mouth. Hachmeister and Vinelli (1984) classified eastern Beaufort Sea lagoons and bays as either open and exposed, limited exchange, or pulsing. Open and exposed habitats are bays or lagoons with little or no spit or barrier island protection from ocean wave action or nearshore water exchange. Limited exchange lagoons have partial barrier island protection, which restricts the flow of nearshore water. Pulsing lagoons have extensive barrier island protection with small narrow outlets and exhibit pulsing effects in water level due to tidal pumping. Traveling east from Barter Island, the coastline has a northeastern aspect, and the lagoons are all pulsing or limited exchange until you reach Demarcation Bay near the U.S.–Canada border. West of Barter Island, the coast has a primarily northwestern aspect, and the barrier islands are more fragmented across open and exposed lagoons and bays. With the exception of Kaktovik Lagoon, most lagoons are long and narrow with their long axis parallel to the shoreline.

Three modes of formation have likely generated the barrier islands: shoreward migration of existing beaches and barriers during the last sea level rise, lateral growth of spits and barriers, and stranding of the islands seaward of the coast as tundra is eroded (Morack and Rogers 1981, Naidu and Kelly 2002, Ruz et al. 1992, Short 1979). The islands are dynamic and migrating westward and landward due to wave action, currents, winds, and ice sediment deposition (Morack and Rogers 1981, Reimnitz et al. 1990). Major rivers may also be a primary source of sand and gravel to the islands with the sands deposited by westward littoral drift (Naidu and Kelly 2002). With the exception of Barter Island, remnant tundra islands are rare, and the majority of barrier islands along Arctic Refuge coast are composed of sand and gravel.

Shoreward of the barrier islands, the shoreline consists of eroding bluffs and complex embayments formed by the breaching of lakes and thermokarst basins through shoreline erosion (Ruz et al. 1992). Mean annual rates for the Beaufort Sea coast of Arctic Refuge estimated by Jorgenson and Brown (2005) varied from 3 feet of erosion per year to nearly 40 feet of accretion per year and depended on coastline type and lithology. The highest accretion rates were associated with deltas at the mouth of glacier-fed rivers.

4.2.1.8 Glaciers

The glaciations of the Pleistocene Epoch had large impacts on the landscapes of Alaska through the construction of outwash terraces, moraines, loess deposition, and erosion (Hamilton 1994, Hamilton and Porter 1975). The maximum extent of Pleistocene glaciations on Arctic Refuge covered the Philip Smith, Franklin, Romanzof, and British Mountains on both the north and south sides of the Brooks Range (Balascio et al. 2005a, Balascio et al. 2005b). Glaciers extended only short distances out into the foothills in some river valleys.

Today, glaciers are a small but important component of the Refuge landscape and have an important influence on downstream terrestrial and estuarine ecosystems (Nolan et al. 2011). Research on glaciers in the Refuge began with the International Polar Year in 1956. McCall Glacier, near Mt. Hubley, has the longest history of research of any U.S. Arctic glacier (Weller et al. 2007). The present day extent of the approximately 400 glaciers in Arctic Refuge is limited to several small areas in the Philip Smith Mountains and cirques and valley glaciers in the Romanzof Mountains. These glaciers covered over 140 mi^2 (360 km^2) in 1956 but have been losing mass at an increasing rate since the late 19th century (Nolan et al. 2005). Most will

likely vanish within the next 50 years (Nolan et al. 2011). McCall Glacier has retreated more than 2,600 ft (800 m) since the late 1800s (Nolan et al. 2005).

Currently, glacier melt water contributes considerably to the mid-late summer flow of several North Slope rivers, particularly the Hulahula, Jago, and Okpilak. This consistent flow benefits stream habitat for anadromous Dolly Varden (*Salvelinus malma*) fish populations and enhances the marine food web by increasing organic matter transport to estuarine ecosystems (Nolan et al. 2011). The freshwater and silts transported to the deltas from glacial melt maintains freshwater invertebrate populations that shorebirds rely on as a post-breeding food source. Reliable food sources are critical for these birds during the post-breeding period when they must put on sufficient fat reserves for long distance migration.

4.2.2 Climate

The climatic conditions of the Refuge mirror its diverse geographic features and latitudes. The mean annual temperature is below freezing in all parts of the Refuge and decreases to the north. The amounts of rain and snowfall are directly related to topography; high mountains receive the greatest amounts of precipitation, and lowland areas receive the least. There is a trend toward increasing continental and diminishing maritime influence with distance from the coast. Thus, temperature ranges and extremes tend to be greater inland.

Table 4-2 shows climate summaries for weather stations near Arctic Refuge. Stations are listed in order from the north coast across the Brooks Range to the interior boreal forest.

Table 4-2. Average temperature, precipitation, snowfall, and snow depth. These data are from long-term climate stations near Arctic Refuge, in order from north to south[a].

	Temperatures (°Fahrenheit) at Weather Stations							
	Barter Island	Kuparuk	Toolik Lake	Atigun Pass	Arctic Village	Old Crow	Bettles	Fort Yukon
January	-14	-17	-10	-5	-23	-24	-12	-19
February	-20	-18	-6	0	-18	-18	-8	-14
March	-16	-15	-5	-2	-2	-7	3	2
April	-1	1	9	13	14	12	21	22
May	21	23	30	30	38	37	43	44
June	34	40	48	41	54	54	58	59
July	40	47	53	44	58	58	59	62
August	39	44	46	38	49	52	53	56
September	32	34	32	26	32	38	41	41
October	15	16	11	10	11	15	19	20
November	-1	-3	-2	2	-11	-10	-1	-6
December	-12	-11	-8	-1	-12	-17	-9	-17
Avg. Annual Temp.	10	12	24	16	16	16	22	21
Annual Precipitation (inches)								
Total[b]	6	4	-[c]	24	9	11	14	7
Snowfall	42	32	-	-	49	51	83	42
Snow Depth	7	5	-	26	9	-	13	9
Station Information								
Station Elevation	30 ft	67 ft	2,362 ft	4,643 ft	2,085 ft	824 ft	630 ft	427 ft
Dates	1949-1988	1983-2009	1989-2007	1992-2009 [d]	1962-1996	1971-2000	1951-2009	1938-1990

[a] Data from Western Climate Data Center, Natural Resource Conservation Service, Toolik Lake Research Station, and Canadian Weather Service.

[b] Total precipitation per year is sum of rain and snow water equivalent.

[c] - = missing

[d] 2008-2010 for snow depth at Atigun Pass

No long-term weather stations exist in the Refuge, but temperatures for different ecoregions of the Refuge can be estimated using the PRISM climate model for Alaska (Table 4-3). This model uses data from weather stations (1961–1990) and a topographic model to estimate temperatures in areas with no weather stations (PRISM Climate Group 2008). Temperatures decrease in the northward direction. South of the Brooks Range the mean annual air temperature averages 20-23 °F. It decreases to 13 °F in the Brooks Range, 12 °F in the northern foothills, and 10 °F on the coastal plain.

Table 4-3. Average temperatures in Arctic Refuge ecoregions. Average temperatures (°F) in six ecoregions of Arctic Refuge, based on data from weather stations near the Refuge and a model that included topographic data (PRISM Climate Group 2008).

Area	Average Temperatures (°Fahrenheit)		
	Annual	February	July
Arctic Refuge	15	-11	50
Beaufort Coastal Plain	10	-19	45
Brooks Range Foothills	12	-17	48
Brooks Range	13	-16	48
Davidson Mountains	20	-10	55
Yukon–Old Crow Basin	21	-8	60
North Ogilvie Mountains	23	-3	57

4.2.2.1 North Slope

The North Slope is defined as the area north of the Brooks Range, including the Beaufort Sea Coastal Plain and the Brooks Range Foothills ecoregions. The climate of the North Slope is classified as arctic: summers are short and cool, and winters are long and cold. The growing season lasts from June to August. Subfreezing temperatures and snow may occur at any time during the year.

The Arctic coast experiences more frequent cloudiness and fog with higher winds; inland, clear skies are more common, winds are variable, and summers become warmer and less cloudy with increasing distance from the coast. At Barter Island on the coast, temperatures average 40 °F in July (warmest month) and -20 °F in February (coldest month) (Table 4-2). Temperatures on the coastal plain and in the northern foothills of the Brooks Range are more similar to those measured at weather stations at Kuparuk and Toolik Lake, ranging from means of 47 to 53 °F in July and -18 to -6 °F in February.

North of the Brooks Range, the Refuge receives little precipitation. The average annual water equivalent precipitation is less than 10 inches (in), most of which falls as summer rainfall, but it includes 32 to 46 in of snowfall. Evaporation rates are low due to low temperatures and a short growing season; the land is underlain by continuously frozen soil, which restricts soil drainage.

Therefore, available soil moisture is considerably greater than the low annual precipitation would produce in a more temperate climate, and soils are usually saturated during summer.

Surface winds along the Arctic coast average 9 to 15 miles per hour (mph), with occasional intense storms generating winds exceeding 70 mph. Winds are predominantly from the northeast, although the strongest winds come from the west. September and October are the windiest months on the coast, probably due to maximum amounts of open water (Wendler et al. 2010).

4.2.2.2 Brooks Range

The climate of the Brooks Range is classified as continental subarctic: a climate dominated by a long, bitterly cold winter season with short, clear days, relatively low humidity, and relatively little precipitation. In the large mountain valleys, the growing season is longer than north of Brooks Range, and summer temperatures are warmer. Based on weather stations near the Refuge, mean July temperatures in the valleys range from 50° to 58 °F. January is the coldest month, with mean temperatures mainly between -12° and -15 °F, similar to the coastal plain. Annual precipitation, snowfall, and snow depth exceed that of the coastal plain and are greater in the south-side valleys than in the north-side valleys. Steep slopes with enhanced drainage and higher evapotranspiration from warmer summers combine to create much drier habitats for plants than those found on the coastal plain.

4.2.2.3 South of Brooks Range

South of the Brooks Range, the Refuge climate is continental subarctic, with extreme temperatures during winter and summer. The distance of the eastern Brooks Range from the open ocean tends to prevent the inland movement of moist maritime air masses, causing the south side of the Refuge to be drier and warmer than similar topography further west towards the Bering Sea. Fort Yukon, about 60 mi south of the Refuge (with the closest official weather station) holds the State record high temperature of 100 °F and comes close to the record low of -75 °F. Because the southern part of the Refuge is at higher elevations than Fort Yukon, weather records from Bettles, approximately 120 miles west of the Refuge, are more representative of the interior Alaska part of the Refuge than Fort Yukon records. July temperatures in Bettles average 59 °F but can be very warm, with highs reaching above 80 °F. January temperatures average -12 °F, with lows periodically reaching -50 °F. Annual precipitation averages 14 in, half of which falls as summer rain; winter snow depths average 13 in.

4.2.3 Climate Change

4.2.3.1 Observed Temperature and Precipitation Trends

Climate analyses suggest that warming in the 20th century was greater than warming during any other century in the past 1,000 years, and the 1990s were likely the warmest decade in 1,000 years (Mann et al. 1999, Folland et al. 2001). The arctic climate has warmed rapidly during the past 50 years, with annual average temperatures increasing nearly twice as fast as the rest of the world (Arctic Climate Impact Assessment 2005). This polar amplification of warming is attributed to: (1) positive feedback effects of greater heat absorption, due to reduced snow and ice cover on land and sea, (2) larger fraction of energy going to warming rather than evaporation compared to the tropics, (3) shallower troposphere (lower atmosphere) and frequent temperature inversions, and (4) atmospheric and oceanic circulation. Compared to the rest of the circumpolar Arctic, northern Alaska, western Canada, and central Russia have experienced the most rapid warming.

Warming in Alaska rose sharply beginning in 1977, concurrent with large scale arctic atmosphere and ocean regime shifts (Parson et al. 2000). Despite considerable annual variation, the 50-year trend in mean annual temperature is positive, rising an average of 3.5 °F statewide between 1949 and 2005. Mean annual temperatures rose 3.6 °F at Barrow, on the arctic coast, and 4.1 °F at Bettles, in the interior boreal forest (Shulski and Wendler 2007). The greatest warming has occurred during winter and spring. Higher temperatures have caused earlier spring snow melt, reduced sea ice, widespread glacier retreat, insect outbreaks, and permafrost warming.

Annual precipitation in interior Alaska increased 30 percent between 1968 and 1990, with high year-to-year variability (Parson et al. 2000). Precipitation trends are not clear on the North Slope, in part because the difficulty of collecting rain and snow in windy sites makes historical precipitation data less reliable than temperature data. Based on the two best long-term time series on the North Slope (Barrow 1949–1996 and Barter Island 1949–1988), precipitation on the coastal plain declined slightly in the latter decades of the 20th century (Curtis et al. 1998). In contrast, a more recent time series from Kuparuk (near Prudhoe Bay, 1983–2009) shows slightly increasing precipitation over that period, again with great year-to-year variability (Western Climate Data Center). Two thirds of the summers between 1995 and 2006 had higher than average amounts of rain. Snow depth data are scant, but LANDSAT satellite images available since 1972 show a decreasing trend in mid-spring snow cover.

4.2.3.2 Projected Climate Change

Projections for future climate in Arctic Refuge are available from the Scenarios Network for Alaska Planning (SNAP) at the University of Alaska, Fairbanks (SNAP 2010). Projections are based on current and past climate data from weather stations near the Refuge, observed trends over the past 50 years at those stations, and models that extrapolate trends into the future based on atmospheric circulation models and topography.

SNAP climate change modeling projects a continued increase in temperature and precipitation for all regions of Arctic Refuge (Figure 4-1 and Table 4-4). Mean annual temperature is expected to increase at an average rate of about 1 °F per decade, to about 6 °F warmer than historical temperatures by 2040, and to 10 °F warmer by 2080. Most of this warming is expected to occur during winter (October–May) and will affect coastal areas more than inland areas, due to the influence of a longer marine ice-free period (Martin et al. 2009). Projected summer temperature increases are of a lesser magnitude and are more pronounced in inland areas.

Precipitation is expected to increase approximately 26 percent by 2040 and 40 percent by 2080. Most of this increase is expected to occur in winter, thereby contributing to a deeper snow pack. In summer and winter, precipitation will increase more on the coast and in the inland boreal forest than in the Brooks Range.

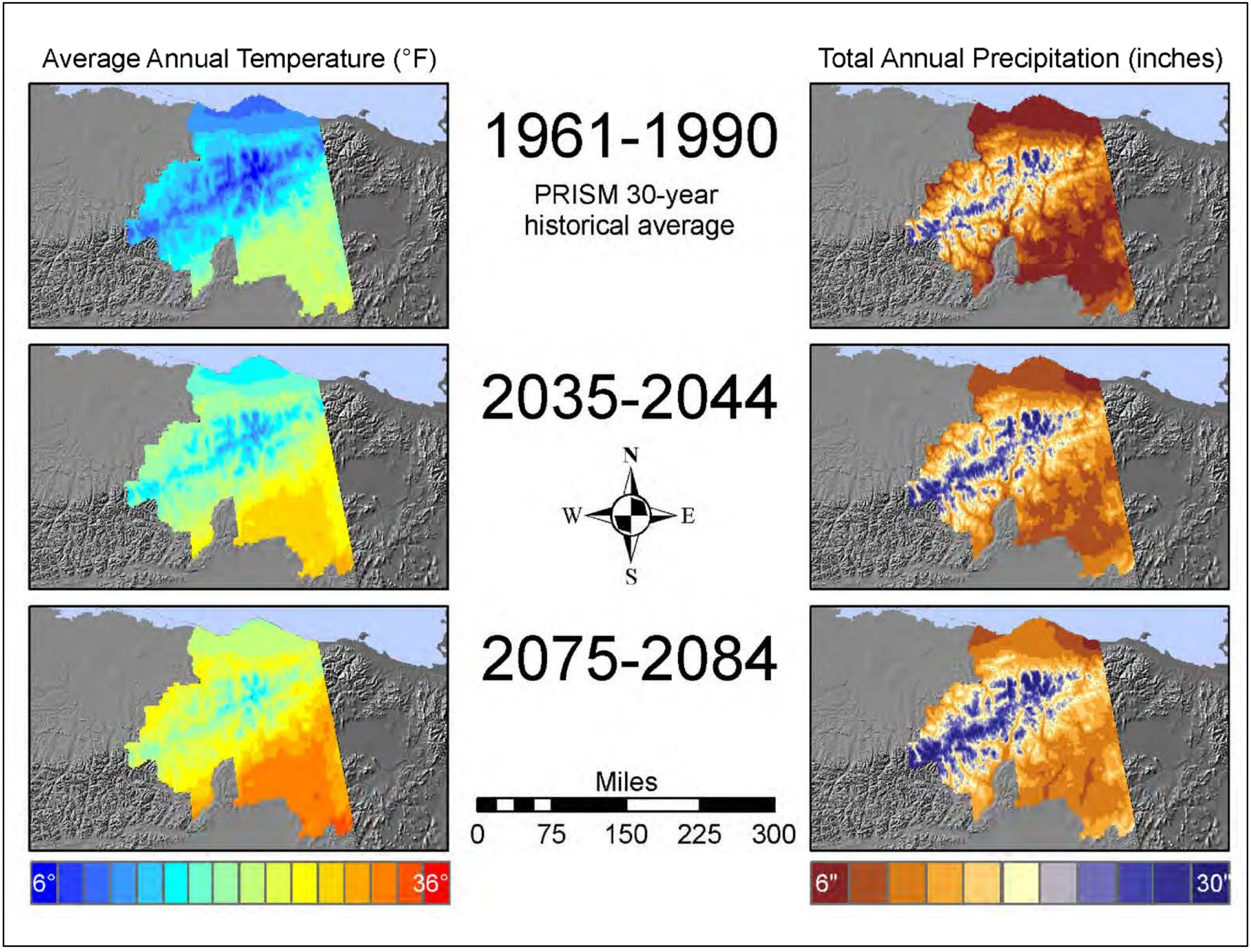
Table 4-4. Projected temperature and precipitation changes in the Refuge

Year	Season	Temperature (ºF)		Precipitation (inches)		
		Average	Change	Total	Change	% Increase over Historical
Historical	Annual	15.0		13.3		
2040		20.5	5.5	15.4	2.1	16%
2080		24.8	9.8	16.8	3.5	26%
Historical	Summer	41.6		8.4		
2040		44.1	2.5	9.4	1.0	12%
2080		46.8	5.2	9.9	1.5	18%
Historical	Winter	-4.0		4.9		
2040		3.6	7.6	6.0	1.1	23%
2080		9.0	13.0	6.9	2.0	40%

Based on climate modeling by Scenarios Network for Alaska Planning (2010). Table is from Loya et al. (2009).

Figure 4-1. Projected increases in temperature and precipitation in Arctic Refuge.

Projected future increases in temperature and precipitation in Arctic Refuge, based on climate models from Scenarios Network for Alaska Planning (2010). Figure is from Loya et al. 2009. This figure presents projections based on 'moderate' estimates of human-caused carbon dioxide emissions, including no increase of worldwide emissions over current levels.


Average Annual Temperature (°F)
Total Annual Precipitation (inches)
1961-1990
PRISM 30-year historical average
2035-2044
N
W
E
S
2075-2084
Miles
0
75
150
225
300
6°
36°
6"
30"

4.2.4 Air Quality

Currently, Arctic Refuge does not monitor or collect air quality data. Historically, because of minimal human-caused inputs, air pollution in the Refuge was thought to be low. Current known sources of air pollution in or near the Refuge include industrial developments (such as oil and gas development), villages, motorized traffic (snowmachines, automobiles, aircraft, motorboats, all-terrain vehicles), fires, and arctic haze. The Service is aware of increasing industrial activity in airsheds affecting the Refuge. Specifically, the Service is involved in National Environmental Policy Act (NEPA) reviews for onshore oil and gas exploration and production at the National Petroleum Reserve-Alaska, overseen by BLM, in reviews of offshore development now managed by the Bureau of Ocean Energy Management, and nearby air permitting activities that are under State of Alaska Department of Environmental Conservation’s jurisdiction. Increasing off-Refuge industrial development is anticipated to generate more air pollution in the future, which may impact resources in Arctic Refuge. Preliminary modeling of air pollution emissions projected for new industrial development on Alaska’s North Slope indicates it could impact the Refuge in sufficient concentrations to present an anthropogenic threat to fish, wildlife, and plants, and to the habitats and ecosystems in Arctic Refuge (M. Bond, Deputy Chief, Service’s Branch of Air Quality, pers. comm.). For example, air pollution transported and deposited into Refuge watersheds may be a large factor affecting water quality and contaminant levels. Air pollution impacts can be intensified during temperature inversions: times when stagnant air masses reduce air mixing and trap pollutants near the ground. Poor visibility is an effect of air pollution during these periods. Air pollutants deposited in the Refuge through atmospheric deposition, primarily sulfur and nitrogen, can affect many ecosystem characteristics, including nutrient cycling and biological diversity.

Arctic haze has been defined as the occurrence each winter and spring of increased air pollution and decreased visibility over arctic regions arising primarily from human-derived emissions (Warneke et al. 2009). Chemical composition of the particles in haze has been used to identify that the primary sources of haze are emissions from Eurasia (Shaw 1982). Arctic haze has been linked to the same sources in Eurasia over the last 30 years. It has been observed that in recent years that there has been a reduced concentration of primary pollutants (Quinn et al. 2009). In 2008, several haze plumes were studied over northern Alaska (including Arctic Refuge). These plumes were determined to have originated from wildland fires in southern Siberia and agricultural fires in northern Kazakhstan. The plumes were transported to the Arctic and trapped in air masses ranging from ground level to more than four miles in altitude (Warneke et al. 2009). In addition to reduced air quality, these plumes deposited black carbon on the surface of snow and ice, which could potentially reduce surface albedo and increase melting events (Warneke et al. 2009).

4.2.5 Soils

Due to the cold, dry climate, the soils in Arctic Refuge are generally not well developed. Soil development is dependent upon underlying materials (such as bedrock, glacial moraine, sand) temperature, water regime, topography, and vegetation. Soil types have been generally described for the ecoregions of the Refuge (Rieger et al. 1979).

The coastal plain region of the Refuge includes low terraces and floodplains of streams draining the North Slope of the Brooks Range. Materials underlying soils in this region consist of fluvial sands and silts, with increasing amounts of interstratified marine sediments near the coast. Generally, soils of the coastal plain thaw less than 18 inches in summer and are poorly drained. Loamy textures are common on terraces and floodplains, and organic soils occur in depressions. Locally, peaty materials are buried beneath windblown sand deposits.

Soils in the rolling foothills area form on a variety of parent materials, ranging from very gravelly deposits on ridges and upper slopes to medium- and fine-grained materials in lower areas. Most soils of the long slopes and broad valleys of the foothills are poorly drained and form from silty and clayey materials. Well-drained, very gravelly soils with dark, non-acidic to slightly acidic upper layers occur locally. Peaty soils are found in valley bottoms; sandy soils, including windblown silt, occur in isolated dunes bordering major streams. Near-surface permafrost in the foothills is evidenced by widespread ice-related surface features. The highly erodible soils above the permafrost layer are stabilized by vegetation.

The Brooks Range consists mainly of very steep, exposed bedrock and coarse rubble surrounding alpine valleys and more gently sloping areas with shallow, very gravelly and stony soils. Steeper terrain has fewer, isolated bodies of gravelly and stony soils. Gravelly glacial till underlies large valleys, while glacial outwash deposits extend from the mouths of these valleys down into the foothills.

Soil types south of the Brooks Range vary considerably. Wet, loamy soils with a thick, overlying peat layer and a shallow permafrost table occur in lowlands along rivers. Peat deposits are found locally in these soils. Upland sites have better-drained soils. Hills and ridges of the southern slopes of the Brooks Range, Davidson Mountains, and Porcupine Plateau are underlain by well-drained, brown loams. Hillsides, slopes, and ridges bordering the Yukon Flats are underlain by moderately well-drained gravelly and stony loams.

4.2.6 Permafrost

Permafrost underlies most of Arctic Refuge. Permafrost is frozen earth material (soil, rock, ice, and organic material) that does not thaw in the summer and remains continuously frozen for at least two years. In areas with a mean annual air temperature at or below -21° to -18 °F, permafrost is continuous (Smith and Riseborough 2002), except in areas below the largest rivers and lakes, which do not freeze to the bottom in winter. Shallow lakes and rivers in this zone freeze to the bottom and are directly underlain by permafrost.

Most of Arctic Refuge falls in the zone of continuous permafrost. On the North Slope, permafrost thickness is generally in the range of 650–1,300 ft (Gold and Lachenbruch 1973). In the lowlands in the Porcupine River drainage in the southeastern part of the Refuge , flat areas are usually underlain by thick permafrost, the base of which may be over 1,000 ft deep (Ferrians 1965). In upland areas, permafrost is of variable thickness, up to depths of 600 ft.

In areas underlain by permafrost, the surface layer of soil that thaws during the summer and freezes again in winter is termed the active layer. Plant roots and burrowing animals can be found in this layer of soil. Soil texture and moisture are important in determining active layer depth. Gravelly soils tend to be well drained with deep active layers; organic-rich soils tend to be poorly drained with shallow active layers. The deepest active layers on the North Slope are in riverine tall willow shrublands with sandy soils.

The active layer is shallow north of the Brooks Range, ranging from less than 1 to 4 ft thick. Permafrost close to the ground surface maintains high soil moisture in the active layer. Without permafrost, which impedes water percolation into deeper layers, soil in the rooting zone of plants would be much drier. Thawing of permafrost would consequently have large effects on at least this portion of Arctic Refuge. South of the Brooks Range, the active layer may be more than 5 ft deep.

4.2.6.1 Observed and Projected Permafrost Trends

Permafrost provides a stable platform upon which arctic ecosystems have evolved. Disruption of this surface stability by thawing of ground ice is a threat to vegetation and human-built infrastructure, and aquatic and terrestrial ecosystems. Long-term monitoring of permafrost temperature profiles across northern Alaska shows a warming trend over the past 25 years (Osterkamp 2005). The greatest warming, 1.67 to 2.22 °F (3 to 4 °C), was detected near the coast; and warming decreased inland. Permafrost temperatures are also increasing in the northern portions of Arctic Refuge, warming 4 to 5 °F (2 to 3 °C) near Kaktovik between 1985 and 2004, and 3 to 4 °F (1.5 to 2 °C) between 1985 and 1998 on the coastal plain of Arctic Refuge (Osterkamp and Jorgenson 2006). Permafrost temperatures have been measured at a network of stations across the North Slope since the late 1970s; 2011 set new record high permafrost temperatures at all stations (Richter-Menge 2011).

Using climate projections, SNAP predicts that permafrost distribution in arctic Alaska will remain stable through the end of the century, as evidenced by a projected mean annual soil temperature below freezing. In contrast, permafrost south of the Brooks Range is at risk of melting. With increased temperatures, mean annual temperatures in the southern part of the Refuge will approach 32 °F, causing permafrost to warm and eventually disappear in this area of the Refuge (Osterkamp 2005). Given the warming permafrost already documented on the coastal plain of Arctic Refuge, permafrost could even disappear on some parts of the coastal plain in the next century (Osterkamp and Jorgenson 2006).

Thawing of ice-rich permafrost soils creates characteristic surface landforms, termed thermokarst features. Processes associated with thermokarst include thawing, ponding, surface and subsurface drainage, surface subsidence, and erosion (Lachenbruch 1962). Despite the relative stability projected for permafrost in arctic Alaska, recent observations suggest that warming summer air temperatures can accelerate thermokarst processes at mean annual ground temperatures well below freezing. Increased thawing of buried ice wedges has already been documented in study areas west of the Refuge (Jorgenson et al. 2006) and in the Refuge (Jorgenson unpublished data). This is probably associated with warm air temperature, which causes a deepening network of water-filled troughs and pits above the ice wedges and drying of adjacent areas. Based on the general distribution of ice-rich soils, surface changes of this type could potentially affect 10–30 percent of arctic lowland landscapes. In the near term, thermokarst processes, such as the degradation of ice wedges (affecting soil stability, local drainage, and vegetation), are the likely agents of habitat change rather than widespread deepening of the soil active layer or a shift to discontinuous permafrost (Martin et al. 2009).

Sensitivity of a permafrost-dominated landscapes to climate warming is greatly influenced by the quantity of ground ice contained in the soil. Hillsides are likely to be very sensitive to climate warming. The soils on mid- to lower slopes tend to be highly organic and saturated, with abundant ice wedges and segregated ice near the permafrost table. Thaw slumps are likely to become abundant on the sloping surfaces (Gooseff et al. 2009). Slumping will create new thaw lakes, expose new soil to plant colonization, and increase sediment transport in runoff. Gullies are likely to become common where water flows through ice wedge networks, causing the ground surface to collapse. The gullies then contribute to channelization of flow and drying of lakes and intervening ridges.

Landscapes underlain by extremely ice-rich silt (yedoma) are highly sensitive to warming and have the potential for drastic change. Yedoma along the lower Colville River, west of the Refuge, consists of only 3.3 ft (1 m) or less of soil, covering 33 to 82 ft (10 to 25 m) of ice. Yedoma is abundant across the lower Brooks Range foothills and may occupy roughly 20 percent of the overall foothills landscape on the North Slope (Carter 1988). It is also present south of the Brooks Range in unknown quantities.

As permafrost warms, its ability to support structures diminishes; this could affect potential industrial development on the Refuge, as well as infrastructure in nearby villages (Esch and Osterkamp 1990). Thicker gravel pads may be needed to support structures, and increased quantities of gravel may be needed to maintain roads above thawing ice wedges. If the climate continues to warm, there may be a shorter period each winter during which snow cover and frozen ground are adequate to support seismic and other exploration activities, and the potential for these activities to disturb vegetation and soil would increase (Jorgenson et al. 2010).

In addition to thawing caused by warming air temperatures, permafrost may also be impacted by wildland fires. After a fire, the change in surface conditions (e.g., removal of vegetation and organic soil) results in soil warming and increased active layer depths. The soil may no longer have a water table perched on top of permafrost and may become well-drained (Brabets et al. 2000).

4.2.7 Oil and Gas Occurrences and Potential

The U.S. Geological Survey's (USGS) most recent comprehensive assessment of undiscovered oil and gas resources in Arctic Refuge was published in 1999. The assessment encompassed the federally managed 1002 Area, Native corporation lands of the coastal plain, and the adjacent Beaufort Sea State waters. Other parts of the Refuge are already permanently off-limits to oil and gas exploration and were not assessed. Like all modern resource assessments, the USGS study dealt with the uncertainty of predicting undiscovered resources by adopting a probabilistic approach, using statistical distributions to capture the range of possible outcomes. USGS estimated that the entire assessment area contains between 5.7 and 16 billion barrels of technically recoverable oil, with a mean (expected value) of 10.4 billion barrels (Bird 1999, Schuenemeyer 1999). Technically recoverable non-associated natural gas (gas in reservoirs containing little or no oil) was estimated to range from 0 to 10.9 trillion cubic feet, with a mean of 3.8 trillion cubic feet. Most of this volume was ascribed to the Federal 1002 lands, with mean recoverable oil and gas estimated at 7.7 billion barrels and 3.5 trillion cubic feet (Bird 1999). Although these estimates were developed using all the available data and standardized assessment methods, they are inherently speculative in nature, since the resources remain undiscovered. Their accuracy can only be determined by systematic exploration of the subsurface—in other words, by drilling test wells.

4.2.7.1 Distribution of Oil and Gas

Undiscovered resources are expected to be distributed unevenly beneath the coastal plain. Of the expected-case recoverable oil volume of 10.4 billion barrels in the assessment area, 74 percent (7.7 billion barrels) is thought to lie beneath Federal lands of the 1002 Area (See Section 4.1.1; Map 4-1). Within the 1002 Area, 83 percent of the expected oil (6.4 billion barrels) is assessed in the northwestern one-third of the coastal plain, where the sedimentary rocks that are likely to host petroleum systems have remained nearly undeformed since their deposition (Schuenemeyer 1999). Several intervals of the stratigraphic succession are prospective as exploration plays, but about two-thirds of the oil resource is predicted to occur in just one of them—the topset play (Schuenemeyer 1999). Topset reservoirs would consist of sandstones and conglomerates deposited in river channels and deltaic settings on the ancient coastal plain and shoreline north of the growing Brooks Range.

The remaining two-thirds of the 1002 Area to the southeast is expected to contain a much smaller share of the recoverable oil (1.3 billion barrels, or 17 percent of the 1002 Area's mean estimate) (Schuenemeyer 1999). There, sedimentary formations were strongly deformed by the folding and faulting that uplifted the mountain ranges just to the south. The more recent episodes of this deformation occurred after the initial stages of hydrocarbon generation and migration in the area, and much of the early-generated oil may have migrated through the area without encountering traps. Furthermore, some may have been detained in early-formed structures and stratigraphic traps, perhaps to be spilled as those traps were disrupted by younger deformation. In any case, the thermal history of the rocks in the deformed part of the coastal plain makes it more prospective for natural gas than for oil. Most of the resources in the deformed area are thought to be structurally trapped in reservoir rocks deposited from erosion of the ancestral Brooks Range.

4.2.7.2 Number and Size of Expected Fields

The USGS assessment provides statistics regarding the size and distribution of oil and gas fields (Bird 1999, Schuenemeyer 1999). It estimates as many as 30 technically producible oil accumulations in the undeformed area, ranging in size from 10 or 20 million barrels up to one or two billion barrel "giant fields." Most are thought to be in the 50- to 250-million-barrel range, and most of the resource is likely to be in fields larger than about 100 million barrels. The deformed area is likely to contain only three to five oil fields, with most of the recoverable resource in reservoirs between 250 million and 2 billion barrels in size (Bird 1999). The statistical distributions for number and size of gas fields are more difficult to translate into plain language but indicate that most of the assessed recoverable non-associated gas is likely to occur in as few as one or two major fields (Schuenemeyer 1999).

4.2.7.3 Economically Recoverable Volumes

The fraction of technically recoverable oil and gas that would be economic to produce depends on numerous factors, including market prices, the sizes of the fields, their locations relative to infrastructure, and environmental restrictions. According to USGS predictions of accumulation sizes, at least 80 percent of the anticipated technically recoverable oil would exist in fields larger than about 100 million barrels. More than 60 percent of the recoverable oil resource may lie in accumulations larger than about 260 million barrels. Most discoveries of this magnitude have now been developed in other areas of the onshore North Slope. Depending on the economic factors cited previously, many of them, particularly those greater than 500 million barrels, would likely be viable for near-term development in Arctic Refuge.

In a 2005 economic update to the 1998 resource assessment, the USGS developed full-cycle cost functions that predict the volume of oil that is economically recoverable at a given market price (Attanasi 2005). The functions are based on a host of assumptions, the uncertainties of which are not readily quantified. Some assumptions seem to be common sense and easily justified; for example, development would use highly efficient horizontal production wells and large fields would shoulder the economic burden during initial stages of development, with clusters of smaller nearby accumulations (satellites) becoming economical to develop later. Other assumptions pose greater uncertainty. For example, due to the current absence of a gas pipeline, gas resources were assigned zero value in the 2005 analysis. It is widely considered that North Slope gas will eventually be brought to market, and the economic impacts of developing gas fields along with the oil could be significant. In any case, among the economic assessment's key findings were that at $30 per barrel, 73 to 82 percent of the technically recoverable oil in the study area could be economically discovered, developed, produced, and transported to market. This fraction was estimated to increase to more than 92 percent at prices of $55 per barrel. Based on the mean estimate of 7.7 billion barrels of technically recoverable oil in the federally-administered 1002 Area, these percentages translate to approximately 5.6 to 7.1 billion barrels of economically recoverable oil. Although potentially distributed in dozens of accumulations, these volumes are the equivalents of 1.5 to 2.0 times the total oil recoverable from the Kuparuk River field, or about 30–50 percent that of the greater Prudhoe Bay Unit.

4.2.8 Minerals

Geologically, the Refuge is part of the Arctic composite terrain that extends across the Alaska-Canada border into the Yukon Territory. Portions of the areas represented by the following USGS topographic maps, with mineral information, are located in the Refuge: Arctic, Christian, Chandalar, Coleen, and Philip Smith Mountains. Prior to ANILCA, the USGS and previous U.S. Bureau of Mines conducted limited reconnaissance geological and mineral investigations in the 1970s in northeast Alaska. Limited mineral industry work was also conducted in the 1970s.

The following text includes: (1) summary descriptions of mineral prospects in the areas of the topographic maps, summarized by the USGS and U.S. Bureau of Mines in the Alaska Resource Data File records; and (2) summary descriptions of mineral deposit model types, of which the prospects may be indicative.

Arctic: Numerous prospects consist of stratiform copper and iron sulfide minerals situated in sedimentary shale units, as well as a volcanic tuff unit, that are indicative of sedimentary hydrothermal deposits such as the Zambian Copper Belt in Africa.

Christian: Several prospects consisting of stratiform chromite associated with ultramafic rocks that are indicative of stratigraphic deposition of iron and magnesium in the basal melt of ultramafic magmatic rocks such as the Stillwater Complex in Montana and the Muskox Complex in Nunavut (northern Canada). One copper prospect that is indicative of sedimentary hydrothermal deposits is also present.

Chandalar: A considerable prospect consisting of strata bound copper and zinc associated with sedimentary shale and meta-clastic rocks overlain by limestone. Several hundred mining claims were located on this prospect in the late 1970s, in which three years of mineral exploration were conducted. The claims were dropped upon creation of Arctic Refuge.

Coleen: Numerous prospects containing uranium, as well as lead, tin, and molybdenum, in association with felsic intrusive vein systems of the Old Crow batholith. Several prospects consisting of barite beds or lenses. Several prospects consisting of poly metallic vein deposits and hornfelsed zones containing copper, lead, and zinc derived from felsic volcanic dikes intruding meta-sedimentary host rocks such as argillite and phyllite. The Old Crow plutonic batholith in this quadrangle is unique in that differentiation has produced uranium, tin, tungsten, silver, and gold mineralization in the form of skarn, replacement and vein mineralization as well as porphyry copper and gold mineralization in the pluton.

Philip Smith: Numerous prospects of veins containing copper sulfides cutting carbonate host rocks. Numerous prospects of quartz veins containing highly anomalous amounts of lead, zinc and copper sulfides in chert breccia caps overlying limestone. Prior to creation of Arctic Refuge, mining industry claims covered many of these prospects. These deposits are classified as Mississippi Valley Type deposits and are the sites of several mines in the world. Numerous fluorite prospects are prevalent in the quadrangle in thick veins and replacement crystals associated with volcanic rocks and underlying carbonates. The Philip Smith Mountains also contain numerous phosphate deposits. These deposits are contained in black, calcareous siltstones and shale's. Some uranium is associated with the phosphate.

4.2.9 Water Resources

The Continental Divide, which arcs along the crest of the Brooks Range, partitions the Refuge hydrologically. All waters on the North Slope of the range flow to the Beaufort Sea. Waters on the South Slope of the divide flow into tributaries of the Yukon River drainage and eventually to the Bering Sea. Nearly the entire Refuge is underlain by continuous permafrost, which limits infiltration of surface water and maintains a high ratio of water storage at the surface relative to that in soils. The distribution of permafrost and depth of the active layer have a strong influence on surface water balance. Potential threats to water resources on Arctic Refuge include climate change, local and global contaminants, and invasive species, as well as off-Refuge threats such as oil and gas development, transportation system impacts, and gravel and mineral extraction.

Data on the Refuge's water resources are temporally and spatially limited. Long-term (greater than five years) data do not exist, and most short-term data were collected on the North Slope in the 1002 Area over two decades ago. Data from mountain headwater streams are particularly rare. Collection of critical ancillary data, such as air temperature, precipitation, radiation, loss of glaciers, and characteristics of vegetation and permafrost, has also been limited and for the most part has not been coordinated with water resource data collection efforts. This lack of coordination limits the interpretation and applicability of existing water resource data. Extending the period of record for existing water resource datasets, collecting data at additional sites, such as headwater streams in contributing watersheds, and coordinating efforts with other physical, chemical, and biological monitoring will improve our understanding of the functioning of aquatic ecosystems and our ability to detect, predict, and prepare for impacts of local and global stressors in the Refuge (Zhang et al. 2000, Vörösmarty et al. 2001, Martin et al. 2009, North Slope Science Initiative 2009).

4.2.9.1 North Slope

Relative to the rest of the North Slope of Alaska, the Refuge has a high density (20,600 mi) of streams and rivers (Brackney 2008). Most major rivers originate in the Brooks Range, flow almost directly north into the Arctic Ocean, and have relatively few tributaries, while smaller streams and rivers contribute substantial volumes of water and sediment to coastal ecosystems.

Based on origin, hydrologic regimes, and chemical and biological characteristics, Craig and McCart (1975) classified North Slope streams and rivers into three categories: mountain, spring-fed, and tundra. Mountain streams are typically fast flowing and fed by varying proportions of snowmelt, glacier meltwater, and spring-fed tributaries. Waters are cold (usually less than 50 °F), occasionally turbid, moderately hard, and support low invertebrate densities. The most common species of fish in mountain streams is Dolly Varden. Spring-fed streams are often tributaries of mountain streams and have relatively stable flows and temperatures throughout the year. Spring-fed waters are characterized by low levels of dissolved solids and very high densities of macroinvertebrates. Many spring-fed streams provide critical spawning and overwintering habitat for Dolly Varden. Tundra streams originate in the Brooks Range Foothills and coastal plain ecoregions, are fed by surface runoff, tend to be meandering systems, and have low to moderate invertebrate densities. Waters are typically warmer and exhibit lower pH and conductivity relative to mountain and spring-fed streams. Huryn et al. (2004) found that gradients in freezing probability, nutrient concentrations, and substratum instability control invertebrate communities in these systems.

Most streams and rivers freeze in October or November and remain frozen until temperatures warm and break-up occurs in late May or early June (Lyons and Trawicki 1994). During late winter, unfrozen water provides critical habitat for fish in the Refuge (Craig 1989) and only exists downstream from springs (Childers et al. 1977, Craig 1989a), in deep pools or lakes (Trawicki et al. 1991, Lyons and Trawicki 1994), and below ice hummocks (Elliot and Lyons 1990, Lyons and Trawicki 1994). Downstream from spring-fed areas, overflow water freezes and forms aufeis which melts later than snow and can be a large temporary reservoir of freshwater (Kane and Slaughter 1973). Childers et al. (1977) reported that nearly contiguous fields of aufeis covered over one hundred miles from the upper reaches of the Canning River down to its delta.

Break-up in the Refuge typically begins in the Brooks Range and foothills and progresses toward the coast, causing snowmelt to flow over land and down ice-covered stream channels in the coastal plain (Lyons and Trawicki 1994). As much as 50 percent of the annual flow may occur during break-up (Clough et al. 1987, Lyons and Trawicki 1994). After break-up, streams and rivers are fed by a variety of sources, including precipitation, springs, and meltwater from aufeis and glaciers (Lyons and Trawicki 1994, Childers et al. 1997). Later in the summer season, infrequent precipitation events can lead to loss of instream connectivity, which can have negative impacts on fish migrating to critical overwintering habitat (Lyons and Trawicki 1994). Relative to the rest of the North Slope, glaciers (Nolan et al. 2011) and springs (Yoshikawa et al. 2007) contribute large volumes of water to a number of streams and rivers in the Refuge. In some systems, these more reliable sources of flow may help sustain flows during dry summers when precipitation events are infrequent.

The physiography of the Refuge and hydrologic and thermal regimes of this region have played an important role in shaping the Refuge's stream and riverine ecosystems and will continue to play an important role in determining their response to a changing climate. Most springs in Arctic Refuge have survived since the last glacial maximum (Yoshikawa et al. 2007), suggesting that they will continue to flow and be refugia for aquatic biota in a changing climate. In contrast, contributions from glaciers may disappear completely in the next 50 years (Nolan et al. 2011). In the Jago, Hulahula, and Okpilak watersheds, discharge from glacial sources is the dominant source of flow when precipitation is low and air temperatures are high.

When glacial discharge is high, runoff is turbid and transports large volumes of water, sediment, and nutrients to downstream ecosystems. Loss of glacial meltwater may alter downstream ecosystems and reduce instream connectivity, especially during dry summers. Deepening of the active layer, the extended duration of the summer season, and increased evapotranspiration rates will also influence surface water availability and instream connectivity. In the foothills, deepening of the active layer may lead to increased base flow at mid to lower elevation slopes (Martin et al. 2009). In the coastal plain, however, increased active layer depth will likely lower water tables and lead to an overall loss of water availability and instream connectivity at the surface. These effects may be exacerbated by increased evapotranspiration rates and the extended duration of the summer season.

Although the density is low compared to the rest of the North Slope, there are over four thousand lakes covering over 37,000 ac in the Refuge. Most (73 percent) of the lakes are in the coastal plain ecoregion. Most lakes in this region are shallow, freeze to the bottom during winter (Trawicki et al. 1991), and are recharged by snowmelt, overbank flooding, and precipitation. When not connected to larger drainage networks, evaporation has a strong influence on water chemistry and plays an important role in regulating lake water balance. Jorgenson and Shur (2007) classified the coastal plain into regions based on lake origin: thaw, depression, riverine, and delta. Thaw lakes are formed by the degradation of ice-rich sediments and, in the Refuge, are only in great abundance in a small thaw lake plain east of Demarcation Bay. Depression lake basins are formed in undulating sandy, alluvial marine or eolian deposits. Most of the lakes in the Refuge are in the depression lakes region between the Hulahula and Niguanak rivers. Riverine lakes include oxbow and floodplain lakes along sinuous channels and thaw lakes formed in ice-rich abandoned channels. Riverine lakes are most concentrated along the Jago and Niguanak rivers. Delta lakes include thaw, riverine, and tidal lakes and most are found in deltas of the Hulahula, Jago, Aichilik, and Canning rivers. Up to 80 percent of the winter water volume is in lakes in the Canning River delta (Trawicki et al. 1991).

Over 25 percent of the lakes on the North Slope of the Refuge are in the mountains and foothills. Most mountain lakes are of glacial origin and tend to be deeper, have larger surface areas, and store much greater volumes of water than coastal plain Lakes. The largest mountain lakes include Lake Peters (3,226), Lake Schrader (1,689 ac), Elusive Lake (772 ac), and Porcupine Lake (333 ac). With the exception of studies on two large deep glacial lakes, Lakes Peters and Schrader, the limnology of mountain lakes in the Refuge has not been well studied. In the late 1950s, Hobbie (1961) found that Lake Schrader was at the northern limit of thermally stratified lakes; Hobbie (1964) found that 50 percent of the annual primary productivity in Lake Peters occurred when the lake was still covered by ice. In the past half a century, the duration of ice cover, thermal regimes, inputs from glacial meltwater, and rates of primary productivity have likely changed. In the future, changes in temperature, active layer depth, fire frequency and severity, and erosion rates could affect lake distribution, water quality, water levels, size, and connectivity to other habitats.

Long-term data on water resources on the North Slope of the Refuge are limited. There are currently three gaging stations, all of which are along rivers in the 1002 Area. In the past, discharge data have been collected sporadically at several springs and major tributaries (Childers et al. 1973) and continuously over short time periods (less than five years) at a smaller number of sites in the 1002 Area (Lyons and Trawicki 1994) and at mountain headwaters streams.

4.2.9.2 The Refuge South of the Brooks Range

There are approximately 36,500 mi (58,000 km) of streams and 9,735 lakes covering more than 67,500 ac (27,315 ha) on the South Slope of Artic Refuge (Brackney 2008). The Chandalar and Porcupine rivers drain the entire South Slope and interior portion of the Refuge. The Porcupine River Basin is a major tributary of the Yukon, accounting for 20 percent of the drainage area and contributing nearly 10 percent of the flow to the Yukon River (Brabets et al. 2000). The headwaters of the Porcupine River flow from Old Crow Flats in Canada. Within the Refuge, the Salmon Trout River flows north from the Ogilvie Mountains, and the Sheenjek and Coleen rivers flow south from the Brooks Range and Davidson Mountains before draining into the Porcupine River. The east and middle forks of the Chandalar River drain the western reaches of the South Slope and the Davidson Mountains before joining to form the Chandalar River south of the Refuge and to the west of the Porcupine River. Prominent lakes on the South Slope include Big Fish Lake at 1,402 ac (560 ha), Vettekwi Lake at 846 ac (342 ha), and Grayling Lake at 565 ac (228 ha).

Spring snow melt typically progresses from the south to the north in late April through May on the South Slope. Due to differences in wind and snow pack, the highest mountain valleys on the South Slope may actually retain snow longer than the north-facing valleys on the North Slope. Very few stream gage or water quality data are available for South Slope streams or lakes. There are no continuous discharge records for headwater streams, but there are data for two large rivers. A long-term gaging station has been maintained by the Water Survey of Canada on the Porcupine River at the U.S.–Canada border, and a short-term station was run by the Service on the Sheenjek River just south of Arctic Refuge in 1993–1998 (Trawicki 2000).

Degradation of permafrost can have a large influence on water flow paths and export of sediment, organic matter, inorganic nutrients, and major ions to downstream ecosystems. The influence of permafrost degradation on these processes will depend largely on the type of permafrost degradation (deepening of the active layer, decrease in permafrost extent, or thermokarst failure). Permafrost in the Yukon River Basin is currently thawing (Hinzman et al. 2005, Jorgenson et al. 2006). With the exception of areas that lack an upper soil organic layer or are underlain by discontinuous permafrost (e.g., the Ogilvie Mountains), the depth of the active layer limits subsurface flow paths to the organic rich soil in the shallow active layer. As permafrost thaws and the active layer deepens, deeper flow paths through mineralized soils will form. As the potential for groundwater storage in the active layer increases, a shift from surface-water dominated flows to ground-water dominated flows may occur (Frey and McClelland 2009). The relative proportion of groundwater flow to the Porcupine River above Fort Yukon is less than 10 percent of mean annual surface flow (Walvoord and Striegl 2007). From 1968 to 2004, groundwater contributions to the Porcupine River increased by 56 percent while mean annual flow decreased by 18 percent. Increases in the relative contribution of groundwater may have resulted from active layer deepening. Deeper flow paths will likely result in changes in retention, processing, and export of organic matter, inorganic nutrients, and major ions. Concentrations of dissolved silica, phosphate, and nitrate may increase (Frey and McClelland 2009); however, the availability of dissolved organic matter may decrease due to adsorption to deep mineral soils (Frey and McClelland 2009, Walvoord and Striegl 2007).

In the future, a decrease in the overall extent of permafrost in the Refuge will likely occur. A decrease in the extent of permafrost may increase the relative importance of subpermafrost groundwater discharge and alter surface water chemistry (Frey and McCelland 2009, Walvoord and Striegl 2007). Increased groundwater flow may result in increased concentrations of dissolved inorganic carbon and decreased concentrations of dissolved organic carbon and dissolved organic nitrogen (Walvoord and Striegl 2007). The rate of thermokarst failures may be increasing in the Refuge. Thermokarst failures are more localized than active layer deepening and declines in permafrost extent, but can have large impacts on downstream sediment and nutrient loads.

Few physical and chemical data are available for streams and rivers in the Refuge, especially headwater streams. More intensive sampling has occurred outside Arctic Refuge in the lower basin of the Chandalar, Sheenjek, Porcupine, and Christian rivers (Dornblaser and Halm 2006). Water chemistry in these rivers is related to surficial geology, physiography, permafrost extent, and discharge. There is a linear relationship between flow and hydrologic yields of total nitrogen and total phosphorus in the Porcupine River, with half the annual export occurring during spring (Dornblaser and Striegl 2007). The Sheenjek River originates in the mountains, is underlain by continuous permafrost, and the lower basin has low concentrations of dissolved organic carbon and sediments (Dornblaser and Halm 2006). In contrast, the lower Christian River has higher dissolved organic matter concentrations. This river originates in the foothills of the Brooks Range where permafrost is continuous and then flows through the Yukon Flats where permafrost is discontinuous. Dornblaser and Halm (2006) reported higher alkalinity in the Sheenjek (123 mg/L as calcium carbonate) and Chandalar River (119 mg/L as calcium carbonate) compared to the Porcupine River above Fort Yukon (65 mg/L as calcium carbonate) or the nearby Yukon River at Circle (67 mg/L as calcium carbonate). This may reflect the predominance of limestone bedrock at the source of the Sheenjek and Chandalar. Total particulate mercury concentrations were generally lower in the Sheenjek, Christian, and Chandalar rivers in comparison to the Porcupine and Yukon River levels (Dornblaser and Halm 2006).

4.2.9.3 Coastal Marine System

Seasonal processes play a major role in the functioning of coastal ecosystems. With the coming of winter on the North Slope in late September or early October, lagoon waters begin to freeze over. Brackish lagoons begin freezing earlier than coastal waters, which tend to be more saline (Wiseman and Short 1976). Lagoon ice may be 6 ft (2 m) or more thick by April or May (Barry 1979). As the ice thickens, sub-ice water circulation is reduced, and waters may become highly saline (Truett 1980), pooling in the deeper portions of the lagoons and embayments. These brine pools remain until they are flushed out by the large influx of fresh water at break-up in late May or early June (Pollard and Segar 1994), or they may remain on the bottom and create stratified conditions (Hale 1991). Fresh water overflows the shore-fast ice and initiates the break-up of ice at river mouths and in lagoons as ice melt proceeds outward from the shore and river mouths (Truett 1980). On barrier-island protected coasts, flooding is confined to the lagoons (Short and Wiseman 1975), whereas in open coastal areas, the fresh water may flow many kilometers over and underneath the ice (Reimnitz and Bruder 1972). Coastal sea ice breaks up four to eight weeks after the initial melt (Short and Wiseman 1975).

The large spring discharge of relatively warm fresh water from rivers creates warm brackish water conditions near the coast (Hale 1991). Depending on the prevailing wind, magnitude of freshwater influx, coastal geometry, and exchange with marine waters, lagoons and bays can stratify in salinity and temperature with warm brackish water overlaying cold dense saline waters. In protected lagoons, surface temperatures may be as high as 50 °F (10 °C), and surface salinities may be as low as five parts per thousand. Offshore, ocean conditions are much colder and more saline at this time. As the open water season progresses, freshwater discharge from the rivers decreases, and combined with wind-driven mixing and upwelling of deep water, the strength of stratification of nearshore waters gradually erodes as salinities increase and temperatures decline (Pollard and Segar 1994, Hale 1991).

Tidal variations along the Beaufort Sea coast are small, with a diurnal range of 4–12 in (10-30 cm), and contribute little to the nearshore circulation. Circulation in the nearshore regions is driven primarily by winds, with currents responding quickly to changes in wind direction. Along the Arctic Refuge coastline, the prevailing summer winds are from the east, causing a general westward nearshore circulation and offshore movement of water and ice seaward of the barrier islands. Strong west winds occur periodically and tend to cause onshore movement. Summer and fall storms may cause upwelling and movement of marine waters into the nearshore environment and can lead to considerable changes in local sea level (Kowalik 1984). Surges of cold, saline marine water associated with these upwellings can contribute to destratification of nearshore waters, increasing salinity and decreasing temperature in the nearshore environment (Hale 1991). Open bays tend to take on ocean conditions and, if stratified, pulsing lagoons may become mixed during ocean upwelling events. Bays and lagoons may become more estuarine in nature if nearshore currents and influx of freshwater are sufficient to restore the warm brackish nearshore band. Large ocean upwelling events can affect terrestrial environments as well. In 1970, a storm surge caused by gale-force westerly winds inundated low-lying tundra on the coastal plain as far as 3.1 mi (5,000 m) inland and 11 ft (3.4 m) above sea level (Reimnitz and Mauer 1979). The driftwood line from that event is still noticeable.

Substantial increases in air temperature and storm frequency, combined with decreases in summer sea ice in recent decades, have increased erosion along the southern Beaufort Sea coastline in recent decades (Wendler et al. 2010). Recent concern about alterations to the carbon cycle brought about by climate warming (McGuire et al. 2009) has brought attention to increased shoreline erosion and the input of carbon into the Arctic Ocean. Estimates of soil organic carbon inputs from the Arctic Refuge shoreline average 6,254 metric tons annually, about 3.5 percent of the total input along the Beaufort Sea coastline (Jorgenson and Brown 2005).

4.2.10 Soundscape

A soundscape refers to the entire acoustic environment of an area, including natural quiet, natural sounds, and human-caused sounds. Natural quiet and natural sounds are intrinsic elements of the Wilderness character of designated Wilderness and the wilderness characteristics of the entire Refuge. As such, their perpetuation is important for meeting the Refuge's purposes, goals, objectives, and special values. Human-caused sounds may mask or obscure natural sounds and disrupt wildlife behavior. They may interfere with locating prey or detecting predators, or with the complex communication systems many species have evolved to assist in mating or other behaviors. As well, human-caused sound interferes with the sense of solitude that is important to many visitors. Currently, aircraft used to transport visitors and Service personnel and cooperators are the most frequent source of human-caused sound on the Refuge.

The Refuge's soundscape was documented in a single study in 2010. This study was conducted in conjunction with the proposed Point Thomson Development Project (U.S. Army Corps of Engineers 2011). The study used basic acoustical concepts and methodologies developed through coordination with the Army Corps of engineers, the National Marine Fisheries Service, North Slope Borough, NPS, and the Service to measure existing sound levels and establish baseline conditions at six locations adjacent to the northwestern border of the Refuge during winter and summer 2010. It also included an analysis of potential project-related noise levels for five alternative development scenarios. The ambient soundscape in the project area was influenced by both human and natural sound sources. The four soundscapes in the noise study area (upland coastal plain, upland coastal plain near surface water features, offshore island, and coastal shoreline) varied in overall noise level, distribution of noise throughout the day, range of noise levels dependent on local fauna, and frequency of human-created noise events.

Natural ambient sound levels along the northwestern boundary of the Refuge are low, and natural sounds dominate the environment during both winter and summer. These sounds include atmospheric/meteorological phenomena, water features, and insects and other animals. Noise from human activities is largely absent from the Refuge's ambient soundscape. Non-natural audible events included infrequent aircraft overflights. Generally, natural noise levels were greater in the summer season due to the influence of water features such as the Canning River. Natural ambient noise levels at the Canning River (upland coastal plain near surface water features), upland coastal plain, and coastal shoreline monitoring locations were reported to be "lower than typical residential noise environments and comparable to an unoccupied building."

During the study, industrial activities were present and quantified at sites 2.5 to 8 mi west of the Refuge (Mary Sacks and Flaxman Islands) and 2.5 to 8 mi from existing developments. Human-caused noises included aircraft overflights and other industrial noises associated with oil- production. Sound intensity ranged from 20 to 50 dBA (A-weighted decibel). During selective audio review, these human-caused noises were audible "between 0 and 100 percent of any particular hour"; however, at these distances ambient conditions were still quiet by most standards, equal to "an unoccupied room or a very quiet room at night."

These data are thought to be representative of the range of natural conditions found in the northwest corner of the Refuge. Other areas of the Refuge (away from water features and the windy coastline) would be expected to be even quieter, with a predominance of natural sounds coming from wildlife and insects. Human caused noise from aircraft would be highest along well-used river corridors, for example along the Kongakut River, and in areas used as flight paths to common landing areas.

4.3 Biological Environment

4.3.1 Land Cover and Vegetation

Arctic Refuge contains a unique juxtaposition of ecosystems compared to the rest of northern Alaska. The southern portions of the Refuge border the Yukon Flats, which have the highest summer temperatures in Alaska. In contrast, the northern portion of the Refuge, along the Beaufort Sea, experiences some of the coldest summer temperatures. Because of the northeasterly sweep of the Brooks Range, the coastal plain in the Refuge is much narrower than it is further west. The highest summits of the range are in close proximity to the coast.

North of the Brooks Range, the coastal plain and Brooks Range Foothills ecoregions are treeless tundra, composed mainly of hardy dwarf shrubs, sedges, and mosses. Habitats on the North Slope can be grouped into four broad categories: coastal lagoons, lowland wet tundra and lakes, upland moist tundra, and river floodplains with willow shrub thickets.

In the Brooks Range Mountains ecoregion, barren rock and sparse, dry alpine tundra predominate. Mountain valleys contain moist tundra and areas of shrub willow thickets. Along rivers south of the mountains, the biological environment is more complex. Spruce forests predominate in the lowlands of the Yukon–Old Crow Basin ecoregion, and spruce woodlands extend far into valleys of the Davidson Mountains ecoregion. Open tundra is present throughout the area and covers vast expanses of uplands in the Davidson Mountains. Dense shrub thickets occur on floodplains, near tree line, and on glacial moraines. Treeless bogs are found mostly along major river floodplains.

There is a strong contrast between vegetation on north- and south-facing slopes due to effects of the sun's low angle at these latitudes. Vegetation also varies depending on soil characteristics, such as texture, moisture content, and bedrock type (particularly whether or not the parent material of the bedrock is acidic).

Broad land cover classes (i.e., vegetation types) can be mapped using satellite images. Map 4-4 provides a map of land cover classes in the Refuge, as mapped by the National Land Cover Database (Homer et al. 2004). This map was developed from classifications of Landsat-7 satellite images.

Table 4-5 provides estimates of the area of the Refuge covered by each land cover class. These estimates are based on the National Land Cover Database map for the Brooks Range and interior ecoregions (Homer et al. 2004) and on systematic field sampling of vegetation types for the coastal plain and northern foothills ecoregions (Jorgenson et al. 1994).

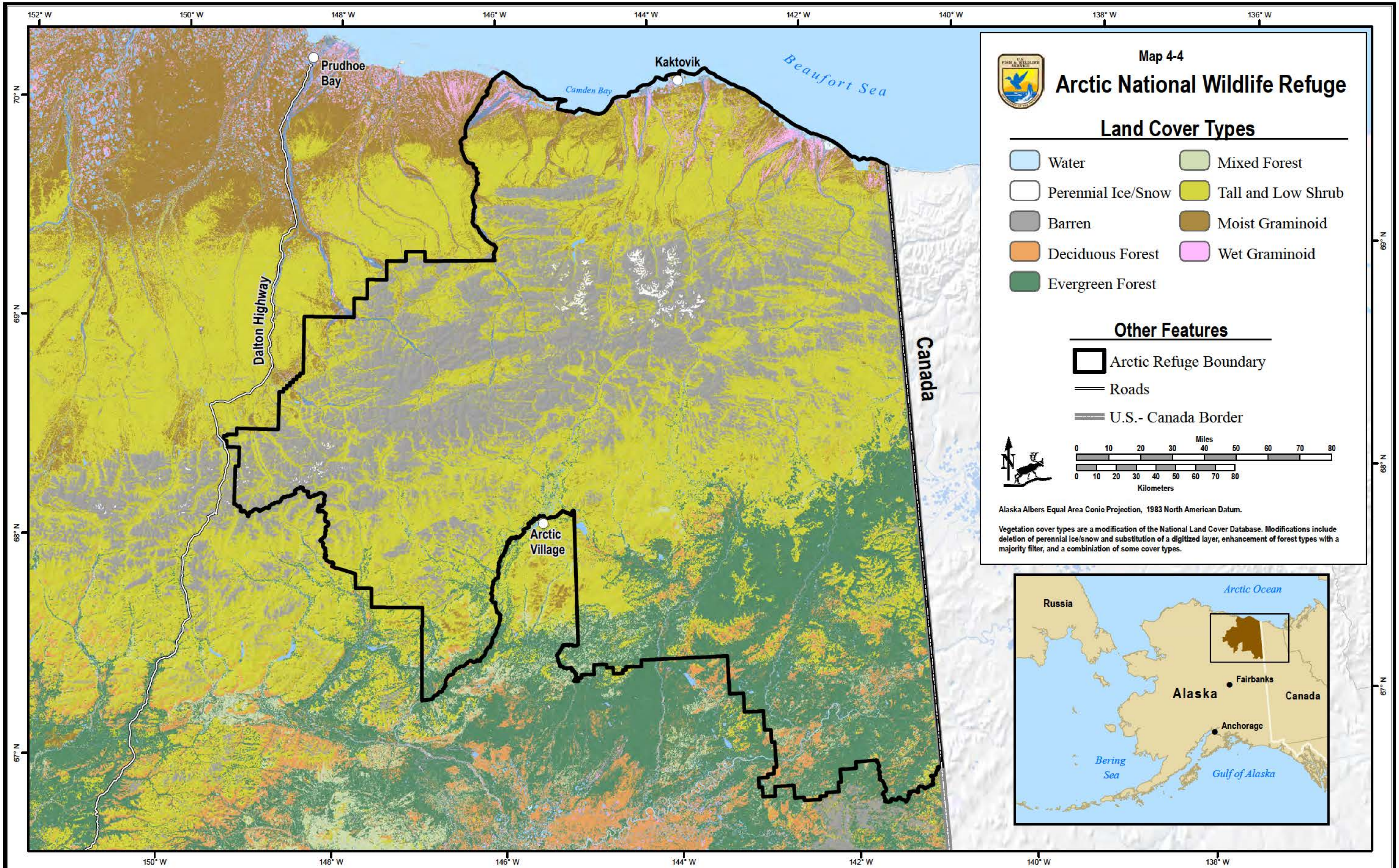
Table 4-5. Land cover classes of Arctic Refuge. Land cover types of Arctic Refuge are based on the National Land Cover Database for most of the Refuge (Homer et al. 2004) and systematic sampling of vegetation types on the North Slope of the Refuge (Jorgenson et al. 1994).

Land Cover Class	% of Refuge	Acres
Forest:		
Evergreen Forest	12	2,376,901
Deciduous Forest	1	242,070
Mixed Forest	1	219,270
Shrub:		
Tall and Low Shrub	22	4,435,104
Dwarf Shrub	25	4,762,434
Herbaceous:		
Moist Graminoid	9	1,487,782
Wet Graminoid	2	494,410
Other:		
Barren or Sparsely Vegetated	26	5,138,892
Ice	1	250,134
Water	1	244,372

The vegetation types listed in the following text can be nested in the mapped land cover classes listed in Table 4-5 and provide more detailed information than can be mapped accurately with Landsat images. Vegetation types are based on the Alaska Vegetation Classification (Viereck et al. 1992), which is a hierarchical classification system that divides vegetation first into three broad categories (forest, shrub, and herbaceous) and then into finer subdivisions to arrive at the vegetation type. The following paragraphs describe the main vegetation types that apply to Arctic Refuge vegetation and list some of the dominant plant species in each. Species are listed in the approximate order of dominance in each class.

4.3.1.1 Forests

Spruce, deciduous, or mixed spruce/deciduous forests cover about 14 percent of the Refuge. The majority of these are white and black spruce forests (*Picea glauca* and *P. mariana*). These spruce forests occur only on the south side of the Brooks Range, though a northward extension along the Canadian border exists on tributaries of the north-flowing Firth River. Though much less common than spruce, deciduous forests comprised of balsam poplar (*P. balsamifera*) occur farther north in the Brooks Range than spruce.



Map 4-4
Arctic National Wildlife Refuge
Land Cover Types
Water
Perennial Ice/Snow
Barren
Deciduous Forest
Evergreen Forest
Mixed Forest
Tall and Low Shrub
Moist Graminoid
Wet Graminoid
Other Features
Arctic Refuge Boundary
Roads
U.S.- Canada Border
Miles
0 10 20 30 40 50 60 70 80
0 10 20 30 40 50 60 70 80
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
Vegetation cover types are a modification of the National Land Cover Database. Modifications include deletion of perennial ice/snow and substitution of a digitized layer, enhancement of forest types with a majority filter, and a combination of some cover types.
Prudhoe Bay
Kaktovik
Camden Bay
Beaufort Sea
Dalton Highway
Arctic Village
Canada
Russia
Arctic Ocean
Alaska
Fairbanks
Anchorage
Bering Sea
Gulf of Alaska
152° W
150° W
148° W
146° W
144° W
142° W
140° W
138° W
136° W
70° N
69° N
68° N
67° N

Spruce Forest (12 Percent of Refuge)

White spruce forests are typically found on well-drained soils, south-facing slopes, and along rivers and streams where permafrost is lacking. White spruce is the only tree growing at altitudinal tree line in the Brooks Range. Black spruce forests occur on north-facing slopes and in areas where soil drainage is moderate to poor, but they do not extend as far north in the Refuge as white spruce.

In closed spruce forests, the tree canopy is dense, covering greater than 60 percent of the area. This type is comprised mainly of white spruce on moist to well-drained sites in the boreal forest of the Yukon–Old Crow basin ecoregion. Species commonly found in the understory include *Rosa acicularis, Shepherdia canadensis, Salix* spp., *Pyrola* spp., *Betula nana, Vaccinium uliginosum, V. vitis-idaea, Carex* spp., *Eriophorum* spp., and *Hylocomium splendens.*

Open spruce forests consists of open stands (30–60 percent tree cover), with crowns not usually touching. This type is primarily dominated by black spruce on low, poorly-drained sites or upland sites with permafrost. Open stands of white spruce on alluvial sites and in the uplands and subalpine zone are also included in this type. Dwarf shrubs are the most common understory vegetation, usually consisting of *Ledum decumbens* or *L. groenlandicum, Vaccinium uliginosum, Betula nana, or Empetrum nigrum*. Non-woody plants common in the understory include *Eriophorum vaginatum, Cladonia* spp., and *Cladina* spp. Other species may include *Arctostaphylos rubra, A. arctica, Dryas integrifolia, Rhododendron lapponicum, Salix reticulata, S. lanata, Carex bigelowii, Festuca altaica, Equisetum arvense,* and *Hylocomium splendens.* On alluvial and well-drained sites, the shrub layer usually consists of *Salix glauca* and *Alnus crispa.*

Spruce woodlands have widely spaced spruce trees (less than 30 percent cover), usually with a dense understory of shrubs. Major shrub species include *Betula nana, Ledum groenlandicum, L. decumbens, Vaccinium uliginosum, V. vitis-idaea, Salix reticulata, S. glauca, S. lanata, Alnus crispa, and Dryas integrifolia*. Non-woody species may include *Lupinus arcticus, Equisetum arvense, E. scirpoides, Eriophorum vaginatum, Carex bigelowii, C. scirpoides, Festuca* spp., *Cetraria* spp., *Cladina* spp., *Polytrichum* spp., *Hylocomium splendens*, and *Dicranum* spp.

Deciduous Forest (One Percent of Refuge)

Deciduous forests are typically found on well-drained to moist soils on hills and river terraces south of the Continental Divide. Deciduous trees grow quickly after disturbances, such as fires, but do not live as long as spruce. This vegetation type is often an early successional stage that will develop into a mixed forest and eventually a spruce forest. Balsam poplar, paper birch (*Betula papyrifera*), and aspen (*Populus tremuloides*) are the dominant tree species. Understory species include *Alnus crispa, Salix* spp., *Rosa acicularis, Shepherdia canadensis*, and *Calamagrostis canadensis*. Small stands of balsam poplar occur in northern valleys of the Brooks Range on sites with year-round subsurface flowing water, especially along the Canning and Kongakut rivers.

Mixed Forest (One Percent of Refuge)

This type is comprised of a mix of deciduous and evergreen trees, with neither clearly dominant, and occurs on well-drained to moist sites in the boreal forest uplands. The primary evergreen is white spruce, while the primary deciduous species are paper birch with occasional balsam poplar and aspen. Understory species common to the spruce and deciduous vegetation types listed in the following text may also be found in mixed forests, along with *Ribes* spp., *Lupinus arcticus*, and *Juniperus communis* on drier sites.

4.3.1.2 Shrub

This vegetation category covers approximately 46 percent of the Refuge and is dominated by shrubs (greater than 25 percent cover) with an understory of herbaceous plants. The taller shrubs are mainly deciduous and shed their leaves simultaneously in the fall, while many of the dwarf shrubs are evergreen.

Dwarf Shrub (25 Percent of Refuge)

Dry prostrate dwarf shrub occupies upper slopes in the mountains and foothills and also occurs on dry areas of coastal plain tundra and on dry, infrequently-flooded river terraces or alluvial fans throughout the Refuge. Moist habitats on slightly elevated microsites of the coastal plain and alluvial terraces in the foothills and mountains are often drier as a result of greater exposure to wind and lack of water from surrounding terrain. Lichens are more common than mosses in these drier habitats. Bare soil as a result of frost action is common in this habitat type. Low snow cover exposes plants to abrasion and desiccation by winter winds, so they do not generally grow more than 4 in tall. Mountain avens (*Dryas* spp.) is the most common shrub in this vegetation type. Other common shrubs are *Arctostaphylos rubra, Salix reticulata, S. rotundifolia*, and *Cassiopia tetragona*. Herbaceous plants include *Saxifraga hircula, Polygonum bistorta, Petasites frigida, Polemonium boreale, Equisetum arvense, Carex* spp., *Festuca* spp., *Hierochloe* spp., *Epilobium latifolium,* and *Geum glaciale*. The *Cetraria* species of lichen are also common.

Moist prostrate dwarf shrub contains similar shrub species as dry prostrate dwarf shrub, but greater winter snow cover and summer soil moisture allows grasses, sedges, and mosses to thrive in the understory. This type occurs on moist habitats on the coastal plain and in foothills tundra on gentle to moderately steep slopes. It grades into moist sedge-Dryas tundra when sedges dominate. In the mountains, this type is frequently found on mid- to lower slopes that receive subsurface drainage from adjacent terrain. *Dryas integrifolia* is often the dominant species. *Carex bigelowii* is usually the main sedge, producing a hummocky surface. Horsetails (*Equisetem arvense*) and the moss *Tomenthypnum nitens* are characteristic species in this type. Other species include *Salix lanata, S. arctica, S. pulchra, Rubus chamaemorus, Saxifraga hirculus, S. punctata, Petasites frigidus, Eriophorum vaginatum*, and *Carex aquatilis*.

Tall and Low Shrub (22 Percent of Refuge)

The riparian shrub type develops on gravels along rivers and is dominated by the willows *Salix planifolia* and *S. alaxensis*. On the North Slope, this is the tallest vegetation type. Species composition and density is controlled by frequency of flooding, water velocity, and the size of particles deposited during flooding. Many other species occur as co-dominants or in the understory, including *Salix lanata, S. richardsonii, S. glauca, S. brachycarpa, S. hastata, S. reticulata, Arctostaphylos rubra, Populus balsamifera, Shepherdia canadensis, Potentilla palustris, Dryas integrifolia, D. drummondii, Equisetum arvense, E. variegatum, E scirpoides, Carex* spp., *Festuca* spp., *Juncus castaneus, Petasites frigida, Hedysarum* spp., and *Hylocomium splendens*.

The non-riparian shrub type is comprised of upright-growing shrubs with interlocking branches, primarily willows (*Salix* spp.), shrub birch (*Betula nana*), and bog blueberry (*Vaccinium uliginosum*). These shrubs are typically 4 in to 1.5 ft tall, although willows in the boreal forest can reach 16 ft. The erect shrub class is common on lower mountain slopes, low rolling hills, and re-growing burned areas. On mountain bases with gentle slopes (less than 15 percent) or on hillsides at lower elevations, tussocks of the sedge *Eriophorum vaginatum* often occur with shrubs, so this class grades into moist sedge-tussock tundra. Other shrub species include *Alnus viridus, Ledum decumbens, Vaccinium vitis-idaea, Cassiope tetragona, and Empetrum nigrum*. Other species present may include *Carex lugens, Carex scirpoidea, Equisetum arvense, E. scirpoidea, Hylocomium splendens, Tomenthypnum nitens*, and *Sphagnum* spp.

4.3.1.3 Herbaceous

This vegetation category covers approximately 10 percent of the Refuge. Herbaceous plants do not have much woody tissue and generally die back to the ground surface each year. There are two major growth forms: graminoids and forbs. Graminoids include grasses and grass-like plants, such as sedges and rushes. Forbs are broad-leaved plants, such as fireweed and lupine.

Herbaceous vegetation types in Arctic Refuge are graminoid-dominated and are divided into wet and moist types. Shrubs and forbs are present but provide less than 25 percent cover.

Wet Herbaceous (Two Percent of Refuge)

The very wet graminoid vegetation type occurs on aquatic habitats surrounding large, open bodies of fresh water; very wet habitats that contain numerous small bodies of open water; and coastal marshes frequently inundated with salt water. Surface forms include low-centered polygons with abundant standing water, thaw lake basins, edges of lakes, and low-bank coastline. The grass *Arctophila fulva* is the primary species in deeper fresh water (to 3 ft deep), with sedges *Carex aquatilis, Eriophorum scheuchzeri*, and *Eriophorum angustifolium* dominating areas where the water is less than 1 ft deep. *Puccinellia phryganodes, Carex subspathacea*, and *Dupontia fisheri* are the most common salt-tolerant species in coastal salt marshes.

The wet graminoid type is found in habitats that generally have standing water throughout the summer, receiving water by surface and subsurface flow from surrounding terrain. This type is most common on low-lying flats and drainages on the coastal plain. Surface forms can be low-centered polygons and strangmoor (string-patterned bog). Graminoids dominate and include many sedge species, with *Carex aquatilis* and *Eriophorum angustifolium* being the most common. Other plant species found in this vegetation type include willows, rushes, *Pedicularis* spp., *Valeriana capitata*, and *Polygonum* spp. There is usually little shrub, forb, or moss cover, except on drier microsites such as polygon rims.

Moist Herbaceous (Nine Percent of Refuge)

Moist herbaceous tundra occurs on flat or gently sloping terrain and is the most common vegetation type in the coastal plain ecoregion. Dwarf shrubs and sedges occur together in habitats intermediate in moisture regime between the wet graminoid and moist dwarf shrub types. Polygonized patterned ground is common, with wet and moist areas often intermixed in a complex pattern.

Moist sedge-willow tundra is found on low-lying flats and gentle slopes, with the sedges *Eriophorum angustifolium* and *Carex aquatilis* and the willows *Salix pulchra* and *S. reticulata* dominating. Other common species include *Dryas integrifolia, Salix lanata, Carex bigelowii, C. membranacea, Polygonum* spp., and *Senecio* spp. Mosses include *Tomenthypnum nitens, Hylocomium splendens, Aulacomnium* spp., *Sphagnum* spp., and *Campylium stellatum*.

The moist sedge-Dryas tundra type occupies moderately well-drained sites on moist calcareous slopes and pebbly glacial and marine sediments. The dwarf shrub *Dryas integrifolia* and the sedge *Carex bigelowii* are dominant species, often occurring with the willows *Salix richardsonii, S. phlebophylla*, and *S. reticulata*, and mosses such as *Tomenthypnum nitens, Hylocomium splendens, Distichium capillaceum,* and *Ditrichum flexicaule*. Forbs (e.g., *Lupinus arcticus*), lichens (e.g., *Cetraria* spp.), and horsetails (e.g., *Equisetum variegatum*) are common. There is often a hummocky surface topography, with patches of exposed mineral soil and extremely variable organic horizons, resulting from active and stabilized frost boils.

The moist sedge-tussock tundra type occurs on moderately well-drained slopes and is dominated by the tussock-forming sedge *Eriophorum vaginatum*. Other common plants include the shrubs *Salix pulchra, S. reticulata, Betula nana, Dryas integrifolia, Vaccinium uliginosum, V. vitis-idaea*, and *Ledum decumbens*. Mosses and liverworts include *Hylocomium splendens, Sphagnum* spp., *Aulacomnium turgidum, Ptilidium ciliare*, and *Tomenthypnum nitens.*

4.3.1.4 Barren and Sparsely Vegetated Areas

Approximately 26 percent of the Refuge is bare of vegetation or sparsely vegetated. In this category, plants are scattered or absent, and bare mineral soil or rock dominates the landscape.

Barren floodplains consist of river deposits, including silt, sand, and rocks. Plant cover is less than five percent and includes the same species described here for scarcely vegetated floodplain, if any vegetation is present.

The scarcely vegetated floodplain type is a result of the initial invasion of plants on recently exposed river gravels. Plant cover is 5 to 20 percent. Some common species include *Epilobium latifolium* and willows. With infrequent river flooding, this type develops into riparian shrublands.

The ground surface in the barren rock and scree type is dominated by bedrock and rocky slopes, usually with less than five percent plant cover. A type of lichen tundra may form, dominated by blackish lichens on rocks, mainly of the genera *Umbilicaria, Cetraria, Cornicularia, and Pseudophebe*. These sites may be devoid of flowering plants.

The sparsely vegetated scree type has 5 to 20 percent plant cover on more or less unstable, steep, rocky slopes. With greater stability of the scree, it develops into dry prostrate dwarf shrub. Some shrubs commonly found in this type include *Betula nana, Dryas integrifolia, D. octopetala, Vaccinium uliginosum, Cassiope tetragona*, and *Salix phlebophylla*. Other plant species include *Lupinus arcticus, Carex* spp., *Umbilicaria* spp., *Crystopteris* spp., *Diapensia lapponica*, and *Cetraria* spp.

4.3.1.5 Other Areas

Water comprises one percent of the Refuge area and includes lakes, ponds, and rivers.

The perennial ice and snow type includes glaciers on the highest mountains and ice patches on river bars below year-round springs (aufeis). It comprises one percent of the Refuge area.

4.3.2 Wildfire

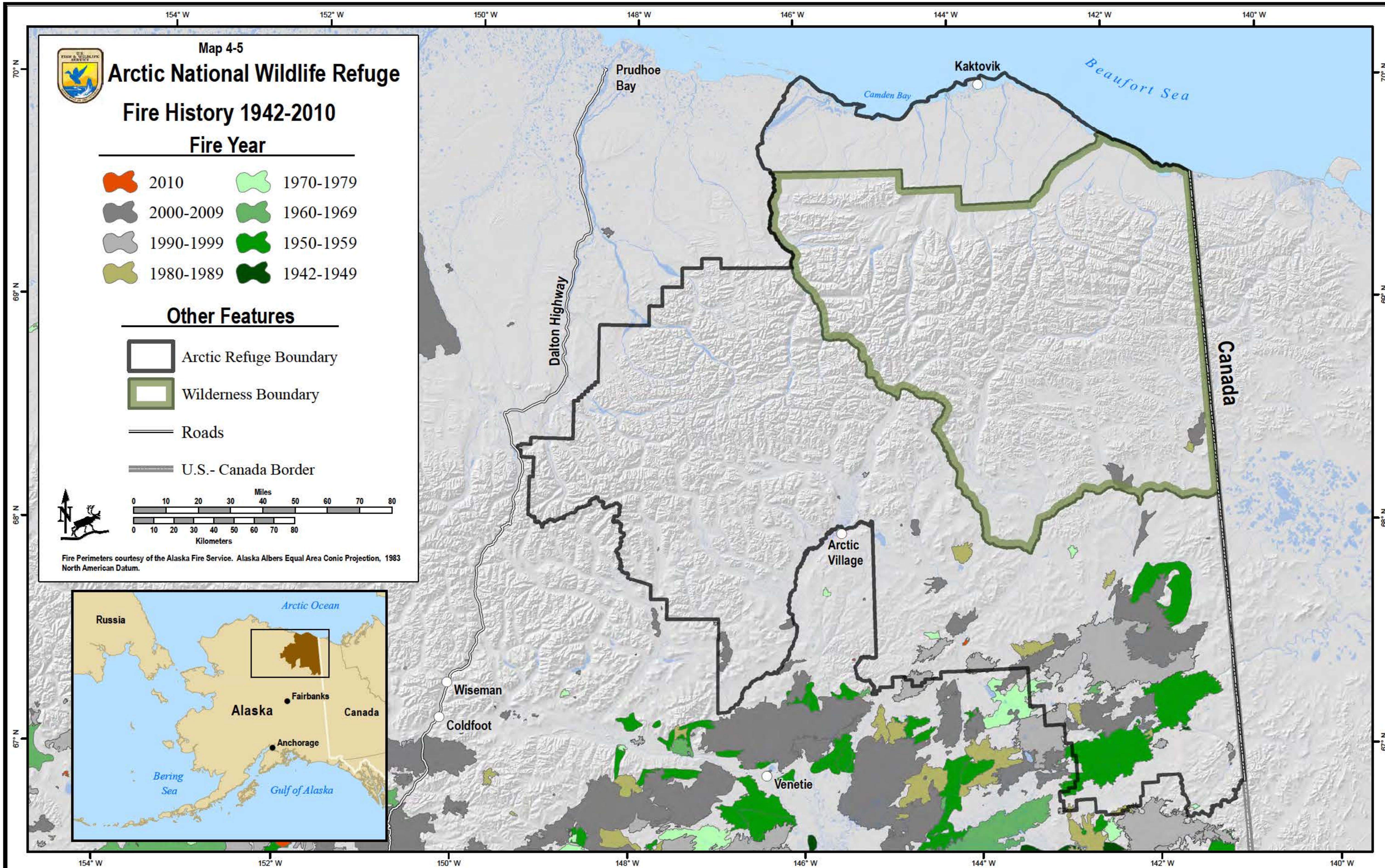
Almost all wildfires in the Refuge have occurred south of the Brooks Range, in the Yukon-Old Crow Basin, Olgavie Mountains, and Davidson Mountains ecoregions (Map 4-5). Only a few small fires are known to have occurred in the Brooks Range region of the Refuge. Fires in the mountains remain small due to a moister climate, less lightning, sparse tree cover, and rugged terrain with many natural fire breaks. Historic fire records document no fires in the Refuge north of the Brooks Range, although a small lightning-caused tundra fire burned less than one mile outside the Refuge's western boundary in 2004.

Wildfires are common in the forested parts of the Refuge. Fire defines the disturbance-driven natural system of the southern Refuge and plays a crucial role in the maintenance of the ecosystem, as in all of interior Alaska. It affects plant and animal species distribution and abundance, diversity of landscapes, and hydrology, carbon, and nutrient cycles. Frequent small fires produce patchy environments with varied habitats that are of value to many wildlife species during the natural fire recovery process. Patchy fires also break up contiguous fire fuel loading and make future large-scale fires less intense. Large intense fires can burn in hot, dry weather and cover hundreds of thousands of acres. Vegetation and changing weather patterns during the fire (e.g., changes in relative humidity and wind) can result in a mosaic of different burn severities, with inclusions of unburned vegetation often due to fire breaks provided by wet areas. Under extreme conditions, these fires can result in large homogeneous areas of high burn severity that may recover slowly due to removal of the entire soil organic layer and long distances to seed sources for spruce and shrubs. The largest recorded fires in Arctic Refuge burned in 1950, 1990, 2004, and 2005.

4.3.3 Climate Change Impacts to Vegetation

4.3.3.1 Potential Changes to the Natural Fire Regime

Concern has been expressed about increasing wildfire frequency in Alaska. The Bureau of Land Management, Alaska Fire Service (BLM-AFS) maintains records of fire occurrences back to about 1950, with incomplete records to about 1942. These records show that total area burned in the boreal forest of Alaska was higher in the 1980s and 1990s than in the 1960s and 1970s (Kasischke and Turetsky 2006). The first decade of this century has had some extreme fire years, with 2004 being the most extreme fire year on record in Alaska. The number and area of wildfires in the Refuge vary greatly from year to year, with 1950 burning more area than any subsequent year, so there is insufficient data to ascertain whether the current fire frequency on the Refuge is greater than historic levels.


Map 4-5
Arctic National Wildlife Refuge
Fire History 1942-2010
Fire Year
2010
2000-2009
1990-1999
1980-1989
1970-1979
1960-1969
1950-1959
1942-1949
Other Features
Arctic Refuge Boundary
Wilderness Boundary
Roads
U.S.- Canada Border
Miles
0 10 20 30 40 50 60 70 80
0 10 20 30 40 50 60 70 80
Kilometers
Fire Perimeters courtesy of the Alaska Fire Service. Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
Prudhoe Bay
Kaktovik
Camden Bay
Beaufort Sea
Dalton Highway
Canada
Arctic Village
Wiseman
Coldfoot
Venetie
Russia
Arctic Ocean
Alaska
Fairbanks
Anchorage
Canada
Bering Sea
Gulf of Alaska
154° W
152° W
150° W
148° W
146° W
144° W
142° W
140° W
70° N
69° N
68° N
67° N

Climate changes, which result in longer, hotter, and drier summers, sustained high winds, low relative humidity and low moisture in fire fuels could cause a change in the natural fire regime on the Refuge. Insect damage to vegetation also increases with drought conditions and weakens trees and shrubs, making them more flammable. These conditions would increase the frequency, intensity, and duration of wildland fire and the amount of acreage burned each year.

In the boreal forest, more frequent and intense wildland fires could burn large areas of spruce and convert forests to a less flammable, deciduous vegetation type (Rupp et al. 2002). If the climate became warmer and drier than current conditions, spruce trees would be weakened by drought stress and insect damage. This could eventually transform the boreal forest portion of the Refuge to a landscape dominated by deciduous forests. Moose habitat would likely be improved, but area and quality of caribou winter habitat would be diminished.

Tundra fires have been rare in northern Alaska, with only eight known occurrences on the whole North Slope from 1955 to 2006 (Jones et al. 2009). In the fall of 2007, coinciding with an unusually warm and dry summer, a 386-square-mile area burned in the central Arctic Foothills (Hu et al. 2010). This is the largest North Slope fire on record and underscores the potential for more frequent, larger tundra fires with warmer summers. The North Slope fire regime may change and become similar to that of the Seward Peninsula in western Alaska. The Seward Peninsula has a tundra landscape but has a warmer climate than the North Slope, with periodic high-fire years, shrubbier tundra, and encroaching spruce trees (Racine et al. 2004).

4.3.3.2 Treeline

It is predicted that the limits of treeline will move north in latitude and upward in elevation with a warmer climate (Hinzman et al. 2005). Modeling studies focused on the Alaska forest-tundra ecotone project that a shift from tundra to spruce forest could occur in about 150 years (Rupp et al. 2000). Migration of spruce trees to higher latitudes or higher elevations has been documented in the western Brooks Range and at lower latitudes in Alaska and the adjacent Yukon Territory. There is no clear evidence for advancing treeline in the central or eastern Brooks Range (Barber et al. 2009). This could be due to the topographic barrier created by the highest peaks in the Brooks Range and perhaps to the drier summers of the eastern Brooks Range, where drought stress may hinder spruce growth on marginal sites (Wilmking et al. 2004).

Patches of balsam poplar trees currently occur north of treeline in scattered locations across the northern Brooks Range and foothills and in floodplain settings with year-round groundwater flow (Bockheim et al. 2003). Some groves of stunted poplar grow within 16 miles of the Beaufort Sea. Because these trees have wind-dispersed seeds and are adapted to growing in early successional habitats, balsam poplar should be able to advance northward on floodplains across arctic Alaska in response to warming temperatures.

4.3.3.3 Plant Phenology

The growing season in Alaska has lengthened by 13 days since 1950 (Keyser et al. 2000), and climate model projections indicate that by 2080, the growing season will be about a month longer than it is at present in all parts of the Refuge (SNAP 2010). Despite projections of an increase in precipitation, increased temperatures and an extended growing season would increase evapotranspiration rates enough that landscape-scale drying is predicted across the entire Refuge. Near mid-century, the landscape may be 10 to 12 percent drier in the north and south ecoregions of the Refuge and 16 percent drier in the Brooks Range; near the end of the century, it may be 23 to 25 percent drier in the north and south and 37 percent drier in the Brooks Range. Warming and drying would likely change vegetation phenology, such as timing of leaf bud out, seed set, and leaf senescence.

Remote sensing methods using satellite images, most notably the normalized difference vegetation index, have been used to assess vegetation trends in the Arctic and Sub-Arctic. Index values are a measure of vegetation “greenness” (i.e., photosynthetic activity) and correlate well with green plant biomass. Index data from northeast Alaska show that green-up occurs earlier in warmer years, with a longer growing season and greater peak summer biomass, and that the date of vegetation green-up has advanced in recent years (Martin et al. 2009).

4.3.3.4 Plant Distribution

A warming environment will change distributions of plants. Some species will adapt to climate change, while others will be unable to adapt and will be lost. Many species will adapt to changing conditions by moving, since the climate is changing too rapidly to adapt in place by natural evolution. Many recent species distribution shifts have been documented elsewhere in the world (Parmesan and Yohe 2003), but a lack of baseline data makes this more difficult in a remote area like Arctic Refuge.

The geographic ranges of North American flora and fauna are expected to shift upwards in elevation and northward in response to projected temperature and precipitation changes in the next 100 years (IPCC 2001, Payette et al. 2001). Shifting species ranges could increase the chances of invasion by non-native plant species. These projected changes would likely affect the biological integrity and environmental health of Refuge ecosystems. The long-term effects to biological diversity would be complex.

4.3.3.5 Non-native Plants

Non-native plants are currently uncommon on the North Slope (McKendrick 2000). Cool summer temperatures and a short growing season may presently impede their invasion in arctic Alaska, but this will change if the climate continues to warm. Warming may create a more suitable environment for some plants, enabling native and non-native plant species to extend their current ranges northward.

The main determinants of non-native plant invasion in northern Alaska are human traffic and disturbance to the ground. Non-native plants are common on disturbed ground in cities of interior Alaska, where extreme winter temperatures are just as cold as most of Arctic Refuge. The Fairbanks area is an excellent point source for infestations in interior and northern Alaska because of extensive disturbed ground and a road connection to the Arctic. Although the vast majority of non-native plant infestations in Alaska are on human-disturbed ground, Carlson and Shephard (2007) observed that non-native plants are spreading into natural ecosystems at an accelerating rate.

Arctic Refuge has few documented non-native plants, but this is likely to change in the near future. Motorized and foot traffic and extent of disturbed ground, associated with recreational or industrial activity, in and near the Refuge are expected to increase. This increase in activity, combined with a warmer climate, will likely lead to an increase in problems with non-native plants in the future. MacFarlane (2003) documented the presence of non-native plants on oil exploration seismic lines in Alberta that were not present in the adjacent forest. Revegetation projects on disturbed sites, specifically the application of commercial seed, could introduce non-native plant species.

4.3.3.6 Vegetation composition changes

Vegetation of Arctic Refuge may be changing under current climate conditions, especially on the North Slope. A 22-year satellite normalized difference vegetation index record analyzed by Verbyla (2008) showed an increasing trend in greenness on the arctic coastal plain and arctic foothills, no major trend in the Brooks Range, and some decrease in index values in the boreal forest. The observed increase on the North Slope could reflect increased shrub cover and stature or more robust growth of sedges and grasses. Decrease in greenness in the boreal forest could be due to increasing summer drought stress in recent warm years, which limits tree growth (Wilmking et al. 2004).

An increase in the amount of shrubs in tundra during the past 50 years has been documented for areas of the south-central North Slope, using repeat aerial photography (Tape et al. 2006). Normalized difference vegetation index increases across the North Slope suggest that shrubbiness has likely increased at a landscape scale, although few long-term field data are available to verify this. In the only long-term vegetation data set from the coastal plain of Arctic Refuge, Jorgenson and Buchholtz (2003, unpublished data) found no significant increase in shrub cover during the period 1984–2009. However, under projections for a warmer and drier climate, shrubs are expected to become more dominant in the tundra. An increase in shrubby tundra would cause a decrease in sedge-dominated vegetation, which would profoundly affect wildlife habitat. Such a change could adversely affect species that feed on sedges, such as geese.

4.3.3.7 Plant disease and pathogens

Plant photosynthetic activity in boreal forests of Alaska, as measured by the normalized difference vegetation index, decreased from 1982 to 2003 (Verbyla 2008). This decrease is attributed to wildland fire activity and tree stress caused by drought and insect infestations (Mattson and Hack 1987, Malmström and Raffa 2000). Stress caused by temperature-induced drought could make trees and shrubs more susceptible to disease and pathogens.

Large areas of the Alaskan boreal forest have been impacted by insect infestations during the past two decades (U.S. Department of Agriculture 2010). The spruce beetle outbreak in south-central Alaska, one of the largest recorded insect outbreaks in North America (Werner 1996, U.S. Forest Service 2010), is attributed to the climate regime shift in Alaska (Juday et al. 1998). Temperature-induced drought stress in interior Alaska may have caused the first-recorded spruce budworm outbreak near Fairbanks and could also be responsible for the vast areas of willow shrubs that were damaged and killed as a result of 19 continuous years of willow blotch miner infestation on the Yukon Flats (U.S. Department of Agriculture 2010).

4.3.4 Climate Change and Refuge Habitats

A habitat is an area with a combination of resources (e.g., food, water, cover) and environmental conditions (e.g., temperature, precipitation, presence or absence of predators and competitors) that allows animals and plants to survive and reproduce (Morrison et al. 2006a). Projected environmental changes have the potential to affect the quality of habitats on the Refuge.

Habitats are not static but change naturally through time. Habitat changes in response to either rapid climate changes or human disturbance are of more concern than those that occur from variation in natural processes over time. Long term, we can expect climate change to cause profound habitat changes in Arctic Refuge, which will result in species shifting their distributions northward and to higher elevations. Local extirpations of some populations may result, while range expansions of others will occur.

4.3.4.1 Drying of Lake and Wetland Habitats

Landscape drying trends have been observed in northeastern Alaska. Riordan et al. (2006) reported a reduction in wetland extent and the number and surface area of lakes on parts of the Yukon Flats between 1980 and 2002. Many wetlands on the Yukon Flats Refuge that were once aquatic habitats, such as lakes, now are shrub and wet meadow habitats. Historical aerial photographs from the boreal forest part of Arctic Refuge also show lakes shrinking or disappearing in the past 60 years.

Increased temperatures and an extended growing season could increase the evapotranspiration rate, increasing the water deficit (defined as the amount by which evapotranspiration exceeds precipitation) and potentially affecting the annual water balance. The annual water balance represents the water available for plants and animals, stream flow, and groundwater recharge. Shallow water systems, including lakes and wetlands, would decrease in number and extent as the annual water balance experiences an ongoing deficit. Permafrost loss on the Refuge could also result in draining of many shallow water systems on the Refuge; the thawing of ice wedges and ice lenses could create more connections between surface water and groundwater systems.

If wetlands and lakes continue to dry, an increase in vegetative cover can be expected; and they could eventually transition to dry meadows and shrublands. This would reduce the amount of habitat available for wetland-dependent species, such as waterfowl.

4.3.4.2 Changing Coastal Habitats

The coastline is a dynamic environment, subject to continual change. Climate change may affect the equilibrium among various coastal processes, however, and result in a net change in habitat availability. Signs of climate change are already apparent in coastal habitats in the arctic. For example, rapid shoreline erosion is occurring, enhanced by the retreat of summer sea ice. Erosion rates of 3–6 ft (1–2 m) per year are typical for many sections of the Beaufort Sea coast.

Coastal erosion is affected by permafrost thawing as well as mechanical, wave-related processes. The combined effect of increased water temperatures, sea level rise, and increased frequency of wind-driven storm surges has resulted in a substantial increase in coastal erosion rates (Jorgenson and Brown 2005). A pronounced sea-surface warming trend since 1995 has been observed for the Arctic Ocean, especially in the Beaufort and Chukchi Seas. Global sea level rise is estimated to have occurred at a rate of 0.12 in (3 mm) per year since 1993, and projections for cumulative global sea level rise by the end of this century range from 0.59 to 1.94 ft (0.18 to 0.59 m) (IPCC 2007c). Wind-driven storm surges can result in very rapid coastal erosion, raising water levels in the Beaufort Sea by more than 6 ft (2 m) (Reimnitz and Maurer 1979). Wind speeds and the number of stormy days, defined by wind speed, have been increasing in the Beaufort Sea (Wendler et al. 2010). The presence of sea ice inhibits wave formation; but in the past few decades, the length of the ice-free period along Alaska's north coast has increased by an average of 50 to 95 days (Rodrigues 2008). Sea ice extent in the Arctic Ocean has also decreased markedly: the peak summer sea ice extent has decreased by 9.2 percent per decade from 1979 to 2005, with a record low extent of polar sea ice in 2007 (Walsh 2010). An increase in open water conditions increases the probability that strong winds will result in a storm surge.

In addition to its effects on coastal erosion rates, reduced sea ice alters habitat conditions for some species. For example, it may change the timing and location of plankton blooms and critically threaten ice-dwelling species such as polar bears and certain seals. Some marine species are shifting northward in response to changing water temperatures and open water conditions.

Increasing ocean temperatures, sea level rise, permafrost degradation, decreased sea ice, increased storm surges, and changes to river discharge and sediment transport will continue to affect coastal habitats, including the barrier island-lagoon system. In Arctic Refuge, this system provides important summer feeding habitat and migration corridors for shorebirds, waterfowl, and anadromous fish. Preliminary evidence suggests that the Beaufort Sea barrier island system may be disintegrating. Total surface area of barrier islands in the central Beaufort Sea (from the Colville River to Point Thomson) has decreased approximately four percent from the 1940s to the 2000s, and the rate of change is steeper since 1980 (Gibbs et al. 2008). A longer period of open water and increased occurrence of larger waves is at least partially responsible for the accelerated decrease in barrier island surface area: barrier islands are typically less than 3.3 ft in elevation and are subject to overwash during storm events. These trends suggest that the deterioration or disappearance of the existing system of barrier islands is possible over a relatively short period of time.

4.3.4.3 Soil Warming, Nutrients, Carbon

The boreal forest and tundra biomes are widely recognized as important in stabilizing global climate by immobilizing carbon in the cold soils. If warming is accompanied by increased soil moisture, there could be a long-term loss of carbon and nitrogen from the system. Experimental studies have shown that a warming of the soil can lead to increased turnover of soil organic matter and redistribution of nitrogen from soils to vegetation (Nadelhoffer et al. 1992).

Predicted changes in vegetation will also affect carbon and nutrient cycles. Increased shrub extent and height will trap more winter snow, insulating the soil and allowing the soil to remain warmer in winter and allowing microbial activity to continue during the winter, which could cause large changes in carbon and nitrogen pools, releasing large amounts of stored carbon to the atmosphere and thus exacerbating warming (Sturm et al. 2001).

4.3.4.4 Contaminants

Interactions between climate change and physical processes may increase availability and uptake of contaminants for fish, wildlife, and their habitats. Contaminants currently stored in glacial ice, multi-year sea ice, and permafrost, including persistent organic pollutants and mercury, will likely be released to aquatic ecosystems as the temperature rises (Schiedek et al. 2007).

4.3.5 Fish

There have been 42 species of fish recorded in the rivers, lakes, and coastal waters of the Refuge (Appendix F, species list). Of these, 14 display freshwater resident life histories in the Refuge, 11 have anadromous life histories, and 17 are marine species. Five of the species classified as anadromous also display freshwater resident life history traits in the Refuge. Some fish species with notable ecological and/or subsistence value in the Refuge are discussed in the following text.

4.3.5.1 Freshwater Species

Sheefish

Sheefish (*Stenodus leucichthys*), also known as inconnu, are large, piscivorous whitefish found in many arctic and subarctic waters of Asia and North America (Alt 1969, McPhail and Lindsey 1970, Morrow 1980). Sheefish populations may exhibit either anadromous or freshwater resident life histories (Howland et al. 2001).

In the Refuge, sheefish are found only on the south side of the Brooks Range, in the Porcupine River (Alt 1974). Sheefish captured in the upper reaches of the Porcupine River in Alaska are freshwater residents (Brown et al. 2007a). Sheefish spawn in flowing water over gravel (Alt 1969, Gerken 2009), but spawning locations in the Porcupine River drainage have not been identified.

Sheefish are considered a good food fish and are routinely eaten wherever they are captured (McPhail and Lindsey 1970, Morrow 1980).

Round Whitefish

Round whitefish (*Prosopium cylindraceum*) are a relatively small, primarily benthic-feeding whitefish common in northern North America and northeastern Asia (McPhail and Lindsey 1970). While anadromous populations of round whitefish exist in certain coastal drainages (Morin et al. 1982), most round whitefish populations are freshwater resident forms, occupying clearwater rivers and lakes (Morrow 1980, Stewart et al. 2007). Round whitefish are generally thought to be less migratory than other whitefish species (Morrow 1980), and large migrations along main-stem rivers are not commonly observed (Brown et al. 2007a). They presumably spawn in tributary rivers and lakes where they are found. Riverine round whitefish spawn in flowing water over gravel (Craig and Wells 1975, Zyus'ko et al. 1993), while lake resident populations spawn over a mixed substrate composed of rocks, gravel, and mud (Normandeau 1969, Bryan and Kato 1975, Haymes and Kolenosky 1984).

Round whitefish are present in the Sagavanirktok (McCart et al. 1972, Alt 1976) and Canning (Ward and Craig 1974, Craig 1977c, Smith and Glesne 1982) River drainages in the northern part of the Refuge but have not been identified in other North Slope Refuge drainages. In the southern part of the Refuge, round whitefish are present in most stream reaches and some lakes in the Chandalar, Sheenjek, and Coleen River drainages (Alt 1974, Ward and Craig 1974, Craig and Wells 1975). Round whitefish have been identified in the main-stem Porcupine River in the Canadian portion of the drainage (Bryan 1973), and it is likely that they occur at times along the Alaska portion of the river.

Round whitefish are occasionally harvested in subsistence fisheries in Alaska but are usually a minor component of the catch (Andersen et al. 2004, Adams et al. 2005, Pedersen and Linn 2005).

Lake Trout

Lake trout (*Salvelinus namaycush*) are long-lived, piscivorous fish that inhabit deep, coldwater lakes and are widely distributed throughout northern North America, from the Alaska Peninsula east across Canada to Nova Scotia and south to northern New York (Scott and Crossman 1973). In general, lake trout spawn in large boulder or rubble substrate at depths less than 13 m (Scott and Crossman 1973).

In the Refuge, lake trout are likely common in coastal and headwater lakes where suitable overwintering habitat (deep water) exists (Scott and Crossman 1973). On the North Slope, lake trout have been documented in Elusive Lake in the Sagavanirktok River drainage, unnamed coastal lakes in the Canning River drainage, Okpilak Lake, Wahoo Lake, Lake Peters, and Lake Schrader (Ward and Craig 1974, Wilson et al. 1977, Glesne 1983, Bendock and Burr 1985, West and Fruge 1989). In South Slope waters, lake trout have been documented in Old John, Blackfish, and Vettatrin Lakes (Craig and Wells 1975, ADFG 1984).

Lake trout are harvested in subsistence fisheries in Old John Lake by the residents of Arctic Village and in Lakes Peters and Schrader by the residents of Kaktovik (Craig 1989b, Adams et al. 2005). Elusive Lake, located in the Ribdon River drainage, supports a small lake trout sport fishery; however, no specific sport harvest data could be found for Refuge waters (Bendock and Burr 1985, Jennings et al. 2010).

Arctic Char

Arctic char (*Salvelinus alpinus*) inhabit freshwater and marine habitats and exhibit a circumpolar distribution in the Holarctic (Johnson 1980, Reist et al. 1997). While anadromous and freshwater-resident forms are present in Alaska, only lake-resident populations exist in the Refuge (Reist et al. 1997). Arctic char feed non-selectively on insect larvae, amphipods, plankton, and fish (Craig 1977c, Armstrong and Morrow 1980). Spawning is thought to occur during fall in deeper portions of lacustrine habitats to avoid ice scouring (Armstrong and Morrow 1980).

In North Slope waters of the Refuge, populations have been documented in numerous lakes in the upper Canning and Sagavanirktok River drainages (McCart et al. 1972, Craig 1977c), Lake Peters and Lake Schrader in the upper Sadlerochit River drainage, and Porcupine Lake (Ward and Craig 1974, Craig 1977c). In South Slope waters, Arctic char have only been documented in Redfish Lake (Ward and Craig 1974, Craig and Wells 1975). No data regarding abundance or harvest of arctic char are currently available.

Northern Pike

Northern pike (*Esox lucius*) inhabit lakes and rivers of the circumpolar north, ranging as far south as southern New England in North America and Spain in Europe (Scott and Crossman 1973). Northern pike are primarily piscivorous but are ambush predators that have been known to opportunistically consume aquatic and terrestrial invertebrates, birds, frogs, and small mammals (Raat 1988). In spring, adults move from overwintering areas in lakes and deeper areas of rivers to spawn in shallow, calm areas containing emergent vegetation and mud bottoms. Adults disperse to summer feeding areas in lakes, rivers, and slough areas.

In the Refuge, northern pike are found in the Chandalar and Sheenjek River drainages on the South Slope (Craig and Wells 1975) but have yet to be captured in a scientific survey on the North Slope, despite documented occurrences to the west and east of the Refuge, in the Colville and Mackenzie rivers (Percy 1975, Bendock and Burr 1985). In South Slope waters of the Refuge, northern pike are harvested in subsistence fisheries by residents of Arctic Village in Old John, Mud, and Loon Lakes (Adams et al. 2005). Recreational harvest is also likely elsewhere; however, no Refuge-specific data could be found (Jennings et al. 2010). In North Slope waters of the Refuge, Jacobson and Wentworth (1982) and Pedersen and Linn (2005) report that northern pike are infrequently harvested in subsistence fisheries in the Hulahula River by residents of Kaktovik. However, the presence of northern pike in North Slope Refuge waters has not been scientifically verified; thus, these data should be viewed with caution.

Longnose Sucker

Longnose suckers (*Catostomus catostomus*) inhabit stream, river, and lake environments of northern North America and Eastern Siberia (Scott and Crossman 1973, Morrow 1980). They are bottom feeders that consume algae, aquatic and terrestrial macroinvertebrates, plants, and fish eggs (Stenton 1951). Spawning occurs in shallow stream habitats over gravel substrate. Besides annual movements to and from spawning grounds, longnose suckers are thought to be relatively sedentary (Scott and Crossman 1973).

In the Refuge, longnose suckers are common in lakes and streams in the Sheenjek, Chandalar, and Coleen rivers on the South Slope (Craig and Wells 1975). In North Slope waters, no documented accounts could be found, despite occurrences in the Colville and Mackenzie rivers to the west and east of the Refuge (Tripp and McCart 1974, Bendock and Burr 1985). Biological data pertaining to longnose suckers in the Refuge are extremely scarce and largely limited to distributional information (Craig and Wells 1975, Ward and Craig 1974). Craig and Wells (1975) located one suspected spawning area in the East Fork of the Chandalar River in the vicinity of the Junjik River. The authors also speculate that, while longnose suckers are present in the Sheenjek, Chandalar, and Coleen rivers, abundances are likely greater in downstream areas.

Longnose suckers are taken in low numbers in subsistence fisheries on the Chandalar River and in Old John Lake by the residents of Arctic Village (Adams et al. 2005).

Burbot

Burbot (*Lota lota*) inhabit deep areas of rivers and lakes of the circumpolar north, extending south into some temperate areas of Europe, Asia, and North America (Morrow 1980). Where burbot and lake trout co-occur, they likely compete for resources, as they have similar habitat and prey requirements (Scott and Crossman 1973). Burbot spawning generally takes place over gravel and sand substrate, in relatively shallow areas of rivers and lakes, but may also occur in river channels (Chen 1969, Breeser et al. 1988). Seasonal movements ranging from a few kilometers to over 250 kilometers have been reported in riverine populations, most likely associated with the connection of spawning and foraging habitats (Percy 1975, Breeser et al. 1988, Evenson 1993).

In North Slope waters of the Refuge, burbot have been documented in lakes and main-stem areas of the Canning (Ward and Craig 1974, Craig 1977c, Smith and Glesne 1982) and Sagavanirktok rivers (Bendock 1980, Bendock and Burr 1985). On the South Slope, burbot have been recorded north of Arctic Village in the Coleen and Chandalar rivers and in three lakes in the Sheenjek River drainage, including Old John Lake (Ward and Craig 1974, Craig and Wells 1975).

Burbot are infrequently harvested in subsistence fisheries by residents of Kaktovik in waters surrounding Barter Island and by residents of Arctic Village in the Chandalar River and Old John Lake (Adams et al. 2005, Pedersen and Linn 2005).

Ninespine Stickleback

Ninespine stickleback (*Pungitius pungitius*) are distributed in North America from Cook Inlet, Alaska, north to the Arctic Ocean and southeast through Canada, terminating on the Atlantic coast of New England (Scott and Crossman 1973, Morrow 1980). Ninespine stickleback prey on aquatic insects and small crustaceans and are an important prey item of lake trout, Dolly Varden char, Arctic char, Arctic grayling, northern pike, burbot, and avian predators, such as loons, terns, and gulls (Palmer 1962, Morrow 1980). They are tolerant of salinities less than 20 parts per thousand (ppt) and may move between fresh and saltwater throughout the year, as access and conditions permit (Wooton 1984). Spawning occurs in freshwater in shallow areas containing aquatic vegetation (Wooton 1984), which are also used as nursery areas. Little is known regarding seasonal movements; however, spawning individuals likely move from shallow areas (littoral, tributary, or slough habitat) to deep areas (river deltas, coastal areas, lake bottoms) (Wooton 1984).

In North Slope waters of the Refuge, ninespine stickleback are widely distributed and abundant in lakes, rivers, and streams of most of the major drainages (Ward and Craig 1974, Craig 1977a, Wilson et al. 1977, Bendock and Burr 1985). Furthermore, ninespine stickleback are commonly found in coastal brackish water lagoons (Griffiths et al. 1977, West and Wiswar 1985, Wiswar et al. 1995, Brown 2008) and coastal lakes, where they are often the only species present (West and Fruge 1989, Trawicki et al. 1991, Wiswar 1994). South Slope waters of the Refuge do not support populations of ninespine stickleback (Scott and Crossman 1973). In the Refuge, biological data regarding ninespine stickleback are presented in numerous publications (Yoshihara 1972, Ward and Craig 1974, Craig 1977a, Griffiths et al. 1977, Wilson et al. 1977, Bendock and Burr 1985, West and Wiswar 1985, West and Fruge 1989, Trawicki et al. 1991, Wiswar et al. 1995, Jarvela and Thorsteinson 1999, Brown 2008). While they are commonly found in most North Slope coastal habitats of the Refuge, catch rates vary dramatically among areas and years.

Slimy Sculpin

Slimy sculpin (*Cottus cognatus*) inhabit lakes and streams throughout northern North America, from as far south as Virginia to the North Slope of Alaska (Bendock 1980, Morrow 1980). Slimy sculpin feed almost exclusively on aquatic and terrestrial macroinvertebrates and are an important prey item in the diet of burbot, lake trout, northern pike, Arctic char, humpback whitefish, and piscivorous birds (Palmer 1962, Craig and Wells 1975, Morrow 1980). Spawning occurs in small tributary and ephemeral habitats (Craig and Wells 1975). Males select and defend nest sites under rocks or logs where females deposit eggs.

In North Slope waters of the Refuge, slimy sculpin have been found in coastal rivers and lakes of the Sagavanirktok, Canning, and Kongakut River drainages (Yoshihara 1972, Bendock 1980, Bendock and Burr 1985). On the South Slope, slimy sculpin are present in the headwaters of the Chandalar, Sheenjek, and Coleen rivers (Craig and Wells 1975).

Biological data pertaining to slimy sculpin in the Refuge are scarce and limited to distributional information in North Slope waters (Yoshihara 1972, Bendock 1980, Bendock and Burr 1985). On the South Slope, Craig and Wells (1975) found slimy sculpin to rank third in abundance behind grayling and round whitefish. Currently, no harvest data are available.

Arctic Grayling

Arctic grayling (*Thymallus arcticus*) reside in lakes and rivers of northern North America, from Hudson Bay to the western shores of Alaska, and in Asia, from Siberia to North Korea (Scott and Crossman 1973). Spawning occurs in small river and lake tributaries over areas of sandy gravel (Bishop 1971). When stream habitat is not available, spawning may also occur in larger substrates in rivers and lakes (Scott and Crossman 1973). Adults feed on aquatic and terrestrial invertebrates and may undertake extensive inter- and intra-drainage movements between overwintering sites (deep pools, lakes, spring-fed areas) and summer feeding habitats

following reproduction (Craig and Poulin 1975, West et al. 1992). Arctic grayling are, at least for short periods, tolerant of saline conditions, as individuals are sometimes captured in estuarine waters during inter-drainage movements in coastal systems (West et al. 1992).

In the Refuge, Arctic grayling are widespread and abundant on the North and South Slopes (Garner and Reynolds 1987, Craig and Wells 1975). Biological information regarding Arctic grayling inhabiting North Slope rivers and lakes of the Refuge are present in numerous publications (Furniss 1975, Garner and Reynolds 1986, Deschermeier et al. 1987, Wiswar 1991, Wiswar 1992, Wiswar 1994, West et al. 1992). Research in South Slope waters of the Refuge is less abundant and largely limited to information on distribution (Ward and Craig 1974, Craig and Wells 1975).

Arctic grayling are harvested in subsistence fisheries by residents of Kaktovik in nearby waters and by residents of Arctic Village in the Chandalar River, Mud Lake Creek, and Old John Lake (Craig 1989b, Adams et al. 2005). Recreational harvest is also likely to occur throughout the Refuge; however, no specific data are available (Jennings et al. 2010).

4.3.5.2 Anadromous Species

Broad Whitefish

Broad whitefish (*Coregonus nasus*) are large, primarily benthic-feeding whitefish found in many arctic and subarctic waters of Asia and North America (McPhail and Lindsey 1970, Morrow 1980). Broad whitefish populations may exhibit either anadromous or freshwater resident life histories (Reist and Bond 1988, Chudobiak 1995, Brown et al. 2007a).

They are present but uncommon in the nearshore waters of the Beaufort Sea in the northern part of the Refuge (Craig 1984, Brown 2008) and are relatively common in the upper Chandalar and Porcupine River drainages in the southern part of the Refuge (Bryan 1973, Craig and Wells 1975, Alt 1976, Brown et al. 2007a). Because Refuge rivers north of the Brooks Range do not support spawning or overwintering habitats for broad whitefish, they spawn and overwinter in aquatic habitats in the lower Sagavanirktok River and farther west or in the Mackenzie River and farther east (Craig 1984, Craig 1989a, Reist and Bond 1988). Therefore, all broad whitefish encountered in the northern part of the Refuge are anadromous fish, foraging in nearshore and estuarine habitats of the Beaufort Sea and occasionally in the lower reaches of the larger rivers (Ward and Craig 1974, Craig 1984, Brown 2008). By contrast, broad whitefish found in the upper Chandalar and Porcupine River drainages in the southern part of the Refuge are freshwater residents and do not migrate to sea (Brown et al. 2007a). Broad whitefish spawn in flowing water over gravel (Chang-Kue and Jessop 1997, Shestakov 2001, Carter 2010); however, the spawning origins and migratory ranges of broad whitefish populations in the southern part of the Refuge are unknown.

Broad whitefish are a very good food fish (McPhail and Lindsey 1970, Morrow 1980) and are harvested in the northern and southern parts of the Refuge (Adams et al. 2005, Pedersen and Linn 2005).

Humpback Whitefish

Humpback whitefish (*Coregonus clupeaformis*) are medium size, primarily benthic-feeding whitefish that are widely distributed in rivers, lakes, and estuaries of northern North America (McPhail and Lindsey 1970). Lake resident populations spawn over rock, gravel, and sand substrates (Bidgood 1974, Bryan and Kato 1975, Anras et al. 1999). River spawning humpback whitefish spawn in flowing water over gravel (Stein et al. 1973, Alt 1979, Brown 2006, Harper et al. 2009).

They are present in the northern and southern parts of the Refuge. They are very rare in the nearshore waters of the Beaufort Sea, in the northern part of the Refuge (Craig 1984, Brown 2008). Humpback whitefish encountered in the northern part of the Refuge are anadromous fish, foraging in nearshore and estuarine habitats of the Beaufort Sea. Similar to broad whitefish, spawning and overwintering habitats of humpback whitefish are in the lower Sagavanirktok River and farther west and in the Mackenzie River and farther east. In the southern part of the Refuge, humpback whitefish are present in several lakes in the upper Sheenjek River drainage (Craig and Wells 1975) and in the main stem Porcupine River (Bryan 1973, Craig and Wells 1975, Alt 1976, Brown et al. 2007a). Humpback whitefish in the Sheenjek River drainage lakes are most likely lake resident populations, living entirely in their home lakes (Ward and Craig 1974, Craig and Wells 1975). It is likely that additional lake resident populations exist in unsurveyed Refuge lakes in the upper Chandalar River drainage. Humpback whitefish populations in the main stem Porcupine River are freshwater residents and do not migrate to sea (Brown et al. 2007a), although their spawning origins and migratory ranges in the freshwater system are unknown.

Humpback whitefish are considered to be a good food fish. They have been exploited in commercial food fisheries in North America more than any other whitefish species (Bodaly 1986, Ebener 1997, Tallman and Friesen 2007) and are routinely harvested in subsistence fisheries in Alaska and northwestern Canada (Corkum and McCart 1981, Adams et al. 2005, Georgette and Shiedt 2005).

Least Cisco

Least cisco (*Coregonus sardinella*) are relatively small, pelagic-feeding whitefish found in many Arctic and subarctic waters of Asia and North America (McPhail and Lindsey 1970, Morrow 1980). They have been documented in estuaries, rivers, and lakes from various locations in Alaska and northwest Canada (Alt 1980, Mann and McCart 1981, Reist and Bond 1988, Moulton et al. 1997, Seigle 2003). Least cisco are known to undertake extensive spawning migrations from lower drainage or estuarine rearing habitats to spawning habitats that may be several hundred kilometers upstream (Reist and Bond 1988, Brown et al. 2007a).

Least cisco distribution in the northern part of the Refuge is limited to summer foraging migrations into nearshore and estuarine habitats of the Beaufort Sea (Craig 1984, Brown 2008). Bendock (1977) found that they were more common on the mainland side of the barrier islands than seaward of these islands in Beaufort Sea coastal waters. Because Refuge rivers north of the Brooks Range do not support spawning or overwintering habitats for least cisco, they spawn and overwinter in aquatic habitats in the Sagavanirktok River and farther west or in the Mackenzie River and farther east (Craig 1984, Craig 1989a, Reist and Bond 1988). The occurrence of least cisco in the southern part of the Refuge appears to be limited to the main stem of the Porcupine River (Bryan 1973, Alt 1974, Brown et al. 2007a), which probably serves as a migration corridor from downstream rearing habitats in the Yukon Flats (Brown and Fleener 2001) or upstream spawning and feeding areas in the Canadian portion of the drainage. Isolated populations in lakes are evidently capable of spawning in the absence of flowing water (Doxey 1991); however, actual spawning habitats in Refuge lakes have not been identified.

Least cisco are harvested in subsistence fisheries as human or dog food, but they are generally captured incidentally to other larger whitefish species (Andersen et al. 2004, Georgette and Shiedt 2005, Moulton and Seavey 2005).

Arctic Cisco

Arctic cisco (*Coregonus autumnalis*) are relatively small, pelagic-feeding whitefish, with a near circumpolar distribution in Arctic waters (McPhail and Lindsey 1970, Moskalenko 1971). Populations have been documented in several large rivers in northern Europe and Asia and in the Mackenzie River in northwestern Canada. All evidence indicates that Arctic cisco observed in Alaskan waters originate in the Mackenzie River drainage (Gallaway et al. 1983, Fechhelm et al. 2007), where several spawning populations have been identified (McLeod and O'Neil 1983, Dillinger et al. 1992).

Arctic cisco are fully anadromous and are not known to exist as freshwater residents (Reist and Bond 1988). Arctic cisco distribution in the Refuge is limited to summer foraging migrations in nearshore habitats of the Beaufort Sea and spawning migrations from overwintering habitats in the Colville River delta, back to the Mackenzie River once they mature (Craig 1989a, Fechhelm et al. 2007, Brown 2008). They are not found in freshwater habitats of the Refuge.

During summer, Arctic cisco are one of the most abundant species in nearshore waters of the Beaufort Sea, including Refuge waters (Craig 1984, Brown 2008) and one of the primary species taken in the Kaktovik subsistence fishery (Griffiths et al. 1977, Pedersen and Linn 2005).

Dolly Varden Char

Dolly Varden char (*Salvelinus malma*) are a coldwater species, distributed on the Arctic coast of North America, from the Mackenzie River west and south through Alaska to British Columbia, and on the western side of the Pacific, from the Chukotsk Peninsula of Russia south to Japan and Korea (Scott and Crossman 1973, Reist et al. 1997, DeCicco 1997). It is important to mention the history of taxonomic confusion surrounding Dolly Varden and Arctic char, in the genus Salvelinus (as reviewed by Reist et al. 1997). In past literature, riverine char inhabiting the Arctic were often described as Arctic char. However, as a result of recent research, anadromous and stream-resident char west of the Mackenzie River have been reclassified as Dolly Varden (Reist et al. 1997).

Stream-resident and anadromous forms of Dolly Varden are present in the Refuge, the latter confined to North Slope waters (Ward and Craig 1974). Resident fish, with few exceptions, utilize spring-fed habitat exclusively for all life history stages (Craig 1977b, McCart 1980). Alternatively, anadromous Dolly Varden migrate to brackish, nearshore coastal areas of the Beaufort Sea from overwintering habitats in deep pools and spring-fed areas in coastal rivers (Craig 1989a, Fechhelm et al. 1997, Jarvela and Thorsteinson 1997). While at sea, individuals move extensively along the Arctic coast in mixed-stock aggregates (West and Wiswar 1985, Craig 1989a, Krueger et al. 1999). Anadromous Dolly Varden return to freshwater to spawn and overwinter (Craig 1984, Craig 1989a).

Dolly Varden are widespread in the Refuge, particularly on the North Slope, with most large coastal rivers supporting populations (Ward and Craig 1974, Bendock and Burr 1985, DeCicco 1997). However, one lake-dwelling population has been documented in the upper Canning River drainage (Craig 1977c). On the South Slope of the Refuge, stream-resident Dolly

Varden are present in the headwaters of major rivers, including documented occurrences in the Sheenjek and Chandalar rivers (Craig and Wells 1975).

Abundance estimates of overwintering aggregations of anadromous Dolly Varden have been conducted in numerous drainages throughout the North Slope of the Refuge since the 1970s (Yoshihara 1973, Craig and McCart 1974, Furniss 1975, Bendock 1980, Bendock 1982, Bendock 1984, Smith and Glesne 1982, Fruge 1987, Arvey 1991, Kristofferson et al. 1991, Viavant 2005, Viavant 2009). The Ivishak River, located in the Sagavanirktok River drainage, has received considerable attention, as it is believed to contain the largest overwintering aggregation of Dolly Varden on the North Slope (Viavant 2005). However, it is unlikely that these fish utilize habitats in the Refuge in any large numbers, as the majority of spawning and overwintering sites are located in lower sections of the drainage, outside Refuge boundaries (Viavant 2005). Similarly, numerous studies have identified spawning and overwintering habitats in drainages in the Refuge (McCart et al. 1972, Yoshihara 1972, Craig 1973, Craig 1977a, Craig and McCart 1974, Glova and McCart 1974, Furniss 1975, Bendock 1982, Bendock 1984, Smith and Glesne 1982, Daum et al. 1984, West and Wiswar 1985, Kristofferson et al. 1991, Viavant 2001, Viavant 2005, Viavant 2009). The abundance and distribution of anadromous Dolly Varden in coastal rivers is likely restricted by the presence of spring-fed areas and deep, oxygenated pools suitable for spawning and overwintering (Craig 1989a). In some small drainages that contain few of these areas, Craig (1978) notes that, "it is conceivable that a single spring-fed site might harbor virtually all members of a particular population, from eggs in the gravel to adult fish, during the eight to nine month winter period."

Anadromous Dolly Varden are one of the primary species caught in subsistence fisheries by residents of Kaktovik, in a winter fishery at Fish Hole 2 on the Hulahula River and in coastal areas during the summer (Craig 1989b, Pedersen and Linn 2005). There is also evidence of recreational use and harvest on the Hulahula and Kongakut rivers and likely elsewhere (Arvey 1991, Jennings et al. 2010)

Chinook Salmon

Chinook salmon (*Oncorhynchus tshawytscha*) are distributed on the western coast of North America, from southern California to Point Hope, Alaska, and in Asia, from Northern Siberia to Japan (Scott and Crossman 1973). Chinook salmon are anadromous, semelparous, and the largest of the Pacific salmon species. Fry emerge in spring and usually spend the first year of life in freshwater habitats (Wipfli 2009). Smolts migrate to sea in spring (Bradford et al. 2009). In the ocean, the majority of Chinook salmon occupy habitats in the Bering Sea, where they will spend between one and five years before returning to natal freshwater streams to spawn (Healey 1991). On the spawning grounds, females construct gravel nests in clearwater streams and rivers where eggs are deposited and covered with substrate (Healey 1991).

In the Refuge, Chinook salmon are common in South Slope waters; however, they have not been captured in North Slope waters, despite occasional catches in the Colville and Mackenzie rivers to the west and east (Craig and Haldorson 1986, Irvine et al. 2009a). In South Slope rivers, Chinook salmon are common in the Chandalar, Christian, and Sheenjek rivers (Barton 1984). However, spawning is primarily observed in lower portions of these drainages, in areas south of the Refuge border. Thus it is likely that only a small proportion of these fish utilize Refuge waters (Buklis and Barton 1984). In the Refuge, tagging data and aerial observations indicate Chinook salmon are present in the East Fork of the Chandalar and Upper Sheenjek rivers (Barton 1984, Eiler et al. 2004, Eiler et al. 2006a, Eiler et al. 2006b) and in the Coleen

River (Barton 1984). Chinook salmon also pass through the Refuge via the Porcupine River, en route to spawning areas in Canada.

Chinook salmon are harvested in commercial, sport, and subsistence fisheries throughout the Yukon River drainage; however, no harvest data exist for Refuge waters (Hayes et al. 2008).

Chum Salmon

Chum salmon (*Oncorhynchus keta*) are distributed on the western coast of North America, from southern California to the Arctic, and in adjacent waters of Asia, from Korea to Japan (Scott and Crossman 1973). Chum salmon are semelparous and anadromous (Horne-Brine et al. 2009). Fry emerge from gravel nests in early spring and shortly thereafter begin to disperse to the marine environment. Individuals return to freshwater to spawn in natal tributaries beginning in summer and fall (Gilk et al. 2009, Horne-Brine 2009). On the spawning grounds, females construct gravel nests where eggs are deposited and subsequently covered with gravel (Morrow 1980).

In the Refuge, chum salmon are found in rivers on the north and south sides of the Brooks Range. In North Slope waters of the Refuge, chum salmon have been captured in low numbers in the Sadlerochit, Sagavanirktok, and Canning rivers, as well as nearshore coastal areas (Smith and Glesne 1982, Craig and Haldorson 1986, Brown 2008). Currently it is unknown if these fish are members of established, reproducing populations in North Slope rivers or strays originating from more southerly drainages (Bendock and Burr 1984, Craig and Haldorson 1986, Irvine et al. 2009b). In South Slope rivers, chum salmon are more common; it is the most abundant salmon species in the Yukon River drainage (Barton 1984). Sonar-derived population estimates between 1995 and 2006 in the Chandalar and Sheejek rivers ranged from 65,000 to 496,000 and 14,000 to 438,000 fall chum, respectively (Melegari and Osborne 2007). However, the proportion of these fish that move into Refuge waters is likely small, as the primary spawning grounds for these fish are located downstream of Refuge borders (Buklis and Barton 1984). Within Refuge borders, chum salmon have been found in the East Fork of the Chandalar River and an unnamed tributary of the East Fork near Big and Little Rock Mountain (ADFG 2009). An aerial survey by Rost (1986) estimated 400 chum salmon in the Coleen River, with some fish located upstream as far as Pass Creek (ADFG 2009). Chum salmon have also been found in the Salmon Trout River and Sheenjek River north of White Snow Mountain (Barton 1984, ADFG 2009). Furthermore, between 1995 and 2006, an average of 35,000 fall chum migrated through the Refuge via the Porcupine River to spawning areas in the Fishing Branch River and other tributaries in Canada (Melegari and Osborne 2007).

The residents of Kaktovik report infrequently harvesting chum salmon in subsistence fisheries in nearshore areas surrounding Barter Island on the North Slope (Pedersen and Linn 2005). South slope populations are harvested in commercial, sport, and subsistence fisheries throughout the Yukon River drainage; however, no harvest data specific to Refuge waters could be found (Hayes et al. 2008).

4.3.5.3 Marine Species

Arctic Cod

Arctic cod (*Boreogadus saida*) are a marine species distributed throughout the entire northern polar basin, around Greenland and Iceland, into Hudson Bay, and in the North Bering Sea (Cohen et al. 1990). Arctic cod prefer cold (0-6 °C), saline (20-30 ppt) habitats but are at least temporarily tolerant of fluctuating temperatures, salinities, and turbidities, as they are found in both inshore and offshore marine areas, estuaries, and occasionally in coastal rivers (Lowry and Frost 1981, Craig et al. 1982, Cohen et al. 1990). During late summer and fall, Arctic cod may aggregate into large schools and move into nearshore coastal areas that are transitioning from estuarine to marine conditions (Craig et al. 1982, Hop et al. 1997). Seasonal movements and schooling behavior may be associated with spawning, foraging, predator avoidance, or habitat availability, as Arctic cod are often found associated with the edges of pack ice (Welch et al. 1993, Hop et al. 1997). Spawning occurs under ice between November and March, presumably close to shore (Lowry and Frost 1981, Craig et al. 1982).

In the Refuge, Arctic cod are widely distributed throughout nearshore coastal areas of the Beaufort Sea (Craig et al. 1982, Underwood et al. 1995) and may be the most abundant and widely distributed fish species in the Beaufort Sea (Lowry and Frost 1981, Craig et al. 1982, Craig 1984). Catch data suggest Arctic cod are more abundant in coastal areas west of the Refuge, with one estimate during the summer of 1978 in Simpson lagoon numbering in the millions (Craig et al. 1982, Jarvela and Thorsteinson 1999). In the Refuge, catch rates of Arctic cod are variable in and among years and areas but tend to increase during late summer and fall (Griffiths et al. 1977, Fruge et al. 1989, West and Fruge 1989, Underwood et al. 1995, Wiswar et al. 1995, Jarvela and Thorsteinson 1999, Brown 2008).

There is some evidence that Arctic cod are harvested in subsistence fisheries in Kaktovik and Jago lagoons by residents of Kaktovik (Griffiths et al. 1977).

Saffron Cod

Saffron cod (*Eleginus gracilis*) are a marine species distributed throughout the North Pacific, from the Yellow Sea in Asia to southeast Alaska and north in the Arctic Ocean, from eastern Siberia to northwestern Canada (Morrow 1980, Cohen et al. 1990). Saffron cod inhabit both in- and offshore marine and estuarine areas and are occasionally found in coastal rivers (Morrow 1980). Fish tend to move inshore in fall and winter to spawn, then move offshore in spring and summer to feed in deeper habitats (Morrow 1980).

In the Refuge, saffron cod are widely distributed in nearshore coastal areas of the Beaufort Sea (Wiswar and West 1987, Fruge et al. 1989, Wiswar et al. 1995, Brown 2008). Biological data pertaining to saffron cod are largely limited to catch data and are available for nearshore areas in the Refuge (Griffiths 1984, Wiswar and West 1987, Fruge et al. 1989, Wiswar et al. 1995, Brown 2008) and outside (Bendock 1977, Craig et al. 1985, Fechhelm et al. 2006) the Refuge. Catch rates vary substantially among years and areas.

Fourhorn Sculpin

Fourhorn sculpin (*Myoxocephalus quadricornis*) are a marine species distributed throughout the circumpolar north, from the Baltic Sea east across northern Siberia, to the Arctic coast of Canada, and south to Norton Sound, Alaska (Andriyashev 1954, Morrow 1980). Fourhorn sculpin rarely descend below 15-20 m and inhabit cold nearshore marine and estuarine coastal areas year-round, occasionally moving into coastal streams and rivers (Griffiths et al. 1977, Morrow 1980).

In the Refuge, fourhorn sculpin are widely distributed in nearshore coastal areas of the Beaufort Sea (Griffiths et al. 1977, West and Wiswar 1985, Wiswar and West 1987, Underwood et al. 1995, Wiswar et al. 1995, Jarvela and Thorsteinson 1999, Brown 2008). Biological data pertaining to fourhorn sculpin are largely limited to catch data and are available for nearshore areas in the Refuge (Griffiths et al. 1977, West and Wiswar 1985, Wiswar and West 1987, Underwood et al. 1995, Wiswar et al. 1995, Jarvela and Thorsteinson 1999, Brown 2008) and outside (Percy et al. 1974, Griffiths et al. 1975, Craig and Haldorson 1981, Jarvela and Thorsteinson 1999) the Refuge. While catches vary among years and areas, fourhorn sculpin are typically one of the most frequently, if not the most frequently, captured species in nearshore areas of the Refuge.

Arctic Flounder

Arctic flounder (*Liopsetta glacialis*) are a marine species that is distributed from Queen Maude Gulf in Arctic Canada, west along the coast of North America to Siberia, and south to Bristol Bay, Alaska (Andriyashev 1954, Morrow 1980). Arctic flounder typically remain close to shore, inhabiting shallow brackish water habitats and river deltas, occasionally entering rivers and delta lakes (Craig 1977c, Wilson et al. 1977). Spawning occurs in coastal areas (Andriyashev 1954, Morrow 1980).

In the Refuge, Arctic flounder are found throughout nearshore coastal areas of the Beaufort Sea (Griffiths et al. 1977, Wiswar 1986, Jarvela and Thorsteinson 1999, Brown 2008). Relative to Arctic cod and fourhorn sculpin, Arctic flounder are less frequently captured but still common in nearshore areas of the Beaufort Sea coast (Percy et al. 1974, Griffiths et al. 1975, Craig and Haldorson 1981, Jarvela and Thorsteinson 1999, Fechhelm et al. 2006), including areas in the Refuge (Griffiths et al. 1977, Wiswar 1986, Underwood et al. 1995, Jarvela and Thorsteinson 1999, Brown 2008). Arctic flounder are infrequently captured in subsistence fisheries by the residents of Kaktovik, in waters surrounding Barter Island (Pedersen and Linn 2005).

4.3.5.4 Climate Change Impacts on Fish

As the Arctic climate continues to warm, biological, chemical, and physical changes to aquatic ecosystems are occurring (Martin et al. 2009). These changes will alter the structure and function of aquatic ecosystems and have direct and indirect effects on fish, especially in Arctic Refuge where species are at the northern limit of their range.

Adequate water quality, food availability, winter water volume, and flow timing and magnitude limit fish habitat use (Craig 1989a). Adequate water quality is important to fish at all life history stages and varies relative to the species and life history stage considered. In freshwater systems, poor water quality conditions are more likely to occur during winter when habitats are ice-covered and summer when temperatures are warm, productivity is high, and habitats are thermally stratified. Food availability in summer feeding habitats must be adequate to meet energetic demands and allow fish to build overwintering reserves. Adequate volumes of water in overwintering habitats are critical during winter and only exist in deep lakes (Trawicki et al. 1991), spring-fed streams (Childers et al. 1977, Craig 1989a), and deep pools in the lower reaches of large rivers (Ward and Craig 1974). Adequate flow between habitats is crucial to the survival of resident and anadromous fish traveling from summer feeding areas to these limited overwintering habitats. During spring, peak flows aid in the downstream dispersal of juvenile fish to rearing habitats and migration of adult fish to summer feeding habitats in lakes, streams, and estuaries. Collectively changes in water quality, food availability, water storage, and the magnitude and timing of flow will likely alter habitats, leading to local extirpations and changes in abundance, distribution, and the prominence of various life history forms. A lack of biological information and an incomplete understanding of the effects of climate change on aquatic ecosystems will make it difficult to predict and quantify the subsequent effects on fish (Arctic Climate Impact Assessment 2005).

Freshwater and anadromous fish use a wide range of Refuge habitats, including small ponds, lakes, streams, rivers, and estuaries. Lakes and small ponds are important to resident and anadromous species at various stages in their life history. Mountain and Foothill lakes tend to be deeper than coastal plain lakes and may support large populations of resident and anadromous fish. Many depression and thaw lakes on the coastal plain are isolated from deeper waters, are too shallow to support overwintering populations, and do not support fish, even seasonally. Other lakes, such as riverine and delta lakes, may be connected seasonally during flooding events and provide spawning, rearing, and feeding habitat for resident and anadromous species.

Refuge streams and rivers provide important habitat and migratory pathways for anadromous and resident species. Craig and McCart (1975) classified North Slope lentic habitats into three broad categories: mountain, spring-fed, and tundra streams. Mountain streams are typically steep, fast flowing, have gravel substrates, and are fed by varying proportions of snowmelt, glacial meltwater, and spring-fed tributaries. These gravel-bottomed streams are often braided, subject to scour during flooding events, and have low invertebrate densities. Flow in small mountain streams is often intermittent. Waters are typically cold relative to streams at lower elevations. Mountain streams may support feeding, rearing, and overwintering of resident and anadromous species in lower reaches and, when contributions from springs are present, in mid to upper reaches. Spring-fed streams are often tributaries of mountain streams, have relatively stable flows and temperatures throughout the year, and tend to have high invertebrate densities. Spring-fed streams provide critical spawning and overwintering habitat for anadromous and resident species. Tundra streams fed by surface runoff originate in the Foothills and coastal plain ecoregions. They are typically meandering or beaded systems with low to moderate invertebrate densities and substrate composed of silt, sand, and organic matter. These systems may be important spawning, rearing, and feeding habitats for resident and anadromous species, but are too shallow to provide overwintering habitat.

During the spring and summer, North Slope streams and rivers deliver water, nutrients, and sediments to shallow coastal habitats. These flows help fuel lower trophic levels and maintain waters that are warm and brackish relative to cold, saline ocean waters. Compared to streams and rivers, lagoons support much higher densities of invertebrates, making anadromy an advantageous life history strategy for species tied to overwintering or spawning in freshwater habitats (Craig 1989).

On the South Slope of the Refuge, streams originate in the mountains and in Old Crow Basin. The upper reaches of large mountain tributaries are often fed by springs. The lower reaches of large mountain tributaries tend to be deeper, have larger volumes of water available in deep pools during winter, and may have more reliable connections to floodplain lakes during the ice-free season when compared to the large mountain streams on the North Slope.

Various climate conditions and hydrologic and geomorphic processes are essential for maintaining water quality, food availability, winter water volumes, and adequate timing and magnitude of flows. By mid-century dramatic changes to the arctic climate, hydrologic cycle, and landforms will likely occur (Martin et al. 2009). The relative importance of and interactions between these changes will likely vary seasonally, between ecoregions and with waterbody type. Warmer temperatures will lead to earlier snowmelt and an extension in the duration of the ice-free season. During the summer, warmer air temperatures, changes in reflected light, and the extended duration of the summer season will lead to increased water temperatures in freshwater systems. Shallow lakes and streams will be more sensitive to warming than deeper waterbodies, especially those fed by springs. The strength and occurrence of thermal stratification in deeper lakes may increase, leading to a decrease in the susceptibility to wind-driven mixing and an increase in the potential for oxygen deficits. Erosion associated with the degradation of permafrost may affect sedimentation rates, turbidity, and productivity. Increased productivity in the summer could lead to shifts in the relative importance of benthic and pelagic productivity, which could result in changes in prey availability and reduce feeding efficiency. Increased productivity could also lead to increased decomposition rates and oxygen demand in overwintering habitats. Increased winter precipitation may limit light availability and primary productivity below ice-cover, which could exacerbate oxygen deficits in overwintering habitat. Changes in precipitation, water storage capacity, freeze-thaw cycles, and rain on snow events will alter the magnitude and duration of peak flows, which will undoubtedly occur earlier. Changes in the timing of snowmelt will vary between ecoregions, which could lead to changes in ice-dam flooding and interrupt dispersal and migratory movement during spring. Increased evapotranspiration rates, loss of glaciers, a deeper active layer, and the extended duration of the summer season could lead to lower surface water levels, drying of streams and rivers, and fragmentation of habitats during the summer. Degradation of permafrost could lead to formation of pits, troughs, and slumps that could intercept subsurface flows or create new drainage networks, resulting in drying of existing migratory corridors. Loss of relatively warm fresh water flows to estuarine habitats coupled with increased frequency and severity of storm events and degradation of barrier islands could cause the physical and chemical environment in lagoons to transition from warm brackish estuarine conditions to cold saline oceanic conditions earlier in the season.

These changes in climate, hydrology, and landforms will have a wide range of effects on fish and their habitat. Water temperature is an important factor determining the survival, growth, and reproductive success of aquatic organisms. In freshwater habitats of Arctic Refuge, many fish species may initially benefit from warmer water temperatures (Craig 1989a, Reist et al. 2006) and the extended duration of the summer season. As water temperatures rise past optima for cold-water adapted species, especially those with a narrow range of thermal tolerance, physiological stress and increasing metabolic demands may lead to declines in productivity (Tonn 1990), genetic change through natural selection (Reist et al. 2006), or local extirpations (Arctic Climate Impact Assessment 2005). Warmer water temperatures will likely increase the incidence of disease and parasites (Reist et al. 2006) and benefit fish species expanding their range northward, giving these species a competitive advantage over native cold-water tolerant species.

As the duration of the summer season increases, the relationship between photoperiod and thermal regimes will change and phenological mismatches between migration, water levels, peak flows, egg hatching, food availability, water quality, and presence of predators may occur. For example, increased water temperature and the extended duration of the summer season could lead to asynchrony in the timing of temperature-dependent egg hatching and juvenile fish dispersal relative to the availability of their prey resources or presence of predators. Unless temperature increases beyond their physiological tolerance limits, however, the extended duration of the ice-free season will likely benefit most juvenile fish species by extending the time available for building reserves prior to a shorter overwintering season.

During the summer, some aquatic habitats may provide thermal refugia and/or be important migratory corridors linking habitats. Changes in temperature and connectivity between habitats may alter habitat quality, influence behavior, and prohibit migration of some species (Martin et al. 2009). The negative effects of increased temperature on some species may be offset by proportional increases in food availability as a result of additional nutrient inputs and the extended summer season (Reist et al. 2006). Increased water temperature and changes in nutrient inputs associated with deepening of groundwater flow paths or increased terrestrial inputs associated with changes in riparian vegetation could lead to increased rates of primary and secondary productivity. Initially fish may benefit from increases in productivity; however, increased ecosystem respiration rates may decrease dissolved oxygen concentrations in ice-covered overwintering habitats and the deepest, coldest layer of thermally stratified lakes (Reist et al. 2006). Reduced oxygen concentrations will have a negative impact on sensitive fish species using these habitats, especially during winter when habitat availability is drastically reduced (Craig 1989a). Additionally, shifts in the relative importance of benthic and pelagic primary productivity associated with increased nutrients could have a negative impact on fish production if feeding efficiencies decrease.

Other changes in water quality may occur as rates of permafrost degradation and glacier melt increase. Rates of erosion, thermokarst failure, and occurrence of thaw slumps will likely increase along moderate elevation gradients with ice-rich soils. The occurrence of thaw slumps could have a negative impact on water quality and lead to local extirpation of populations (Brown et al. 2011). Bioavailability of mercury is also expected to increase with deepening of the active layer, increased rates of glacier melt, and increased fire frequency and intensity. Changes in riparian vegetation, canopy cover, shifts to deciduous species could lead to changes in snow distribution, channel morphology, terrestrial inputs, invertebrate community composition and food availability for fish.

Large-scale changes in hydrologic regimes that lead to a change in the timing or magnitude of peak flow or decreased connectivity in streams and between lakes could have a negative impact on fish. These changes could alter timing and extent of juvenile dispersal, decrease genetic flow between populations, and prevent seasonal migrations, stranding adults traveling to overwintering areas.

In areas of discontinuous permafrost on the south side of the Refuge, degradation of permafrost has led to an increase in the relative contribution of cool sub-permafrost groundwater relative to surface flow in some locations (Walvoord and Striegl 2007). If these trends continue, an increase in the contribution of cool groundwater inflows may mitigate the effects of surface water warming in areas of discontinuous permafrost. While cooler groundwater inflows may buffer increases in temperature, decreased oxygen concentrations may increase physiological stress to some fish species (Brown et al. 2011).

On the coastal plain, deepening of the active layer, a downward shift to subsurface flows, and increased evapotranspiration rates will likely to lead to shallower nutrient-enriched waters that are more susceptible to solar warming and in some cases drying. Extended periods of drying and prolonged high temperatures could prevent migration to overwintering habitats and could have a negative impact on some anadromous and freshwater resident species that use shallow coastal plain lakes for summer feeding and overwintering (Deegan and Peterson 1992). This loss of late summer connectivity between habitats could also keep fish from benefitting from the extension of the summer feeding season.

On mid to low elevation slopes of the foothills and Davidson Mountains, increased storage associated with deepening of the active layer and groundwater flow paths could lead to an increase in late summer and winter base flows and changes in water chemistry. An increase in summer base flows could buffer effects of increased warming, help maintain access to summer feeding and overwintering habitats, and have a positive effect on most species.

Collectively, these losses in surface water discharge from rivers fed by glacial meltwater, and mountain, foothills, and coastal plain streams on the North Slope could have a negative impact on coastal ecosystems where relatively warm freshwater inputs help maintain warm brackish conditions in lagoons and nearshore coastal habitats. Ocean water conditions tend to be extremely cold (below 32 °F), saline (30 ppt), and outside the long term thermal and salinity tolerance limits of most freshwater and anadromous species inhabiting Arctic Refuge. Loss of freshwater input coupled with loss of sea-ice and protective barrier islands, and an increase in the frequency and severity of storm surges will contribute to the deterioration of the nearshore band and lead to earlier mixing of cold saline ocean waters into lagoons and other nearshore areas. Colder, more saline conditions in these productive nearshore marine environments would have a negative impact on anadromous species, but would likely increase habitat quality for cold-water tolerant marine species. Freshwater resident species, such as Arctic grayling, using nearshore environments as a corridor for interdrainage exchange (Wiswar et al. 1986, West et al. 1992) would also be negatively affected. In addition to changes in salinity and temperature, acidification of ocean ecosystems may affect multiple food web components and have cascading effects on both marine and anadromous fish.

Predicting responses of anadromous fish that integrate changes in marine and freshwater environments will be difficult, particularly for species such as Dolly Varden that have facultative life history strategies (Reist et al. 2006). Loss of glacial meltwater will have important implications for adult Dolly Varden during two critical life history stages: summer feeding in estuarine areas and late summer migration to spawning and overwintering habitat. Loss of instream connectivity and fragmentation of habitat could occur any time following break-up, but will likely increase in frequency and extent as the summer progresses and Dolly Varden are undergoing critical migrations to upstream spawning and overwintering habitat. During the summer feeding season, loss of glacial meltwater could have a negative impact on Dolly Varden feeding in lagoons where relatively warm freshwater inputs help maintain warm brackish conditions. Without substantial freshwater input, the thermal stratification that formed early in the summer season may not be maintained, causing coastal lagoons to take on cold, saline ocean conditions that are far outside the optimal thermal and salinity conditions for Dolly Varden. If their estuarine summer feeding habitat becomes inhospitable and/or late summer connections between summer feeding and overwintering habitat become unreliable, Dolly Varden may spend less time feeding in coastal waters and more time feeding in rivers. Since coastal waters have relatively high densities of prey compared to glacial rivers, this change would have a negative effect on individual growth rates and population size. Cooler, more saline conditions in these productive nearshore marine environments may increase habitat quality for cold-water tolerant marine species, such as saffron cod.

To better understand and predict the effects of climate change on future distributions, health, and biodiversity of fishes in Arctic Refuge, we need a better understanding of physical, chemical, and biological processes that drive the functioning of aquatic ecosystems. To document the effects of climate change on fish in Arctic Refuge, long-term monitoring of climate, phenology, hydrology, and geomorphic processes should be conducted in concert with aquatic ecosystem studies. Studies on fish in Arctic Refuge have been scarce over the past few decades, and baseline data on distributions, lower trophic levels, productivity, diets, life history strategies, genetic diversity, and phenotypic plasticity are needed to assess future changes and help guide future studies and long-term monitoring. A more detailed assessment of potential threats relative to biological thresholds will help guide these efforts. The potential for synergistic interactions between climate change and other threats such as development, introduction of invasive species, contaminants, and consumptive use should be considered as well. Freshwater habitats along the coast will become more vulnerable to salinization and drainage as sea level rises, the severity and frequency of storm surges increase, and rates of coastal erosion increase.

4.3.6 Birds

Common and scientific names of birds follow American Ornithologists' Union (1983) and subsequent supplements. There have been 201 species of birds recorded on the Refuge (see Appendix F). Of these, 109 are confirmed as breeding on the Refuge, and another 35 species likely breed there, although breeding has not been confirmed. Twenty-two species use the Refuge during migration only or are regular visitors, and 35 species are rare visitors or vagrants that do not regularly occur on the Refuge. In the northern foothills of the Brooks Range, Arctic coastal plain and adjacent marine waters, 158 species have been recorded, including 79 breeding species and 79 species that are migrants, visitors, or vagrants. In the Brooks Range, 107 species have been recorded, of which 68 are breeders and 39 are migrants, visitors, or vagrants. On the south side of the Brooks Range and in the adjacent boreal forest areas, 136 species have been recorded, of which 105 are breeders, and 20 are migrants, visitors, or vagrants.

Birds that use the Refuge have ranges that include all 50 U.S. states and six continents. Birds that breed and are reared in northern Alaska likely migrate as far as Antarctica (Arctic terns), New Zealand (bar-tailed godwits) and sub- Saharan Africa (northern wheatear). There are also 25 species that are year-around residents on the Refuge, mostly in boreal forest areas. Residents include two species of ptarmigan (rock and willow), three grouse species (ruffed, spruce, and sharp-tailed), gyrfalcon, five species of owls (great-horned, snowy, northern hawk-owl, great grey, and boreal), four species of woodpeckers (downy, hairy, American three-toed, and black-backed), gray jay, common raven, three species of chickadees (black-capped, boreal, and gray-headed), American dipper, pine grosbeak, white-winged crossbill, and common and hoary redpolls.

Although some Refuge bird species have been well studied, e.g., golden eagles and snow geese (Douglas et al. 2002), distribution and abundance data are lacking for many. In the following sections, we describe what is known about the various species and species groups found on the Refuge.

4.3.6.1 Waterfowl

Thirty-five species of waterfowl have been observed on the Refuge. Of these, 24 species occur as breeders or migrants (Appendix F), including 2, 5, and 17 species of swans, geese, and ducks, respectively. The ducks include 5 species of dabblers, 2 species of bay or diving duck, and 10 species of sea ducks. The geese primarily breed on the coastal plain, but one species, the Canada goose, is only found on the south side of the Refuge. Tundra swans mostly breed on the coastal plain and trumpeter swans breed in wetlands in boreal forest areas.

Most of the dabbling ducks breed on the south side of the Refuge, although green-winged teal and northern pintail also breed on the coastal plain. The sea ducks can be further broken down in to several sub-groups: eiders, harlequin ducks, scoters, long-tailed ducks, goldeneyes, and mergansers. Eiders and long-tailed ducks breed on the coastal plain and utilize adjacent coastal areas. Scoters are most abundant as migrants in the Beaufort Sea but also breed on the inland coastal plain, in the Brooks Range, and on the south side of the Refuge. Harlequin ducks are primarily associated with fast moving streams in the Brooks Range during the breeding season. Buffleheads and goldeneyes are primarily associated with the boreal forest. Red-breasted mergansers, the more common of the two merganser species, breed throughout the Refuge and spend post-breeding molting periods in coastal areas.

Waterfowl are an important subsistence resource for local rural residents (P. Willams, local resident, pers. comm., Jacobson and Wentworth 1982, Naves 2010). Kaktovik residents hunt brant, snow geese, cackling geese, northern pintails, long-tailed ducks, common eiders, and king eiders (Jacobson and Wentworth 1982). Eider and long-tailed duck eggs are occasionally harvested as well. In the following sections, we summarize results from surveys and research conducted on specific waterfowl species on the Refuge.

Swans

Tundra Swan—In 1986, the U. S. Fish and Wildlife Service, Division of Migratory Bird Management, initiated annual surveys for breeding birds on the Arctic coastal plain, including a portion of Arctic Refuge (Larned et al. 2009). Arctic Refuge stratum covers less than two percent of the entire survey area. During the period 1992–2008, Tundra swan populations increased across the Arctic coastal plain of Alaska (Larned et al. 2009).

Trumpeter Swan—Every five years since 1968, U.S. Fish and Wildlife Service, Division of Migratory Bird Management, has conducted summer surveys of trumpeter swans in interior Alaska, including the south side of Arctic Refuge (Conant et al. 2007). Numbers of swans observed in the Yukon Flats survey region, which includes southern portions of Arctic Refuge, have increased dramatically over this period. Ground-based surveys are needed to verify whether these birds are trumpeter swans or tundra swans (A. Brackney, wildlife biologist at Arctic Refuge, pers. comm.).

Geese

Snow Geese—During fall, snow geese and other geese concentrate on the coastal plain. Snow geese in particular occur in great numbers during late August and September; at times more than 300,000 snow geese stage on the coastal plain prior to fall migration (Table 4-6) (Garner and Reynolds 1986, Kendall 2006). These geese nest on Banks Island and other areas in the Canadian Arctic. After breeding, they move westward to the coastal plain of northwest Canada and northeast Alaska. Numbers of snow geese using Arctic Refuge vary inversely with the numbers staging in Canada. These birds remain on the coastal plain for several weeks, foraging on cotton grass and equisetum in upland and coastal tundra habitats (Hupp et al. 2002). When the first persisting snowfall occurs, they fly back east for their southward migration through the MacKenzie River valley.

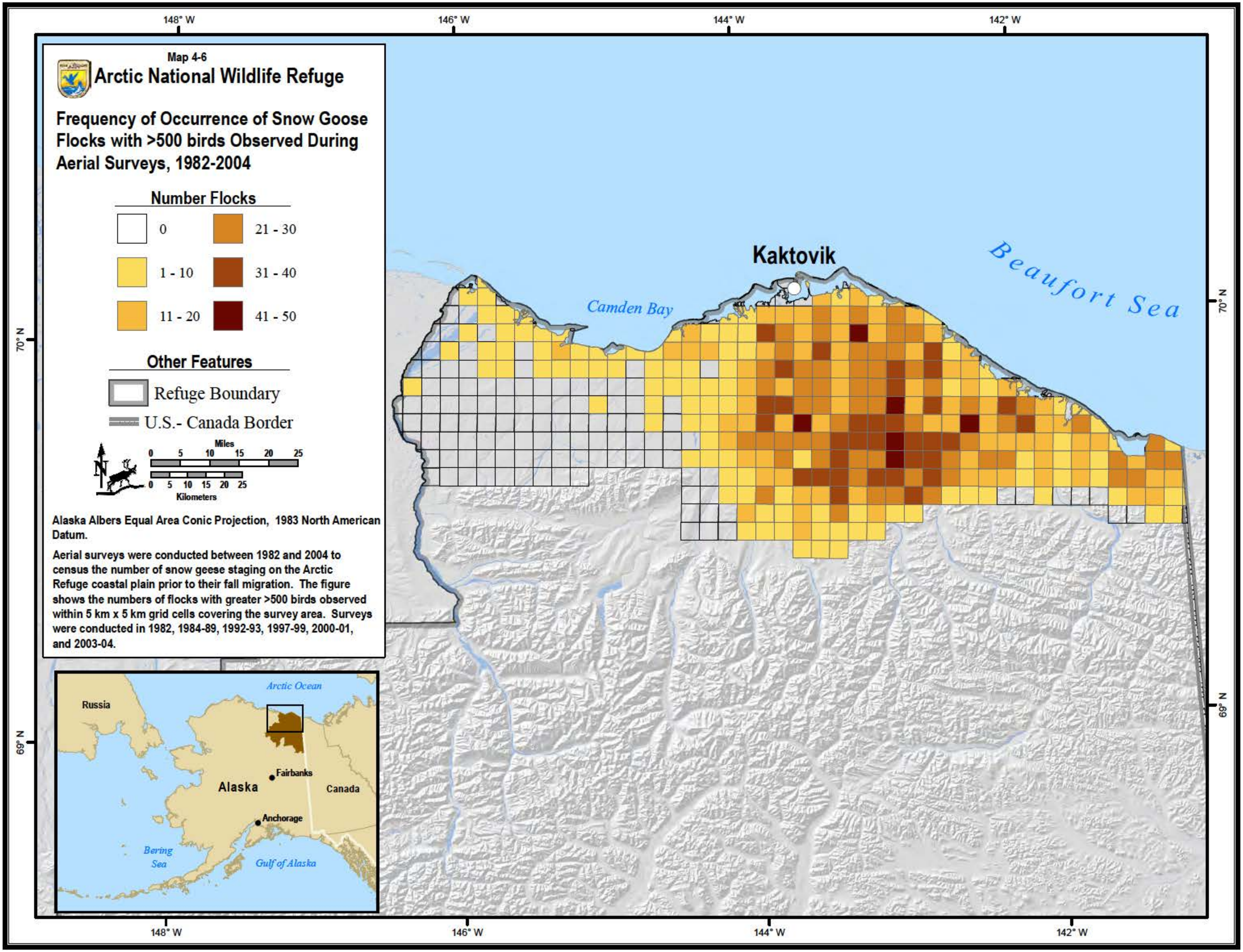
Map 4-6 shows frequency of observations of snow goose flocks on Arctic Refuge coastal plain during surveys from 1982–2004. Snow geese depend on this staging period to build energy reserves needed for their southward migration (Brackney and Hupp 1993). They are easily disturbed by aircraft or other human intrusions during the staging period, making them vulnerable to displacement from important foraging areas.

Table 4-6. Maximum post-breeding snow goose counts on the Refuge

Year	Peak Count
1973[1]	44,037
1974[1]	48,591
1975[1]	0
1976[1]	228,793
1978[1]	325,760[4]
1979[2]	195,000
1980[2]	8,996
1981[2]	20,000
1982[3]	107,072[4]
1983[3]	19,787[4]
1984[3]	94,528[4]
1985[3]	309,225
1986[3]	217,435[4]
1987[3]	107,000[4]
1988[3]	50,800[4]
1989[3]	72,000[4]
1992[3]	60,700
1993[3]	89,500
1997[3]	104,626
1998[3]	28,365
1999[3]	108,000
2000[3]	164,562
2001[3]	93,905
2003[3]	76,422 (186,715[5])
2004[3]	189,636[4]
Mean	106,109
Std Dev	87,933
Median	89,500

[1] Populations extrapolated from transect counts.
[2] Combination of total flock counts and photographic counts
[3] Total flock counts.
[4] Adjusted for observer error.
[5] Adjusted for observer error using the correction factor from 2004.

Notes: Maximum post-breeding snow goose counts on the Arctic National Wildlife Refuge, Alaska: 1973–1981 (Spindler 1982a), 1982 (Spindler 1982b), 1983 (Spindler 1983), 1984 (Oates et al. 1985), 1985 (Roberstson et al. 1997), 1986–1987 (Brackney 1988), 1988 (Brackney 1989), 1989 (Brackney 1990), 1992–1993 (Robertson et al. 1997), 1997–2001 (Boyle et al. 2002), and 2003–2004 (Kendall 2006).



Map 4-6
Arctic National Wildlife Refuge
Frequency of Occurrence of Snow Goose Flocks with >500 birds Observed During Aerial Surveys, 1982-2004
Number Flocks
0
1 - 10
11 - 20
21 - 30
31 - 40
41 - 50
Other Features
Refuge Boundary
U.S.- Canada Border
Miles
0 5 10 15 20 25
0 5 10 15 20 25
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
Aerial surveys were conducted between 1982 and 2004 to census the number of snow geese staging on the Arctic Refuge coastal plain prior to their fall migration. The figure shows the numbers of flocks with greater >500 birds observed within 5 km x 5 km grid cells covering the survey area. Surveys were conducted in 1982, 1984-89, 1992-93, 1997-99, 2000-01, and 2003-04.
148° W
146° W
144° W
142° W
70° N
69° N
Kaktovik
Camden Bay
Beaufort Sea
Arctic Ocean
Russia
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska

Ducks

Common Eider—Common eiders are an important subsistence resource for residents of Beaufort Sea coast villages (Jacobson and Wentworth 1982). U.S. Fish and Wildlife Service, Division of Migratory Bird Management, conducts annual aerial surveys to estimate the number, population trend, and distribution of breeding common eiders in coastal habitats of the Alaskan Arctic coastal plain, including Arctic Refuge (Dau and Taylor 2000, Dau and Anderson 2001, Dau and Anderson 2002, Dau and Hodges 2003, Dau and Larned 2004, Dau and Larned 2005, Dau and Larned 2006, Dau and Larned 2007, Dau and Larned 2008, Dau and Bollinger 2009). The number of common eider pairs observed on the Refuge has ranged from 75 to 445, with considerable annual variation (Dau and Bollinger 2009). A ground based survey was conducted in 2003 and 2004 to estimate numbers of birds, common eiders in particular, that were nesting on Refuge barrier islands (Kendall 2005). A total of 341 eider nests were found during this survey. This was considerably higher than the number of nests (n=14) found during earlier surveys (Divoky 1978), in spite of decline in their population in northern Alaska during the intervening time period (Suydam et al. 2000). The increased nesting population on Refuge barrier islands maybe due to habitat changes. For example, warmer springs may have caused earlier melt of ice in lagoons, making barrier islands less accessible to nest predators such as Arctic foxes. However, these islands and the nesting habitat they provide, primarily driftwood, may be vulnerable to changes in sea conditions such as increased erosion and flooding associated with climate change.

Long-tailed Duck—Coastal lagoons formed by barrier islands provide molting and migratory staging areas for tens of thousands of long-tailed ducks (Brackney et al. 1987). Aerial survey conducted in 2002 and 2003 found up to 28,000 long-tailed ducks staging in lagoons on Arctic Refuge (Lysne et al. 2004). Long-tailed ducks nest on the Arctic coastal plain, but the number of birds found in Arctic Refuge lagoons likely far exceed the number breeding on adjacent tundra. This suggests that birds are migrating from a larger geographic area to use these habitats. There were large declines in numbers of long-tailed ducks breeding on the Arctic coastal plain from 1977 to 1998 (Hodges et al. 1996, Conant and Groves 1998), but in recent years, populations have been fairly stable at lower levels (Larned et al. 2009).

4.3.6.2 Upland Birds

Three grouse and two ptarmigan species occur on the Refuge (Appendix F). Ruffed, spruce and sharp-tailed grouse are found only on the south side of the Refuge. Rock and willow ptarmigan are found in all regions of the Refuge. All of these species are harvested by residents of villages adjacent to the Refuge (P. Willams, local resident, pers. comm., Jacobson and Wentworth 1982, Naves 2010). Ptarmigan are an important food source, especially in the spring, for Kaktovik residents (Jacobson and Wentworth 1982).

4.3.6.3 Loons and Grebes

Four species of loons are found on the Refuge (Appendix F). Red-throated and Pacific loons breed in all regions, whereas common loons breed only on the south side and occasionally visit coastal areas. Yellow-billed loons breed in low numbers on larger lakes in the Brooks Range, but also are fairly common migrants in marine areas.

Two species of grebe, red-necked and horned, occur on the Refuge. Both likely breed on the south side and visit other regions. Horned grebes have been identified as a species of Conservation Concern by the Service (2008a).

Yellow-billed Loon—In 2009, the Service determined that listing the yellow-billed loon as a threatened or endangered species was warranted under the Endangered Species Act, but listing was precluded by other higher priority listing actions. Listing a species as "warranted, but precluded" means the proposal to list is delayed while the Service works on listing proposals for other higher priority species.

Yellow-billed loon populations are vulnerable because of small population size, low reproductive rate, and very specific breeding habitat requirements. The species is also identified as a species with conservation concerns by the Service (2008a), Audubon Alaska (Stenhouse and Senner 2005), and Alaska Department of Fish and Game (ADFG 2006). Subsistence harvest surveys indicate a substantial number of yellow-billed loons are harvested in some years on the North Slope (Naves 2010). While they are not harvested in Kaktovik (Jacobson and Wentworth 1982), they may be occasionally taken in fish nets (Magoun and Robus 1977). In 2006, the Service worked cooperatively with a variety of Native, State and Federal partners to develop a conservation agreement to protect yellow-billed loons and their habitats in northern Alaska.

Yellow-billed loons breed in low numbers on Arctic Refuge, primarily in the northern foothills of the Brooks Range (Bee 1958). They are uncommon migrants and summer residents in the marine areas of the Refuge.

Red-throated Loon—Red-throated loons also have been identified as a species of Conservation Concern by the Service (2008a), Audubon Alaska (Stenhouse and Senner 2005) and the ADFG (2006). On Arctic Refuge, this species is more abundant than the yellow-billed Loon. Its highest densities are found on the coastal plain and adjacent marine areas, but a few also breed in the Brooks Range and on the south side of the Refuge.

4.3.6.4 Seabirds and Alcids

Northern fulmars, short-tailed shearwaters, thick-billed murres, and horned puffins are rare coastal visitors in the summer. Black guillemots are summer residents in coastal areas and breed in low numbers on barrier islands.

4.3.6.5 Raptors

Birds of prey, or raptors, including hawks, eagles, falcons, and owls, are found in all regions of the Refuge. Most hawks breed on the south side or in the Brooks Range. Sharp-shinned hawks, northern goshawks, Swainson's hawks, and red-tailed hawks are all thought to breed on the south side. Northern harriers and rough-legged hawks occur in all regions of the Refuge and likely breed on the inland coastal plain, in the Brooks Range, and on the south side. Ospreys have been observed occasionally in all regions of the Refuge but are most often seen on the south side. Bald eagles visit the Brooks Range and coastal plain, but likely only breed on the south side. Golden eagles breed on the inland coastal plain, in the Brooks Range, and on the south side of the Refuge. Golden eagles are commonly observed on the coastal plain in late June and early July during years when calving and post-calving caribou herds are present (Garner and Reynolds 1986). These are primarily subadult birds (Mauer 1985a, Mauer 1987, Young et al. 2002) that are preying on or scavenging caribou calves. In a 1983–1985 study, golden eagles were the main predators on caribou calves on the calving grounds (Whitten et al. 1992, Griffith et al. 2002). It also appears that northern Alaska, including the Brooks Range and coastal plain of Arctic Refuge, is utilized by birds from other regions in the State. Eagles that were hatched in the Alaska Range were found in the Refuge during at least during two subsequent summers (McIntyre et al. 2008, C. McIntyre, wildlife biologist, National Park Service, pers. comm.).

Four species of falcons are found on the Refuge. Gyrfalcons breed throughout the Brooks Range, though not in high numbers. Merlins and American kestrels visit the coastal plain and breed in the Brooks Range and on the south side. Peregrine falcons also nest throughout the Brooks Range and foothills but are more abundant along south-side rivers with bluffs, particularly the Porcupine River. Two subspecies of peregrine falcons nest on the Refuge: the Arctic peregrine falcon north of the Continental Divide, and the American peregrine falcon to the south. These subspecies had been listed for protection under the Endangered Species Act, but both have been delisted.

Surveys have been conducted on several rivers in the Refuge to monitor cliff-nesting raptors, including the Canning, Hulahula, Kongakut, Porcupine, and Coleen rivers. Species nesting on cliffs along north-flowing rivers include golden eagles, peregrine falcons (*tundrius* subspecies), gyrfalcons, and rough-legged hawks. The primary cliff-nesting species along rivers draining into the Yukon River are peregrine falcons (*americanus* subspecies) and golden eagles (Payer and Kendall 2005, Ritchie and Maguire 2007).

4.3.6.6 Shorebirds

Twenty-six species of shorebirds breed on Arctic Refuge, 22 of which breed on the coastal plain. Another species, the red knot, occurs as a migrant only (Appendix F). Of these 27 species, 21 are identified as species of Moderate or High Conservation Concern by the U.S. Shorebird Conservation Plan (Brown et al. 2001), Alaska Shorebird Conservation Plan (Alaska Shorebird

Group 2008), the Service (2008a), and/or Audubon Alaska (Stenhouse and Senner 2005) because of small or declining populations. Information about critical breeding and migration stopover sites is needed to guide and support conservation activities for these species (Brown et al. 2001, International Wader Study Group 2003, Bart et al. 2007). Baseline data on shorebird population sizes, distributions, habitat requirements, and demographic parameters are needed to evaluate effects of climate change, which is projected to impact shorebird habitats through northward expansion of shrubs into tundra habitats and inundation and erosion of coastal habitats (Sturm et al. 2001, Arctic Climate Impact Assessment 2004). Shorebirds are also vulnerable to direct and indirect impacts from any development of oil and gas reserves in the vicinity of the Refuge (Meehan 1986, Troy 2000, National Research Council 2003).

The Program for Regional and International Shorebird Monitoring (PRISM) was developed as a method to monitor shorebirds in Canada and the United States (Harrington et al. 2002, Skagen et al. 2003, Bart et al. 2005). Using PRISM protocols, we conducted a study to provide baseline data on shorebird abundance and habitat use on the coastal plain of the Refuge (Brown et al. 2007b). We found the five most abundant shorebird species had estimated population sizes of 16,000–53,000, and the total estimated number of shorebirds of all species was approximately 230,000 (95 percent CI: 104,100–363,000, Table 4-7). This was approximately 1.7 percent (95 percent CI: 0.8 percent–2.6 percent) of the combined total estimated North American population for these species (Morrison et al. 2001, Morrison et al. 2006b) and higher than the biological criterion for designation as a site of International Importance under the Western Hemisphere Shorebird Reserve Network (WHSRN); 100,000 birds; (Western Hemisphere Shorebird Reserve Network 2006) and the Ramsar Convention (20,000 birds) (Ramsar 1999). The population size estimated for the pectoral sandpiper was greater than 10 percent of the estimated total population size for the species, which meets the criterion for a WHSRN site of International Importance for a particular species (Western Hemisphere Shorebird Reserve Network 2006). Population estimates were greater than one percent of the estimated total North American population for eight species (Table 4-7), the WHRSN criterion for designation of a site as a site of Regional Importance. Two of these species, American golden-plover and dunlin, are listed as species of Conservation Concern in the Alaska Shorebird Conservation Plan because of small or declining populations (Alaska Shorebird Group 2008).

Estimated densities, population sizes, and percentage of each shorebird species' total estimated population size in the 1002 Area of Arctic Refuge are displayed in Table 4-7. Estimates are grouped according to the number of intensive survey plot detections for each species. From Brown et al. (2007b).

Table 4-7. Estimated densities, population, and percentage of estimated shorebird populations in the 1002 Area

Species	Population size		Percent of population estimate (95% CI)[a]
	Estimate ± SE	(95% CI)	
American Golden-Plover	15,686 ± 3,340	9,142–22,232	7.8 (4.6–11.1)
Semipalmated Sandpiper	49,698 ± 12,300	25,590–73,804	1.4 (0.7–2.1)
Pectoral Sandpiper	52,978 ± 9,176	34,992–70 962	13.2 (8.7–17.7)
Dunlin	10,506 ± 4,112	2,448–18,564	1.4 (0.3–2.5)
Red-necked Phalarope	42,762 ± 8,814	25,488–60,038	1.7 (1.0–2.4)
Red Phalarope	23,226 ± 9,874	3,872–42,580	1.9 (0.3–3.4)
Ruddy Turnstone	2,984 ± 1,484	76–5,892	5.4 (0.1–10.7)
Western Sandpiper	252 ± 252	0–748	0.01 (0.00–0.02)
Stilt Sandpiper	6,218 ± 2,194	1,920–10,518	0.8 (0.2–1.3)
Long-billed Dowitcher	6,848 ± 3,190	594–13,102	1.7 (0.1–3.3)
All species	229,960 ± 22,487	104,122–362,938	1.7 (0.8–2.6)

[a] Percent of population estimate compares the number of birds of each species estimated to occur in the 1002 Area of Arctic National Wildlife Refuge coastal plain and the estimated total population size reported in Morrison et al. (2001), as revised (R. Morrison et al. 2006).

Brown et al. (2007b) found that wetland and riparian habitats, particularly in coastal areas and river deltas, are of particularly high value to many shorebird species. The importance of these habitats for breeding shorebirds should be considered when making management decisions. Shorebird density appears to be highest in wetland areas in the Canning River Delta region (Map 4-7) (Brown et al. 2007b). This is the portion of the Refuge closest to existing and proposed oil development on contiguous State-managed lands. Future research should address the importance of the Canning Delta wetlands for shorebirds and potential effects and mitigation of anthropogenic activities in the region.

Human development in Alaska’s Arctic coastal plain, primarily associated with exploration and extraction of petroleum, may directly influence breeding bird populations through habitat loss, disturbance, and presence of contaminants (National Research Council 2003). There may also be indirect consequences, such as the availability of human food sources and man-made structures benefiting predator populations. Changes in predator populations could be an important factor affecting birds breeding on the Arctic coastal plain (National Research Council 2003). However, the dynamic of this predator prey relationship is not well understood.

A multi-year, multi-site study (including Arctic Refuge) that investigated the relationship between human development, nest predator populations, and nest survival of tundra-nesting birds found a negative effect on nest survival for passerines (lapland longspurs) but not shorebirds (Liebezeit et al. 2009). As with other studies conducted in the Arctic, Liebezeit et al. (2009) found substantial temporal and spatial variability in nest survival (Summers and Underhill 1987, Troy 2000).

A development (infrastructure) effect, if present, may be small relative to natural variability in the Arctic, rendering such effects difficult to detect. However, the higher predation risk detected for passerine nests near oil field facilities, along with evidence of the predator effects from elsewhere in the Arctic (Restani et al. 2001, R. Lanctot, unpublished data), is sufficient to warrant continued efforts to minimize benefits for predators. Any developments near the Refuge should be designed to reduce artificial nesting, perching, and denning sites and managed to limit access to food wastes.

Several species of shorebirds aggregate in coastal habitats of the northern Alaska after their breeding season (Connors 1984, Taylor et al. 2010). Staging in these habitats is thought to be necessary for building energy reserves for migration. Coastal areas of Arctic Refuge are vulnerable to climate change and offshore oil development in the eastern Beaufort Sea. Possible impacts include reduced sea ice cover and changing sea conditions causing flooding and increased coastal erosion, which threatens mudflats and other littoral areas used by shorebirds. In addition, large areas of the eastern Beaufort Sea north of Arctic Refuge have recently been leased for oil exploration and development. An oil spill in this region could have direct effects by oiling birds aggregated in coastal areas and indirect effects by impacting the food resources used by birds. Furthermore, onshore activities associated with offshore development may disturb and displace shorebirds from preferred staging areas.

Starting in 2005, Arctic Refuge worked with multiple partners to investigate shorebird use of coastal areas of the Refuge. We identified several high-use areas, but also found considerable inter-annual and within-season variability (Figure 4-2). It may be that there are no particular areas that are most important but rather birds depend on the conglomeration of all coastal habitats and move among sites depending on environmental conditions and food availability. Timing of use of coastal areas varied by species, but generally peak abundance was during the last week of July and the first week of August. However, shorebirds continue to use coastal habitats into September. Our observations suggested that habitat use is influenced by weather and water conditions, which likely determine food availability.

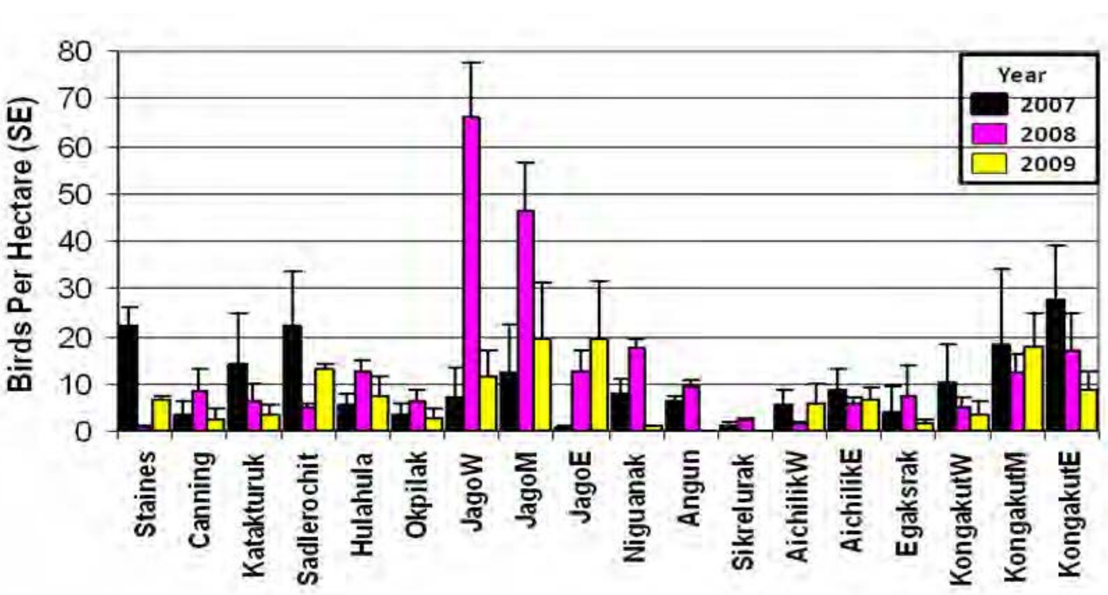
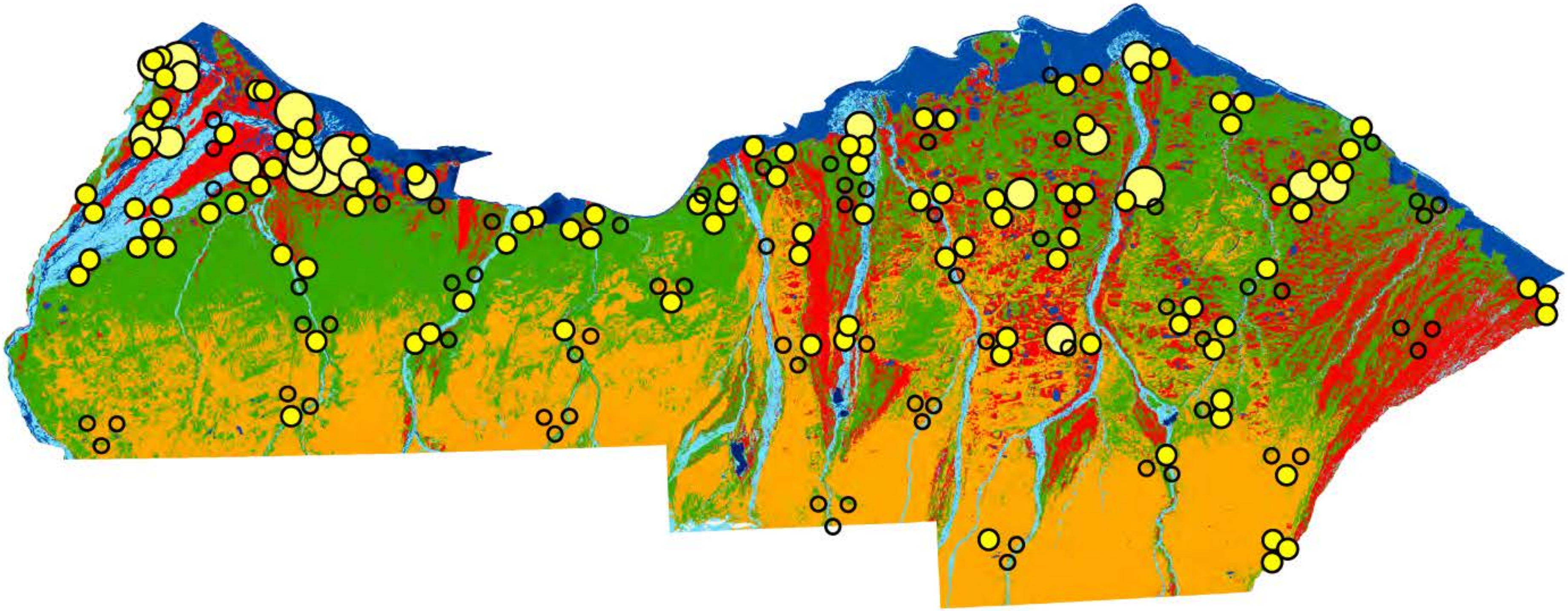


Figure 4-2. Shorebird density on Arctic Refuge delta mudflats observed during surveys, 2007–2009.



Map 4-7

Arctic National Wildlife Refuge

Habitat and Numbers of Shorebirds Detected on Plots during Surveys, 2002 and 2004

Habitat Types

- Riparian
- Wetland
- Upland
- Water
- Moist

No. Shorebirds

- 0
- 1 - 5
- 6 - 10
- 11- 19

Miles: 0, 4, 8, 12, 16, 20

Kilometers: 0, 4, 8, 12, 16, 20

Alaska Albers Equal Area Conic Projection, 1983 North American Datum.

Relative numbers of shorebirds detected during surveys of plots on the Arctic National Wildlife Refuge Coastal Plain, 2002 and 2004. Plots were randomly distributed in clusters of three throughout the 1002 Area of the Refuge. The study area was stratified by the 4 habitat classes shown (water was not included) and the number of plots in each strata was determined by relative abundance of shorebirds in each habitat as reported in Garner and Reynolds (1986). Fourteen habitat classes reported in Jorgensen el al. (1994) were combined to form the 4 habitat classes used as stratum.

Brown, S., J. Bart, R. B. Lanctot, J. Johnson, S. Kendall, D. Payer, and J, Johnson. 2007. Shorebird abundance and distribution on the coastal plain of the Arctic National Wildlife Refuge. Condor. 109:1-14.

4.3.6.7 Larids

Three jaegers species occur on the Refuge (Appendix F): parasitic jaegers, which breed in all regions of the Refuge; long-tailed jaegers, which breed on the coastal plain and in the Brooks Range; and Pomarine Jaegers, which breed on the coastal plain only in years of high microtine abundance (Wiley and Lee 2000, Kendall et al. 2007). Eleven gull species have been found on the Refuge. The most common are mew, glaucous, herring, and Sabine's gull. Sabine's gulls breed only on the coastal plain, glaucous gulls breed on the coastal plain and in the Brooks Range, herring gulls breed only on the south side, and mew gulls breed in all regions of the Refuge. Other gull species occur as migrants or vagrants.

Local residents report that glaucous gull populations on the coastal plain have been increasing. There is some evidence of increases in gull populations in the Arctic generally (National Research Council 2003), which could be due to global changes in their populations and/or increased human development in the area (Weiser and Powell 2010). Results of aerial surveys have shown glaucous gull populations across the Arctic coastal plain were stable from 1992 to 2008 (Larned et al. 2009), but increases could have occurred prior to this period or birds may have shifted their distribution. Distribution maps from these surveys indicate that gulls tended to be concentrated in the vicinity of human development on the coastal plain, including Kaktovik on Arctic Refuge (Mallek et al. 2002, Noel et al. 2006). Glaucous gull populations are likely regulated by the availability of nesting areas that are free of mammalian predators and close to abundant food sources (Gilchrist 2001). There are numerous accounts of glaucous gulls foraging in North Slope landfills (Day 1998, Weiser and Powell 2010), and they do nest on small islands in lakes and barrier islands (Kendall 2005). The combination of these conditions may benefit gull populations.

Sabine's gulls nest in single pairs or small colonies on the shores or islands of tundra lakes on the coastal plain (Johnson and Herter 1989). There are several small colonies at the Canning River Delta (Martin and Moitoret 1981, Kendall et al. 2007). Sabine's gull populations have increased in the past 10 years (Larned et al. 2009). Arctic terns breed on barrier islands, the coast plain, and in the Brooks Range. Arctic terns are listed as species of Conservation Concern by the Service (2008a) and as a species of High Conservation Concern in the North American Waterbird Conservation Plan (Kushlan et al. 2002). Herring gull, Long-tailed jaeger, parasitic jaeger, pomarine jaeger, and Sabine's gull are listed as species of Moderate Conservation Concern in the North American Waterbird Conservation Plan (Kushlan et al. 2002).

4.3.6.8 Owls

Six species of owls breed on the Refuge. Most are permanent residents in boreal forest areas. Snowy owls are intermittent visitors on the coastal plain, where they breed in years with high microtine populations. Short-eared owls breed in all regions of the Refuge and migrate south during the non-breeding season. Snowy, great grey, and boreal owls are identified as Priority Species for Conservation by Boreal Partners in Flight (Boreal Partners in Flight Working Group 1999), and short-eared owls are identified as a species of Conservation Concern by Audubon Alaska (Stenhouse and Senner 2005).

4.3.6.9 Woodpeckers

Five species of woodpeckers occur on the Refuge, four of which are rare or uncommon year-round residents in the boreal forest. A fifth species, northern flicker, nests in the Brooks Range and on the south side and migrates during the breeding season. Black-backed woodpeckers are identified as a Priority Species for Conservation by Boreal Partners in Flight (Boreal Partners in Flight Working Group 1999).

4.3.6.10 Landbirds

Sixty-seven species of passerines have been recorded on the Refuge: 53 of these species breed on the Refuge, two visit but are not known to breed, and 12 are vagrants. Most of the breeding birds (23 species) occur only in the boreal forest, but landbirds are well represented throughout the Refuge. The majority of landbirds migrate during the non-breeding season, but nine species are year-round residents. The following landbird species have been identified as species of Conservation Concern by Boreal Partners in Flight (Boreal Partners in Flight Working Group 1999), the Service (2008a) or Audubon Alaska (Stenhouse and Senner 2005): olive-sided flycatcher, Hammond’s flycatcher, northern shrike, American dipper, gray-checked thrush, varied thrush, bohemian waxwing, blackpoll warbler, Smith’s longspur, rusty blackbird, white-winged crossbill, and hoary redpoll. However, reviews of avian monitoring programs for landbirds found that populations of most species breeding in Alaska were not adequately monitored (Rich et al. 2004, Dunn et al. 2005).

Arctic Refuge is likely the only refuge in the United States with a notable breeding population of Smith's longspur, which is listed as a species of Conservation Concern due to low populations and potential vulnerability on their wintering grounds. The breeding range of Smith's longspurs in Alaska is not well known (Boreal Partners in Flight Working Group 1999) but thought to be primarily located in the foothills of the Brooks Range east of Anaktuvuk Pass (Sage 1976). In order to develop effective conservation measures for this species, it is necessary to understand population abundance and distribution, demographic parameters, habitat requirements, basic biology, and threats throughout their annual cycle. To meet those goals the Service, the NPS, and the University of Alaska initiated studies in 2006 to investigate breeding Smith's longspurs in northern Alaska. The objectives of this study included: 1) to estimate Smith's longspur abundance, 2) to evaluate survey methods for estimating abundance, 3) to identify habitat preferences and environmental factors that influence the distribution and abundance, and 4) to develop a species distribution model to predict the distribution of breeding Smith's longspurs in the Brooks Range. In this study, we found Smith's longspurs prefer the forest-tundra transition at the northern edge of the boreal treeline on the south side of the Brooks Range and mixed tundra and dwarf shrub in the Brooks Range foothills on the north side (Kendall 2007, T. Wild unpublished, data). The amount of woody vegetation in these transitional habitats may increase as a result of climate change with unknown impacts to breeding Smith's longspurs, underscoring the importance of continued monitoring and development of effective conservation measures for this species.

4.3.6.11 Climate Change Impacts on Birds

North Side of the Brooks Range

Martin et al. (2009) summarized the possible impacts of climate change on bird species on the North Slope. These effects stem primarily from changes to the abundance and distribution of surface water, changes to vegetation communities, and impacts on coastal processes and habitats. Although precipitation is predicted to increase on the North Slope, increased evaporation and evapotranspiration are predicted to decrease the overall abundance of surface water.

A decrease in the abundance of surface water would cause drying of saturated soils and shallow wetlands, with negative impacts to invertebrate productivity and availability. This in turn would decrease productivity and abundance of some shorebirds and waterfowl. The local redistribution of water through the drying of polygon centers and the formation of thermokarst pits and troughs would also result in a decrease in invertebrate availability for shorebirds and waterfowl using polygon habitat. Concurrently, it would increase invertebrate availability for open water and shoreline-feeding species such as the red phalarope, geese, and dabbling ducks that utilize thermokarst features. Lake drainage and drying resulting from the reduction in surface water would decrease the number of open water bodies, negatively impacting loons, terns and diving ducks. However, these newly formed drained-lake basin-complex wetlands would have positive effects on shorebirds and other waterfowl.

Vegetation community changes associated with a drier soils and loss of shallow wetlands may include increased shrub abundance, changes in plant phenology (e.g., earlier green up), and increased plant productivity and biomass. Increased shrub abundance would favor shrub-associated bird species including many passerines and ptarmigan, while decreasing habitat for wetland species such as waterfowl and shorebirds. Changes in plant phenology may decrease forage quality for post-hatch herbivores, affecting survival of juveniles, and may lower the body condition of molting, post-molt, and pre-migratory herbivores such as geese and ptarmigan.

Coastal processes and habitats are vulnerable to sea level rise and increased shoreline erosion caused by intensified storm surges due to the loss of sea ice. The loss of barrier islands and the lagoons they protect would negatively affect nesting common eider habitat and the foraging and molting habitat of waterfowl, loons, gulls, terns, and shorebirds. Terrestrial habitat losses along shorelines would impact foraging, nesting, and brood-rearing by waterfowl and shorebirds.

South Side of the Brooks Range

Impacts to bird communities from climate change on the south side of the continental divide would occur primarily from the drying of lakes and wetlands (Riordan et al. 2006) and from increased frequency, severity, and extent of natural fires (Rupp et al. 2002). Nearly 14 percent of the Refuge is forested, with about 12 percent in evergreen forest composed of black spruce and white spruce. Increased fire frequency is expected to convert much of this evergreen forest into early successional deciduous forest over the next 80 years (Rupp et al. 2002). Moreover, landscape drying and loss of vegetation productivity may already be occurring in the Alaskan interior (Verbyla 2008).

Bird communities at northern latitudes of the boreal forest may be highly adapted to severe fires regimes (Hutto et al. 2008). A post fire deciduous forest supports a higher abundance of birds along with an altered community of species adapted to early successional forest (Drapeau et al. 2000, Morissette 2000, Smucker et al. 2005). However, densities of Neotropical migrants are higher in old boreal forest (Kirk et al. 1996) and these species may be negatively impacted by the conversion to an early successional deciduous forest.

Although lakes and wetlands are uncommon in the Refuge south of the Brooks Range, the Wind, East Fork of the Chandalar, Sheenjek and Porcupine River valleys have important lake and wetland complexes. Lake and wetland loss from drying would have negative impacts on waterfowl, loons and shorebirds in this area. Climate induced increases in the growing season may allow birds species that are limited by the length of the nesting season, such as the Trumpeter Swan, to colonize these valleys.

4.3.7 Mammals

4.3.7.1 Introduction

Mammals are essential elements of northern ecosystems and contribute to the biodiversity of Arctic Refuge. The ecological role of many northern mammals is not completely understood, but all species shape the dynamics of tundra, alpine, and taiga environments in the Refuge.

Mammals played an important role in the establishment of Arctic Refuge. Advocates for creation of a conservation area in northern Alaska, in testimony before Congress, emphasized the importance of wildlife in the region, including caribou, polar bears, and habitat for reestablishing muskoxen. The proposed region was often seen as “a sanctuary for charismatic mammals” (Kaye 2005). A purpose of Arctic Refuge identified by ANILCA was to conserve mammal populations and their habitats, “including (but not limited to) caribou, polar bears, grizzly bears, muskoxen, Dall sheep, wolves, and wolverines.”

People come to Arctic Refuge from all over the United States and the world to experience northern wilderness and to see or hunt large mammals in undisturbed habitats. Mammals are hunted and trapped by local residents living in and near Arctic Refuge and are used for food and clothing or sold as furs and handicrafts.

4.3.7.2 Description

Attributes of life history, status, and distribution of mammals described in this section are based on locations where mammal species have been observed or collected in northern Alaska and on general descriptions of habitat use by species (Bee and Hall 1956, Wilson and Ruff 1999, MacDonald and Cook 2009). Common and scientific names follow (MacDonald and Cook 2009). Common names of mammals vary among sources. For example, all brown/grizzly bears (*Ursus arctos*) in Alaska are the same species, *Ursus arctos,* but the name "grizzly bear" is often used to distinquish smaller brown bears north of the Alaska Range from larger brown bears in southern Alaska. Dall's sheep (*Ovis dalli*) versus Dall sheep is a similar situation. In this document, except in direct quotes from other documents such as ANILCA, the common names "brown bear" and "Dall's sheep" are used (MacDonald and Cook 2009). Forty-eight species of mammals (including humans and marine mammals) have been observed in Arctic Refuge or in adjacent waters (MacDonald and Cook 2009) (Appendix F). With the exception of humans and some large herbivores, few details are known about trends in abundance, distribution, and habitat use of most of the 41 terrestrial mammal species living in the Refuge.

The vast Arctic Refuge has a broad diversity of ecoregions and subarctic and arctic terrestrial and aquatic habitats (Nowacki et al. 2001, Gallant et al. 1995). Some mammals in the Refuge occupy all ecoregions and/or a broad array of habitats, while others have limited distributions and use few habitats.

Mammal diversity (defined as the number of species occupying an area) is generally less in northern regions than in more southern latitudes (Gaston 2000). Only 20 percent of 412 mammal species in North America also occur in Alaska, and only 11 percent of these North American species are found in Arctic Refuge. Forty-five percent of Alaskan mammals occur in Arctic Refuge.

Arctic Refuge encompasses latitudes ranging from 67.5° to 70.2° north, contains a variety of terrain and habitats, and supports several species such as polar bears, muskoxen, and Alaska marmots found in few other conservations units. Carnivores (Order Carnivora) and hoofed mammals (Order Ungulata) are particularly well represented in Arctic Refuge with 35 percent and 33 percent of North American species, respectively (Figure 4-3). All three species of North American bears and six of 10 North American weasels occur in the Refuge. Thirty-eight percent of all mammal species in the Refuge are carnivores, compared to 12 percent throughout all of North America.

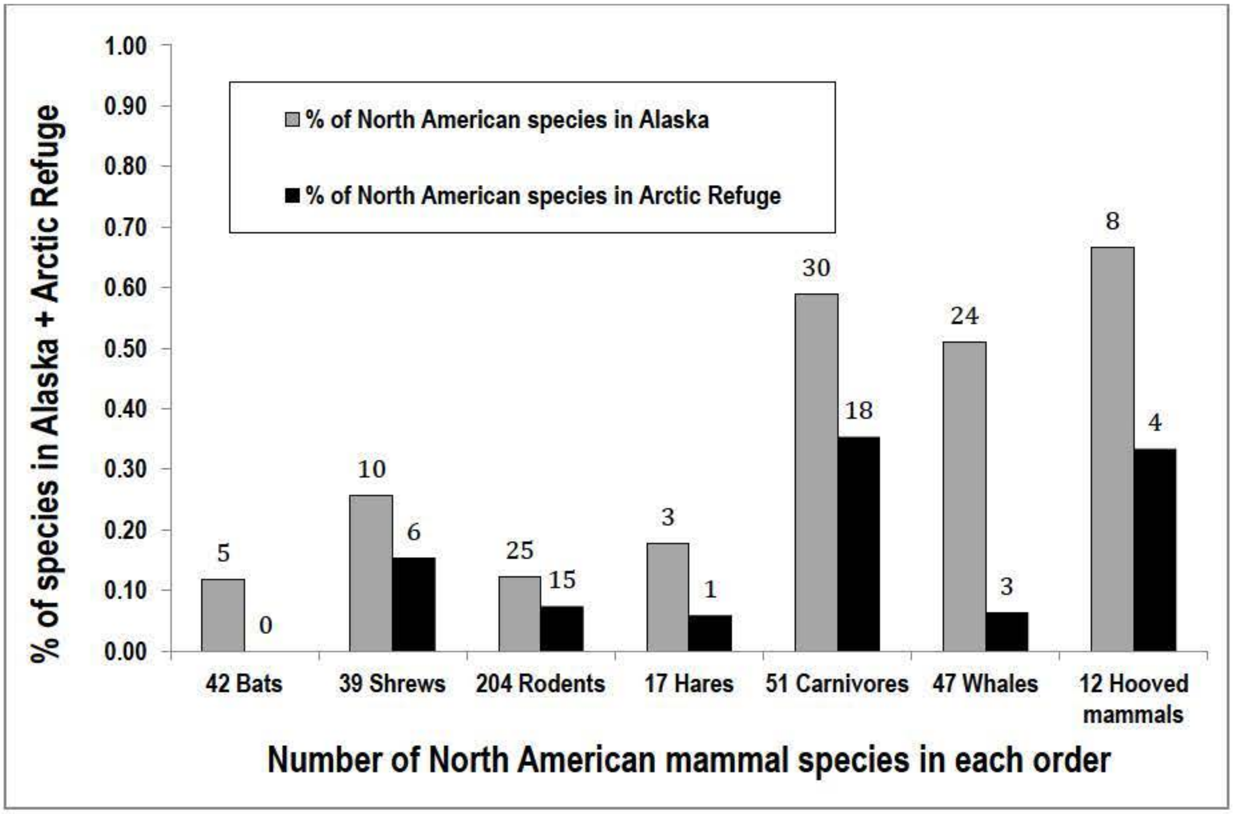


Figure 4-3. Diversity of mammals in Alaska and Arctic Refuge (including adjacent marine waters), shown as a percentage of North American mammal species. Numbers over columns are numbers of North American species also in Alaska and in Arctic Refuge. Data sources: Wilson and Ruff 1999, MacDonald and Cook 2009.

Winter is a defining characteristic of Arctic Refuge. In arctic Alaska, winter conditions exist for 8–9 months of the year. Terrestrial mammals are generally year-round residents of the Refuge and use a diversity of strategies for living in cold and severe weather. Some—such as bears and squirrels—are dormant in winter dens for 6–8 months. Others, such as wolves and foxes, are active all winter. Muskoxen reduce their activity and movements in winter to conserve energy (Reynolds 1998a). Lemmings and voles live beneath the insulating snow. Caribou move to winter ranges in the Refuge or in Canada. The diversity of habitats in the Refuge provides seasonal ranges that accommodate strategies used by mammals during the long winter and short growing season.

Most terrestrial mammals in Arctic Refuge are at the northern limits of their distributions. But some arctic-adapted species, e.g., collared lemmings, muskoxen, arctic foxes, and polar bears, are circumpolar and are found at even higher latitudes in Canada and Greenland. The Alaska marmot lives only in north of the Yukon River and the Alaska tiny shrew is likely found only in Alaska (MacDonald and Cook 2009).

4.3.7.3 Species of Special Interest and Concern

Terrestrial mammal species or groups of species used by humans or known to be important to ecosystem function are of special interest (Table 4-8). Hoofed mammals (ungulates) are hunted for food, and carnivores and herbivores are trapped for their fur. Visitors to Arctic Refuge often want to see mammals as part of their arctic wilderness experience. Several species of mammals, including lemmings and voles, foxes, hares, and lynx vary widely in number from year to year and have pronounced effects on local ecological systems when they are at peak numbers.

Table 4-8. Terrestrial mammals of Arctic National Wildlife Refuge are of special interest because they are used by humans and/or are known to be important components of northern ecosystems. An X indicates that species are of special interest but do not imply that one use is more important than another is. Common names are from MacDonald and Cook (2009).

Mammal Species (by common name)	Human Use		Ecological Component		
	Hunting/ Trapping	Viewing	Grazer/ Browser	Prey Base	Predator
Brown and collared lemmings, singing, root (tundra) and northern red-backed voles.			X	X	
Muskrat	X		X	X	
American beaver[1]	X		X		
Arctic ground squirrel	X	X	X	X	
Alaska marmot	X	X	X		
Snowshoe hare	X		X	X	
American marten, American mink, ermine	X	X			X
North American river otter	X	X			X
Wolverine	X	X			X
Canada lynx	X	X			X
Arctic fox	X	X			X
Red fox	X	X			X
Wolf	X	X			X
American black bear	X	X			X
Brown (grizzly) bear	X	X			X
Polar bear	X	X			X
Caribou	X	X	X	X	
Dall's sheep	X	X	X	X	
Muskox	X	X	X	X	
Moose	X	X	X	X	

[1]Beavers can affect wetlands through dam building

Marine mammals like whales and seals are important subsistence species for Kaktovik residents, and they are of particular concern with respect to changes in sea ice related to a warming climate. However, because they generally live outside the Refuge boundary and are not directly managed by the Refuge, they are not included in the following discussions of species of special interest.

Caribou

Caribou (*Rangifer tarandus*) are the most abundant large mammal in Arctic Refuge and are an important subsistence species for Iñupiat and Athabascan (Gwich'in) hunters. Caribou are also hunted and viewed by other visitors to the Refuge and are prey for brown bears and wolves (*Canis lupus*).

Caribou have been present in northeastern Alaska and the northern Yukon since the early Pleistocene. Human use of caribou in the region may date back thousands of years. Remnants of caribou fences and corral structures used by the Gwich'in people are found throughout the current southern range of the Porcupine caribou herd (Warbelow et al. 1975).

Large caribou herds tend to migrate over long distances using seasonally available forage resources that are often widely distributed. Caribou move in response to changing weather conditions, biting and parasitic insect harassment, and predators. In arctic areas, caribou reproduction is highly synchronous and the majority of calving occurs in a two- to three-week period. Most adult females give birth to a single calf. Caribou calves are precocious, being able to stand and nurse within one hour after birth and follow their mothers within a few hours. The first 24 hours of life are critical, when a behavioral bond is formed between the calf and its mother. Disturbance of maternal groups on the calving grounds may interfere with bond formation and can increase calf mortality. After calving, small bands of cows withnewborn calves gradually merge into larger groups and are joined by yearlings, barren females, and bulls arriving from wintering areas.

Summer weather conditions promote the emergence of mosquitoes, nose bots, warble flies, and other biting insects. Insect harassment drives caribou into densely packed groups. These post-calving aggregations often move toward the Arctic coast or to higher elevations in the mountains to find relief from insects.

By August, large aggregations gradually dissolve into widely dispersed small groups that move slowly toward winter ranges. Breeding takes place en route, and by mid-November, caribou arrive in areas where they will spend the winter.

Until recently, caribou throughout the circumpolar Arctic were experiencing population declines (Vors and Boyce 2009), but a more recent assessment in November 2011 found that many arctic caribou and reindeer herds in North America are now increasing or are stable (Russell and Gunn 2011).

Effects of climate change on caribou in northern Alaska are likely to differ by season (Martin et al. 2009). Delach and Matson (2011) found that caribou were "highly vulnerable" to possible changes in climate. Conditions during the snow season that could affect caribou include deep snow or icing events that affect spring migration. Warmer temperatures and longer growing seasons could increase the availability of summer forage (Lenart et al. 2002). This could positively affect female body condition and increase rates of conception, calf production and survival. But mismatches between the emergence of nutritious forage and the arrival of caribou on calving grounds could also occur (Post et al. 2008). Plant species tend to have higher nutrient concentrations and less fiber and lignin in earlier phonological stages (Jorgenson et al. 2002). If tussock sedges emerge and flower before the arrival of caribou on calving grounds, lactating females may miss the highest quality forage of the season. Warmer, longer summers may also increase numbers of parasites and biting insects such as warble flies and nose bots that attack caribou (Witter et al. 2012).

Four caribou herds live in northern Alaska. Two of these, the Porcupine and Central Arctic herds, consistently use Arctic Refuge seasonally or throughout the year. Some caribou from the Teshekpuk caribou herd occasionally overwinter in Arctic Refuge.

Porcupine Caribou Herd

An iconic symbol of Arctic Refuge wilderness, this herd migrates hundreds of miles from wintering grounds to give birth on the coastal plain and northern foothills of Arctic Refuge and nearby Yukon Territory in Canada. Residents of Arctic Village and, to a lesser extent, Kaktovik, hunt Porcupine caribou. Many visitors come to Arctic Refuge during early summer with hopes of seeing large numbers of caribou.

During the 1960s and 1970s, the Porcupine caribou herd was relatively stable at about 100,000 animals. Numbers steadily increased after 1978, peaked at 178,000 in 1989, and declined to 123,000 caribou in 2001 (Lenart 2007a) (Figure 4-4). Between 2002 and 2009, no estimates of abundance were available. During this period, caribou left the coastal plain and northern foothills of Arctic Refuge earlier and did not form large post-calving aggregations, or weather conditions precluded flights to photograph groups (E. Lenart, wildlife biologist, ADFG, pers. comm.). In 2010, 169,000 caribou were counted in a photocensus of the Porcupine caribou herd. Between 2001 and 2010 the herd increased to levels not seen since the early 1990s (Figure 4-4). The Teshekpuk and Central Arctic caribou herds also increased between 2002 and 2009 (Figure 4-4).

Birth rates of radio-collared adult females and calf survival by late June were high in the Porcupine herd in most years from 1987 to 2009 (Lenart 2007b, Caikoski 2009). Griffith et al. (2002) found that these measures did not differ between the period of population increase (1983–1989) and the period of decline (1990–2001). These studies suggest that the decline in numbers of Porcupine caribou from 1989 and 2001 likely was not caused by low calf production or low calf survival.

Reduced survival of caribou during late summer, fall, or winter may be a more important factor (Griffith et al. 2002). Non-hunting related mortality for adult females averaged 15 percent in 1975–1988 and 17 percent in 1989–2001 (Wertz et al. 2006). Small changes in adult cow survival could have large effects on growth of the Porcupine caribou herd (Fancy et al. 1994, Walsh et al. 1995, Arthur et al. 2003). The increase in abundance between 2001 and 2010 suggests that the Porcupine caribou had high rates of survival and recruitment of calves during part or all of this period. Population trends of Porcupine caribou herd were associated with phases of the Arctic Oscillation (shifts in sea level pressure over the Arctic Ocean) that influenced winter snowfall and summer growing conditions (Joly et al. 2011).

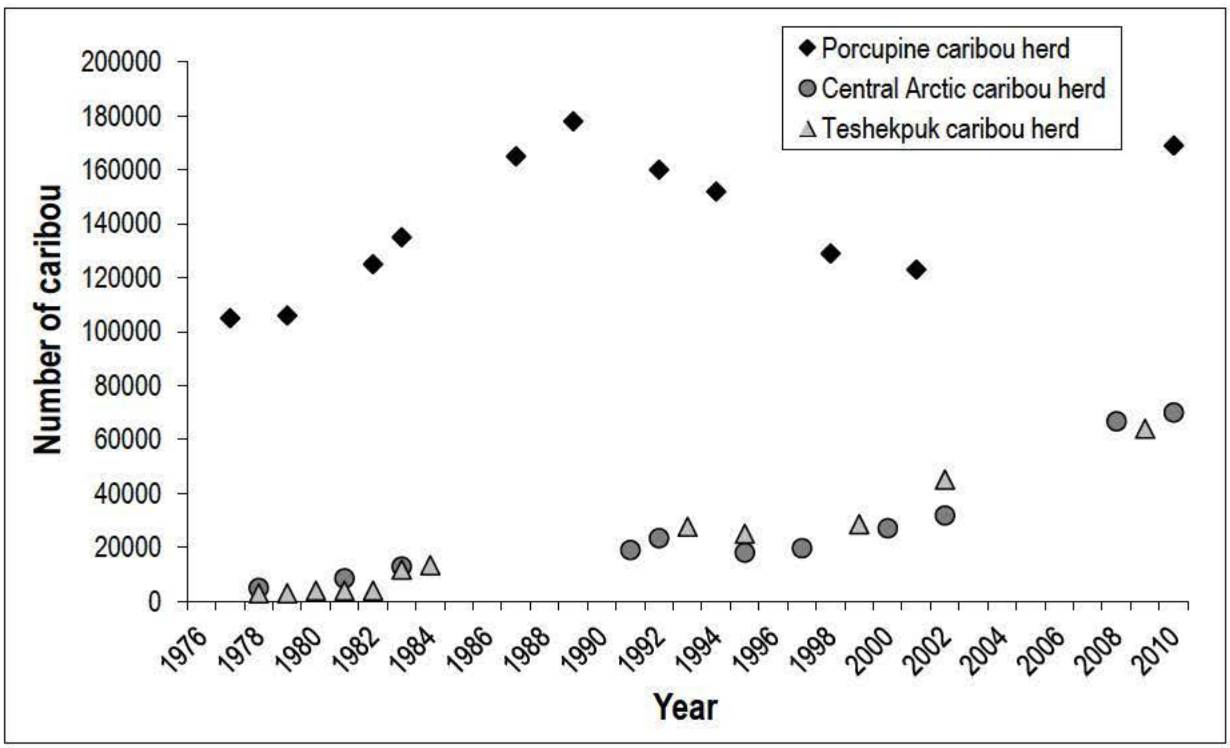


Figure 4-4. Population trends (estimates from photocensuses) of the Porcupine, Central Arctic, and Teshepuk caribou herds in northern Alaska. Data sources: Lenart 2007a, Lenart 2007b, Carroll 2007, Arthur and Del Vecchio 2009, J. Caikoski, wildlife biologist, ADFG, Fairbanks, Alaska, pers. comm., E. Lenart, area biologist, ADFG, Fairbanks, Alaska, pers. comm.

The Porcupine caribou herd ranges over 130,000 square mi (337,000 square km) of wild lands in northeastern Alaska and northwestern Canada (Lenart 2007a) (Map 4-8). The entire Arctic Refuge coastal plain is key calving and post-calving habitat for Porcupine caribou (Griffith et al. 2002). Foothills and mountains of Arctic Refuge are also important summer, fall, and winter habitats, as well as spring and fall migration routes. As the summer progresses and willows (Salix sp.) emerge, caribou also use riparian habitats. The Porcupine caribou herd generally overwinters south of the Brooks Range in Arctic Refuge and in the Richardson and Ogilvie mountains of the Yukon Territory, Canada. Winter distribution varies by year (Griffith et al. 2002, Wertz et al. 2006).

Spring migration to calving grounds begins in mid-April and continues through May. Pregnant caribou move northward from wintering areas toward calving grounds, where they give birth during the first week in June. Timing and routes of migration vary annually depending on where they overwintered, snow conditions, and timing of the onset of spring weather. Caribou wintering in Alaska often follow a northeasterly route to calving grounds, crossing the southern flanks and valleys of the Brooks Range, and eventually entering Canada near the Firth River. Caribou wintering in Canada also converge in this region. Some caribou wintering in Alaska move in a more northerly direction, crossing the eastern Brooks Range and traveling more directly toward calving grounds. As snow melt progresses, caribou in the foothills spread northwestward along a broad front, primarily following the major river corridors and associated terraces where snow melt has advanced.

For the past few decades, the Porcupine caribou herd has calved in a region encompassed the arctic foot hills and the coastal plain from the Canning River in Arctic Refuge to the Babbage River in Canada, an area of nearly 8.9 million ac (3.6 million ha) (Griffith et al. 2002). The distribution of calving caribou varied from year to year (Map 4-9). From 1983-1999, concentrated calving areas were in Arctic Refuge in all years and also occurred in the Yukon in 3 of 17 years. By contrast, during 2000-2010, concentrated calving areas were in the Yukon or near the USA-Canada border in 7 of 11 years. In 2011, the Porcupine caribou herd calved primarily in the northern Yukon, Canada (E. Wald, wildlife biologist, Arctic Refuge, Fairbanks, Alaska). This variability indicates that the Porcupine caribou herd needs a large region from which the best conditions for calving can be selected in a in a given year.

During the calving season in early June, Porcupine caribou selected areas of wet sedge, herbaceous tussock tundra and riparian vegetation types (Griffith et al. 2002). Emerging tussock cotton grass (*Eriophorum vaginatum*) flowers were an important source of high quality forage in areas used by calving caribou (Jorgenson et al. 2002). This plant species had greater biomass and forage quality in tussock tundra compared with other vegetation types. The distribution of tussock tundra and moist sedge-willow tundra was greater in calving areas in the Arctic Refuge 1002 Area than in areas further south and east (Jorgenson et al. 2002).

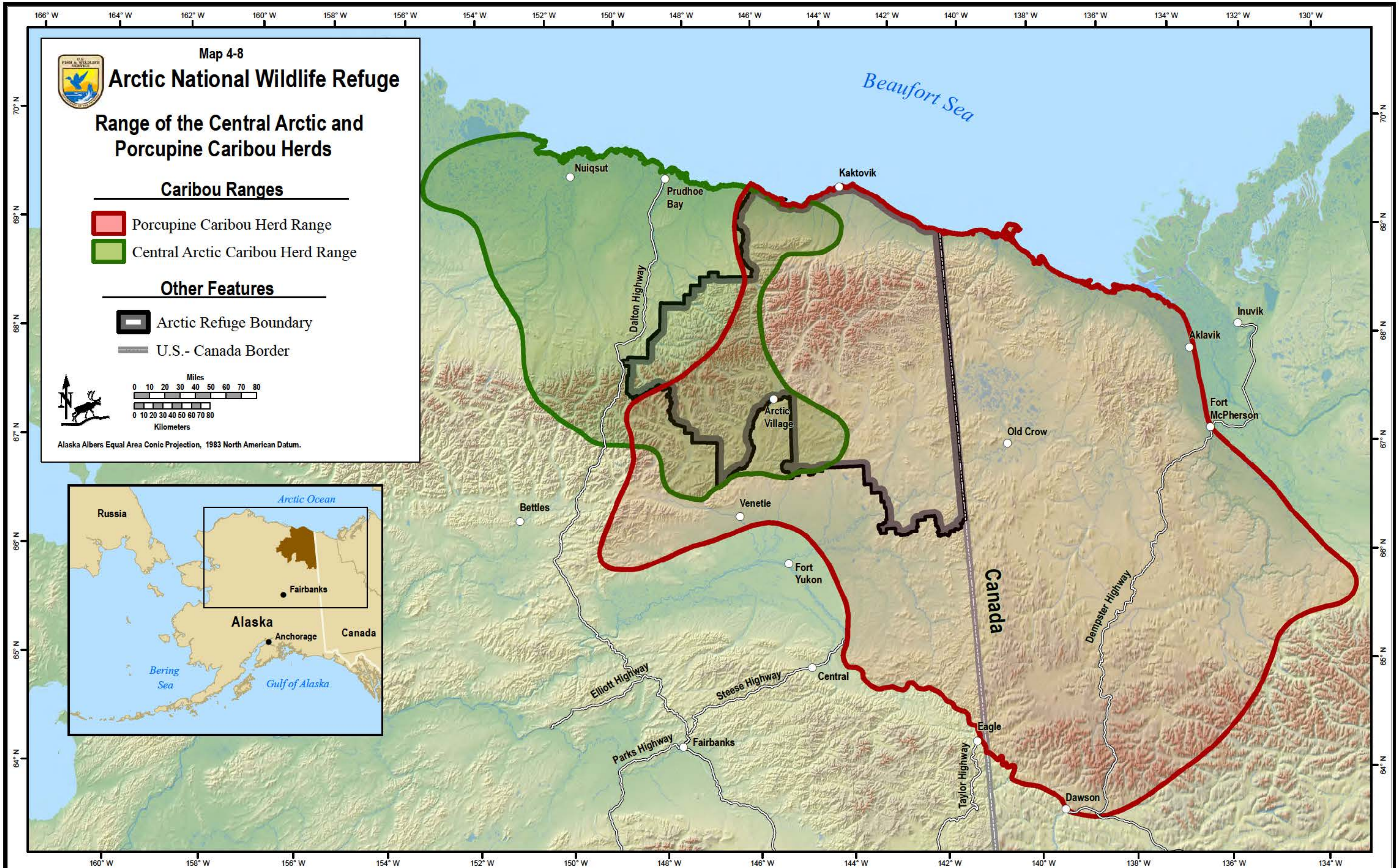
As cotton grass flowers matured, caribou shifted their diet to include a mix of newly emerged willows and herbaceous plants, which they continued to eat until they left the calving grounds at the end of June. In calving areas east of the US-Canada border, habitat quality was poorer and calf survival in June was lower (Griffith et al. 2002).

During the post-calving period (about three weeks after calving), the Porcupine caribou herd tends to move westward. Animals that calve in northwestern Canada move into Arctic Refuge after calving, where the presence of newly emerging sedges provides forage needed by females to quickly regain body reserves used during pregnancy and lactation (Griffith et al. 2002).

By mid- to late June, females with calves are joined by males and non-reproducing females arriving from the wintering grounds. The emergence of biting insects causes caribou to form large post-calving aggregations that frequently move north to the coast or south into the mountains, where winds and cooler temperatures reduce insect harassment.

In the 1980s and 1990s, caribou left Arctic Refuge coastal plain and foothills in early July and moved southward or eastward into Canada. After 2000, caribou generally departed the coastal plain before the end of June (E. Lenart, wildlife biologist, ADFG, pers. comm.).

Caribou from the Porcupine herd are hunted in Alaska and Canada. The Harvest Management Plan for Yukon, Canada (Porcupine Caribou Management Board 2010) outlines different harvests levels to be implemented when numbers of caribou reach targeted levels. For example, if numbers decline below 115,000 animals, harvest levels are reduced. Because numbers from 1989 and 2001 indicated a declining trend and no new information was available after 2001, a reduction in the Canadian caribou harvest was scheduled to take place. But in 2010, Porcupine caribou were well above the target of 115,000. At this level, Canadian subsistence hunters can take an unlimited number of caribou and general licensed hunters in Canada can take two males. All hunters taking Porcupine caribou in Canada are required to report their harvest (First Nation of NaCho Nyak Dun et al. 2010). People from the community of Kaktovik also hunt caribou from the Porcupine herd.



Map 4-8
Arctic National Wildlife Refuge
Range of the Central Arctic and Porcupine Caribou Herds
Caribou Ranges
Porcupine Caribou Herd Range
Central Arctic Caribou Herd Range
Other Features
Arctic Refuge Boundary
U.S.- Canada Border
Miles
0 10 20 30 40 50 60 70 80
0 10 20 30 40 50 60 70 80
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
Beaufort Sea
Nuiqsut
Prudhoe Bay
Kaktovik
Dalton Highway
Arctic Village
Old Crow
Inuvik
Aklavik
Fort McPherson
Bettles
Venetie
Fort Yukon
Canada
Dempster Highway
Elliott Highway
Steese Highway
Central
Eagle
Parks Highway
Fairbanks
Taylor Highway
Dawson
Russia
Arctic Ocean
Fairbanks
Alaska
Anchorage
Canada
Bering Sea
Gulf of Alaska

Central Arctic Caribou Herd

This herd had about 5,000 caribou in the mid-1970s when it was first identified as a distinct herd (Cameron and Whitten 1979). By the early 1980s, it had grown to almost 13,000 and by the late 1990s, when net calf production was greater than 70 percent calves per female, it increased to over 25000 (Cameron et al. 2002). A photocensus in 2010 counted more than 70000 caribou in the Central Arctic herd (J. Caikoski, wildlife biologists, ADFG), (Figure 4-4).

The average birth rate for adult females of the Central Arctic herd was 89 percent during 1997–2006. During this same period, an average of 80 percent of adult females from the Porcupine caribou herd gave birth annually (Lenart 2007a), Arthur and Del Vecchio 2009). Rapid growth of the Central Arctic caribou herd was due to high birth rates, high calf survival rates, and low adult mortality (Lenart 2007b).

The annual range of the Central Arctic caribou herd overlaps that of the Porcupine caribou herd (Map 4-8). Two main calving concentration areas have been identified for the Central Arctic caribou herd: a western area between the Kuparuk and Colville rivers, and an eastern area between the Sagavanirktok and Canning rivers. The eastern area includes the Canning River delta region in northwest Arctic Refuge.

Arthur and Del Vecchio (2009) studied rates of survival, changes in body mass, and skeletal growth of calves in both areas from June 2001 through May 2007. Survival rates during the early post-calving period did not differ between calving areas in most seasons and years. However, calves born in the eastern area, which includes portions of the Refuge, were heavier in June and September than calves born in the western calving area.

Arthur and Del Vecchio (2009) found that heavier calves were more likely to survive the following winter. Differences in the size of calves at birth and in September could be influenced by habitats on calving grounds, suggesting that the eastern calving area has higher habitat quality (Arthur and Del Vecchio 2009). Caribou from east and west calving areas overlap on summer ranges. Central Arctic caribou use the coastal plain between the Colville River in the National Petroleum Reserve-Alaska and the Okpilik River on Arctic Refuge from late June through mid- or late July. In August and September, they expand their distribution southward into the foothills and mountains (Arthur and Del Vecchio 2009). The Prudhoe Bay-Kuparuk oilfields, the Trans-Alaska Pipeline System, and the Dalton Highway lie in the herd's range. The herd uses riparian areas as travel corridors and for foraging during spring and summer. In late summer and fall, some Central Arctic caribou are found scattered across the coastal plain south of Camden Bay, in the foothills north of the Sadlerochit Mountains, and in uplands south of the Sadlerochit Mountains, where they may remain for the winter.

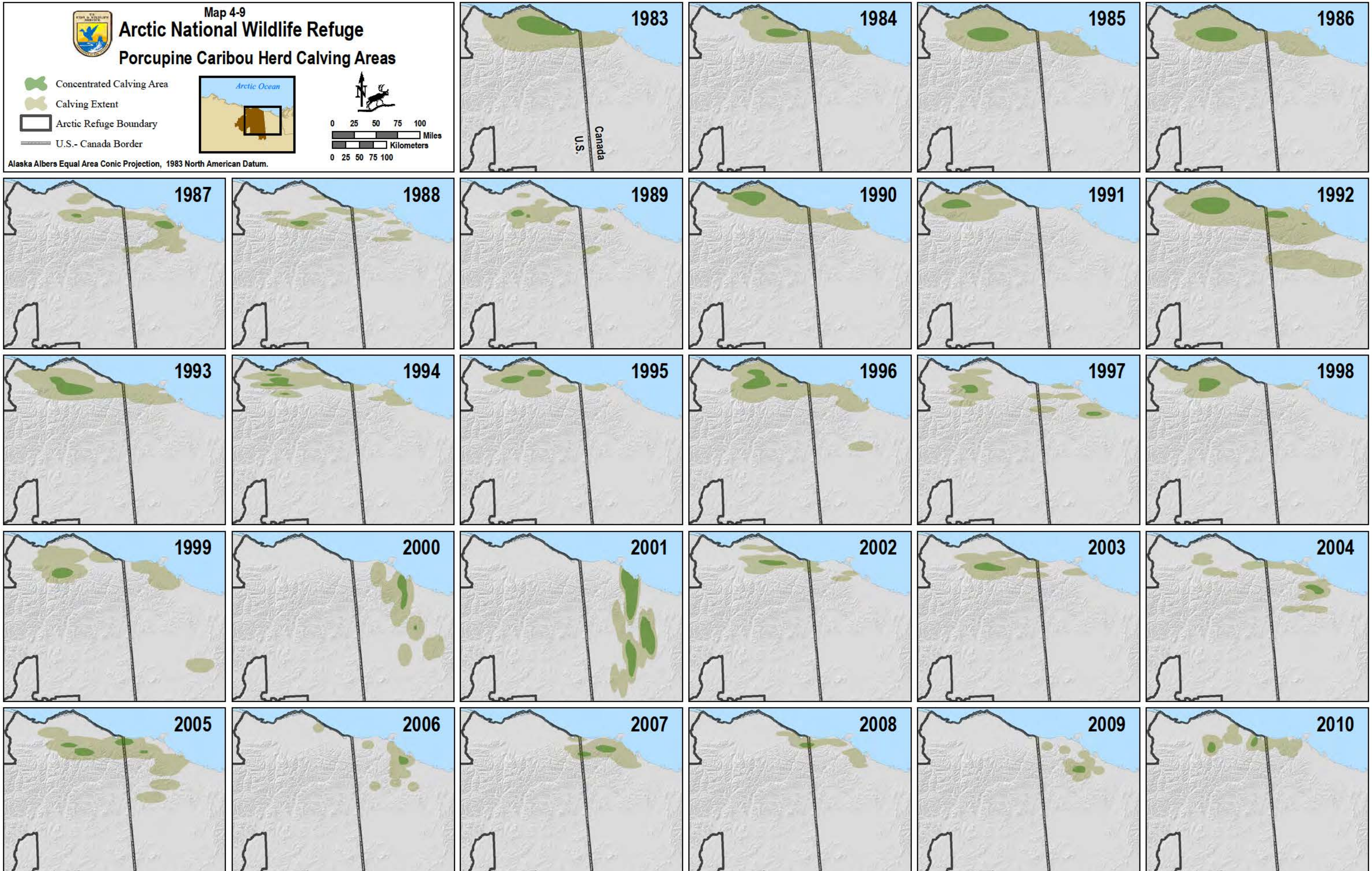
During most winters, scattered groups of animals range throughout the coastal plain west of the Katakturuk River and adjacent uplands to the south. Between 2002 and 2009, the winter distribution of the Central Arctic caribou was north and south of the Brooks Range in Arctic Refuge. In some years, they mixed with Porcupine caribou wintering in the same region. In 2010, almost all Central Arctic caribou wintered on the south side of the Brooks Range in Alaska, as did Porcupine caribou (S. Arthur, wildlife biologist, ADFG, pers. comm.)

Residents of Kaktovik hunt caribou from both the Central Arctic and Porcupine Caribou Herds depending on annual herd distributions. Other visitors to Arctic Refuge also hunt Central Arctic caribou north of the Brooks Range. In the years when Porcupine and Central Arctic caribou overlap in wintering ranges south of the Brooks Range, animals from both herds are harvested by people from Arctic Village.

Teshekpuk Caribou Herd

This herd was first identified as a distinct herd in the 1970s (Davis et al. 1978). Like the Central Arctic caribou herd, it increased rapidly in the past two decades (Figure 4-4). The year-round distribution of these caribou is generally in the vicinity of Teshekpuk Lake, 150 miles west of Arctic Refuge in the National Petroleum Reserve-Alaska. Teshekpuk caribou occasionally winter as far east as Arctic Refuge (Carroll 2007). During fall 2003, an extreme ice storm apparently caused some caribou from the Teshekpuk herd to move east to Arctic Refuge. Several hundred caribou overwintering near Barter Island died of starvation in the winter of 2003–2004 (K. Beckmen, veterinarian, ADFG, Fairbanks, Alaska, pers. comm.). Other caribou wintering in the Brooks Range in Arctic Refuge experienced higher survival rates (G. Carroll, wildlife biologist, ADFG, pers. comm.). This was the only documented use of Arctic Refuge by the Teshekpuk caribou herd in the past three decades.

Map 4-9. Porcupine Caribou Herd Calving Area. Porcupine caribou herd annual calving areas in the Arctic National Wildlife Refuge, Alaska, and northern Yukon, Canada, 1982–2010. Calving distribution was based on locations of radio collared Porcupine caribou cows in early June. Tan = extent of calving grounds determined by the isopleths encompassing 95 percent of the fixed kernel utilization distribution of locations of females with a calf. Green = concentrated calving areas (areas with greater than average densities of female caribou with calves). Data sources: Griffith et al. (2002), Caikoski (2009), J. Caikoski, wildlife biologist, ADFG, pers. comm.



Map 4-9
Arctic National Wildlife Refuge
Porcupine Caribou Herd Calving Areas
Concentrated Calving Area
Calving Extent
Arctic Refuge Boundary
U.S.- Canada Border
Arctic Ocean
0 25 50 75 100
Miles
Kilometers
0 25 50 75 100
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
1983
U.S.
Canada
1984
1985
1986
1987
1988
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2008
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2010

Other Ungulates (Hoofed Mammals)

In addition to caribou, three other large ungulates provide hunting and viewing opportunities for local residents and visitors to Arctic Refuge.

Dall's sheep (Ovis dalli)

This species occupies mountain habitats in Alaska and western Canada. The Sadlerochit Mountains in the northwestern portion of Arctic Refuge constitute the northernmost extent of the species range (Smith 1979). Dall's sheep have high fidelity to traditional winter and summer ranges, including lambing areas and mineral licks. Their activities are confined almost exclusively to the alpine zone in barren and sparsely vegetated areas of dry prostrate dwarf scrub where forbs, dwarf shrubs and graminoids constitute their primary foods. In alpine habitats, sheep are often near cliffs or steep rocky ridges that they use as escape terrain to avoid predators. Winter habitat consists of windblown slopes and ridges, often with a southerly aspect. Winter conditions are an important determinant of adult survival. Deep snowpack or icing conditions that reduce access to browse can cause increased mortalities. Predators of Dall's sheep include humans, wolves, and golden eagles.

Dall's sheep are social ungulates. Throughout most of the year, rams are segregated from ewes, lambs, and subadults. Dominant rams join these ewe groups during November and December, when breeding occurs. Dall's sheep in Arctic Refuge give birth to a single lamb and can experience years of high production followed by years of low production. Lambs are typically born in May. The births are highly synchronized, and most lambs are of similar age (Bowyer and Leslie 1992).

Smith (1979) estimated that there were 6,800 sheep in the original 8.9-million-ac (3.6-million ha) Arctic Range in 1979. Sheep densities are generally higher on the north side of the Brooks Range (3.7 sheep per square mile between the Sagavanirktok and Atigun rivers) than on the south side (0.6 sheep per square mile in portions of the Chandalar River drainage) (Mauer 1990). Recent sheep counts have focused on smaller areas, particularly the Hulahula River drainage, and on population composition counts during the post-lambing period in index areas in Atigun Gorge, the Hulahula River, and the Arctic Village Sheep Management Area.

The Hulahula River drainage is an area of high-quality sheep habitat on the north side of the Brooks Range in Arctic Refuge. This drainage provides sheep hunting opportunities for federally qualified subsistence hunters from Kaktovik and for general hunters, as well as possibilities for Refuge visitors to observe Dall's sheep.

In the early 1990s, the sheep population declined in the Hulahula and Atigun drainages (Figure 4-5). During this period, similar declines in sheep populations occurred elsewhere in arctic Alaska as a result of severe winters (Caikoski 2008). The number of Dall's sheep taken by general hunters and the percentage of successful hunters throughout the Refuge also declined in the 1990s (Figure 4-6). As sheep numbers declined, they were less available to hunters.

In recent years, Dall's sheep populations across the eastern Brooks Range appear to have stabilized. However, populations remain below those observed in the mid-1980s, and current survival rates, distribution and habitat quality are not completely known (Caikoski 2008).

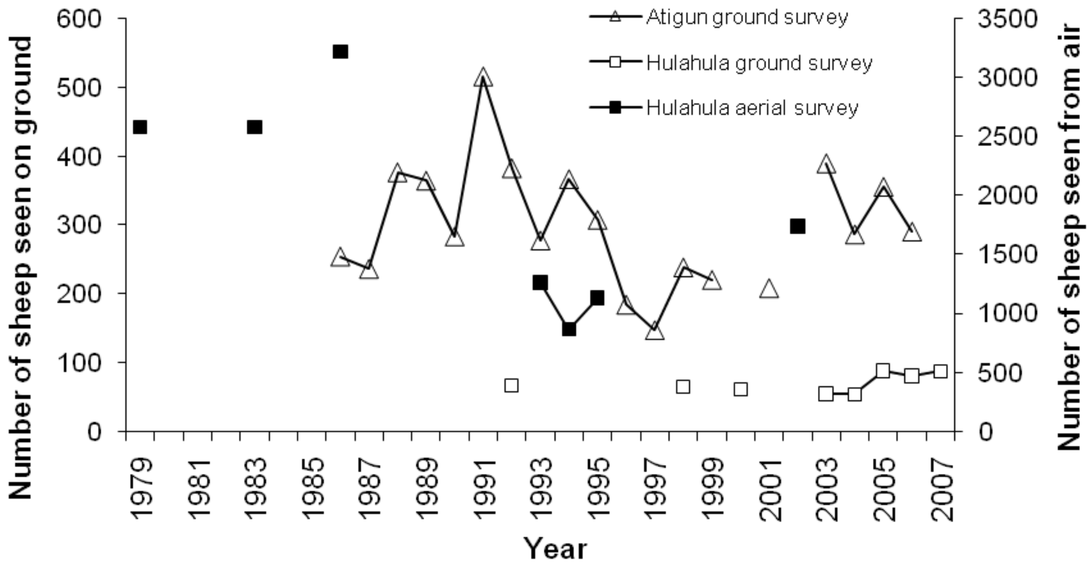


Figure 4-5. Dall's sheep population trends in two northern drainages, Arctic National Wildlife Refuge, Alaska. Data sources: Caikoski 2008, U.S. Fish and Wildlife Service unpublished data

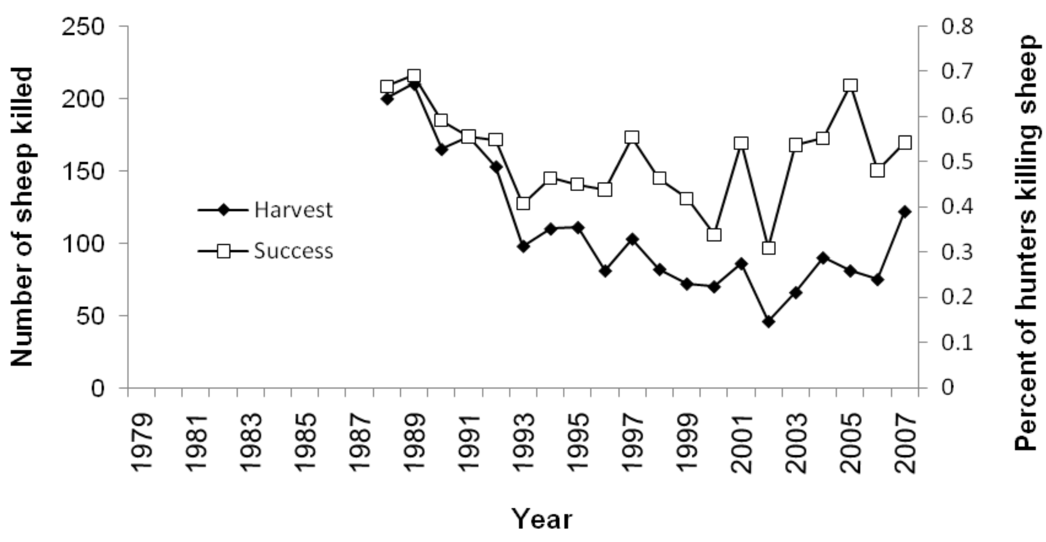


Figure 4-6. Hunter success and number of Dall's sheep killed by all general hunters in Arctic National Wildlife Refuge, Alaska 1988–2007. Data source: U.S. Fish and Wildlife Service unpublished data summarized from ADFG harvest records.

The Arctic Village Sheep Management Area was established in 1991 to include that area west of the East Fork Chandalar River between Crow Nest Creek and Cane Creek. The area was expanded in 1995 to include the entire drainages of Red Sheep Creek and Cane Creek. In this area, only local resident subsistence hunters could kill sheep, and general hunting was prohibited. In 2006, the Federal Subsistence Board approved a temporary Special Action to open hunting for full-curl rams to general hunters in the Red Sheep Creek and Cane Creek drainages, which comprise the northern portion of the Arctic Village Sheep Management Area and made the change permanent in 2007. In 2012, the Federal Subsistence Board once again limited sheep hunting in Red Sheep and Cane Creek drainages to federally qualified subsistence hunters from the communities of Arctic Village, Venetie, Fort Yukon, Chalkyitsik, and Kaktovik. Further, the Refuge does not authorize commercial big-game guides in the area around Arctic Village, including the Arctic Village Sheep Management Area, to minimize conflicts between local and nonlocal users. Payer (2006) estimated that the density of Dall's sheep was 1.7 per sq. mile in this area, slightly less than the 1990–1991 estimates of 1.9 to 2.2 sheep per sq. mile, but nearly eight times greater than the estimated density in the southern portion of the Arctic Village Sheep Management Area (Mauer 1990).

Dall's sheep are found throughout the mountains of Arctic Refuge. Densities are higher on shale slopes where vegetation communities are more extensive than on limestone slopes that have less soil development, lower nutrients, and sparser vegetation (Mauer 1990). During the hottest summer weather, sheep are most frequently seen on green alpine meadows between 3,000 and 4,000 ft (915 and 1208 m), although they may climb above 6,000 ft (1830 m) to reach areas where temperatures are cooler and insects less bothersome. They often lie in the shade of rocky areas near feeding sites. These sheep are excellent climbers and usually stay near rocky areas and cliffs that provide escape terrain from wolves and other predators.

Sheep traditionally move between summer and winter ranges. In early winter as the snowline descends and lowlands become snow covered, sheep move to their wintering grounds on windswept ridges and promontories. With the approach of spring, sheep concentrate on south-facing slopes in valley bottoms where vegetation first emerges. They may be seen in these valley bottoms at any time of the year, either crossing between mountain ranges or feeding in areas of new plant growth. Ewes with young lambs seek steep, rocky areas with maximum security from predators during the first few weeks after lambing and later join larger groups of ewes, lambs, and sub-adults.

Dall's sheep in the Refuge are hunted by people living in the communities of Kaktovik and Arctic Village (federally qualified local resident subsistence hunters), as well as by general hunters visiting the Refuge. In 1988–2007, most sheep (annual mean = 83 percent) harvested by general hunters were taken on the north side of the Brooks Range (ADFG harvest data summarized by Arctic Refuge). The total number of sheep killed by local residents of Kaktovik and Arctic Village is not well documented. Dall's sheep on the Refuge also provide memorable viewing opportunities for non-hunting visitors to Arctic Refuge.

Dall's sheep in Arctic Refuge are at the northern limit of the species' range. Warming temperatures in the arctic may have consequences for montane habitats and alpine vegetation in the mountains of the Brooks Range if vegetation communities shift up mountain slopes. Dall's sheep in Arctic Refuge could be vulnerable to adverse effects of climate change, including altered vegetation communities, increased incidence existing or novel diseases and parasites, and more frequent occurrence of icing conditions or deep snow (Martin et al. 2009). According to Delach and Matson (2011), Dall's sheep are "highly vulnerable" to climate change because they are adapted to specific niches that could change.

Muskoxen (Ovibos moschatus)

This arctic-adapted ungulate is found only at high latitudes. Females, sub-adults and males live in social groups. Adult males are often solitary in summer and found in small male-only groups in winter (Reynolds et al. 1999).

Muskoxen in Arctic Refuge have a relatively low reproductive potential. Age at first breeding can be delayed until age four or five. Females produce a single calf, and most only breed every other year or less frequently (Reynolds 2001). Unlike caribou that give birth in early June just as nutritious sedges are emerging, most muskox calves are born between mid-April and mid-May when winter conditions still prevail. Pregnant and lactating females do not have access to high quality green forage for 4-6 weeks after the birth of calves. Muskoxen must maintain their body reserves throughout the long winter, followed by calving and early lactation periods, to successfully reproduce. Conserving energy by reducing activity and movements during winter and subsisting on small amounts of poor-quality winter forage (Adamczewski et al. 1994) are important strategies for this species. Groups of muskoxen frequently remain in one small area for most of the winter (Reynolds 1998a).

Muskoxen are year-round residents of the coastal plain and foothills of Arctic Refuge. During the growing season, groups often live in riparian habitats along drainages and in moist herbaceous and prostrate shrub habitats in adjacent uplands, where they feed on shrubs, forbs, and graminoids (During the 8–9 months of winter, muskoxen select areas of soft shallow snow, often on windblown ridges or areas with micro-terrain that provides windswept areas (Reynolds et al. 2002a, Nellemann and Reynolds 1997). In winter, muskoxen in Arctic Refuge eat mostly dried sedges and grasses, mosses and forbs (Reynolds et al. 2002a).

Muskoxen disappeared from Alaska and northwestern Canada by the late 1800s but were successfully returned to the State when animals from Greenland were released on Nunivak

Island in 1935–1936. Survivors and offspring from this population were successfully moved to four other regions of the State between 1967 and 1981. In 1969 and 1970, 64 muskoxen were released in two areas near the Refuge (Reynolds 1998b).

The population in the Refuge increased rapidly from 1978 to 1985 and was relatively stable through the late 1990s (Reynolds et al. 2002a) (Figure 4-7). The population range expanded as some groups left the Refuge and moved west into north central Alaska and east into Yukon, Canada. Abundance of muskoxen declined rapidly between 1998 and 2002, and numbers remained very low (1-44) in 2002–2010. In Arctic Refuge, only one muskox was observed in the 2006 census, a few small groups moved between the Refuge and adjacent regions in 2007–2010 and none were counted in April 2011 (Reynolds 2011).

The entire population increased from about 1978 to 1995, declined between 1996 and 2006, and was relatively stable for the past six years (Figure 4-7). Most of the 50 percent decline in population abundance was due to losses from Arctic Refuge. Today the population appears to be split into two distinct populations with about 200 muskoxen living in northern Alaska west of Arctic Refuge and 100 muskoxen living in the northern Yukon, east of Arctic Refuge (Reynolds 2011).

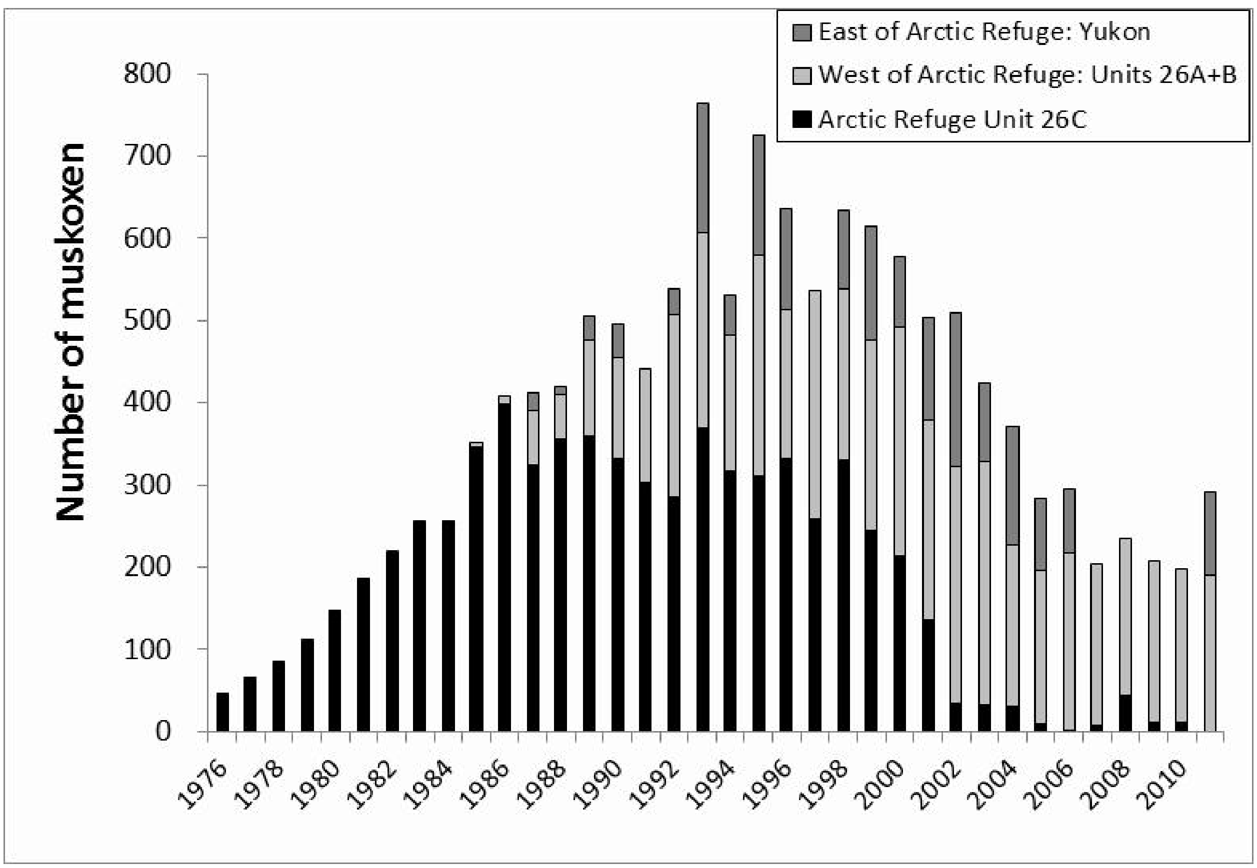


Figure 4-7. Abundance of muskoxen in the Arctic National Wildlife Refuge and adjacent areas in northern Alaska and northern Yukon, Canada, 1976-2011.

Note: Muskoxen were not surveyed or only partly surveyed in the Yukon in 1991-1992, 1994, 1997, and 2007-2010. Total censuses in 2006 and 2011 covered the entire range of the population from Judy Creek in northern Alaska to the Babbage River in northern Yukon. Data sources: Reynolds 2006, Lenart 2007c, Cooley and McDonald 2010, Reynolds 2011, and S. Arthur, wildlife biologist, ADFG, pers. comm.

The decline in the muskox population in northeastern Alaska and the disappearance of most muskoxen from Arctic Refuge since 1999 was caused by low calf recruitment, reduced survival of adults, and shifts in distribution. A combination of interacting factors, including predation, severe winters, and disease, could have affected recruitment, adult female survival, and movements of muskoxen (Reynolds 2011, S. Arthur wildlife biologist, ADFG, pers. comm.).

Brown bears and wolves prey on muskoxen, but bears are the dominant predator. Several incidents of bears killing muskoxen have been documented (Reynolds et al. 2002b, S. Arthur, wildlife biologist, ADFG, pers. comm.). Predation events, including human hunting, can cause groups to fracture into smaller units and move long distances; it can also result in the abandonment of young calves (Reynolds 2006).

Winters with deep snow or freezing rain-on-snow (icing) events likely reduce access to forage and increase energetic costs for muskoxen. An icing event in October 2003 likely caused the deaths of hundreds of caribou on the coastal plain of Arctic Refuge (K. Beckmen, veterinarian, ADFG, pers. comm.) and thousands of muskoxen on Banks Island (Grenfell and Putkonen 2008). Snow conditions may limit winter habitats used by muskoxen (Reynolds et al. 2002a). Because muskoxen move infrequently in winter, habitats occupied by large groups for several consecutive winters may become overgrazed. Diseases and parasites as well as possible copper deficiencies may also be affecting rates of successful production and adult survival (K. Beckmen, veterinarian, ADFG, pers. comm.).

In 1982, the ADFG opened hunting in the Refuge and issued five permits to residents of Alaska to hunt muskoxen in Arctic Refuge, Unit 26C. From 5–10 registration permits were issued until 1992 (Lenart 2007c). In 1992, the Federal government took over responsibility for hunting on Federal lands and limited muskox hunting in the Refuge to federally qualified subsistence hunters from the community of Kaktovik. Muskox permits issued by the Federal Subsistence Board to residents of Kaktovik increased to a high of 15 per year (including three females) in 1996–1997 through 2001–2002 (Reynolds 2011). Because of concerns about low abundance, the harvest limit in the Refuge was reduced to two bulls per year in 2002–2003. Harvest levels ranged from 12 males and three females in the 1996–1997 season to two males in 2001–2002. Current Federal regulations in Arctic Refuge (Unit 26C) limit the annual subsistence hunt to three percent of the number counted during a pre-calving census. Because of low numbers, no muskox permits were issued between 2003–2004 and 2010–2011, except for one issued for the 2007—2008 season. No muskoxen have been killed during a legal subsistence hunt in Arctic Refuge since April 2001 (Reynolds 2011). In 2003, the State of Alaska closed all hunting of muskoxen (Tier I, Tier II, and drawing hunts) on State lands adjacent to the Refuge (Unit 26B) in response to the decline in muskox numbers (Lenart 2007c).

As an arctic-adapted species with low reproductive potential, muskoxen are relatively vulnerable to local weather events and climatic changes in the northern environment. Icing events or deep snow likely affect successful reproduction, recruitment, and survival of adult females. If icing events increase in frequency as a result of temperatures warming in winter, muskox populations could be adversely affected and abundance and distribution could change. Increases in the length of the summer season may provide a longer foraging season and increased reproductive rates. However, warmer and longer summers would likely increase the incidence of diseases such as lungworm, which could negatively affect muskox populations (Kutz et al. 2004). Delach and Matson (2011) found that muskoxen are “highly vulnerable” to climate change because of the species’ adaptations to the arctic environment and its low genetic diversity).

Moose (Alces americanus)

Moose are the largest member of the deer family and one of the largest terrestrial mammals in North America. In arctic Alaska, moose are living at the northern limit of their North American range. Their presence here may represent a relatively recent range extension (Kelsall 1972). Chesemore (1968) found evidence that moose were established in the region by 1940.

Moose usually mate in late September or early October and give birth, often every year, to one or two young in May and early June. Calf mortality is usually high, although females aggressively defend their young from bears and wolves. Moose are solitary except when breeding but sometimes form aggregations on winter ranges (Peterson 1999).

Moose occur throughout Arctic Refuge, primarily along drainages with patchy, willow-dominated riparian communities. River bars with tall and low willows (*Salix alaxensis* and *Salix planifolia*) are common habitats for moose.

Four regions in the Refuge have been periodically surveyed for moose: Unit 26B (northern drainages from Accomplishment Creek to the Canning River that includes State and Refuge lands); Unit 26C north (northern drainages east of the Canning River between the Sadlerochit and Egaksrak rivers on Arctic Refuge); Unit 26C south (upper reaches of the Kongakut and Firth rivers and Mancha Creek); and Unit 25A east (Sheenjek and Chandalar rivers south of the Brooks Range).

Moose populations in Unit 26B-east and other arctic areas increased rapidly from the mid-1950s and the late 1980s, expanding into limited riparian habitats. From 1989 to 1994, moose populations throughout Unit 26B declined by 50 percent or more, and moose hunting on State lands was closed during 1996–2005 (Lenart 2008). A similar decline occurred in the Refuge (Figure 4-8). Fall calf survival was only 4 percent in 1994 and 5 percent in 1995, 10 percent lower than in the early 1990s. Several dead adult females were found on the Colville River west of Arctic Refuge in 1995. Disease or copper deficiency, exacerbated by long winters and short growing seasons, were factors that may have caused the decline; predation and forage conditions appeared to be less important (Lenart 2008). By 2002, numbers of moose in western drainages of Unit 26B began to increase, but recovery has not occurred on the Canning River in Arctic Refuge (Lenart 2008) (Figure 4-8).

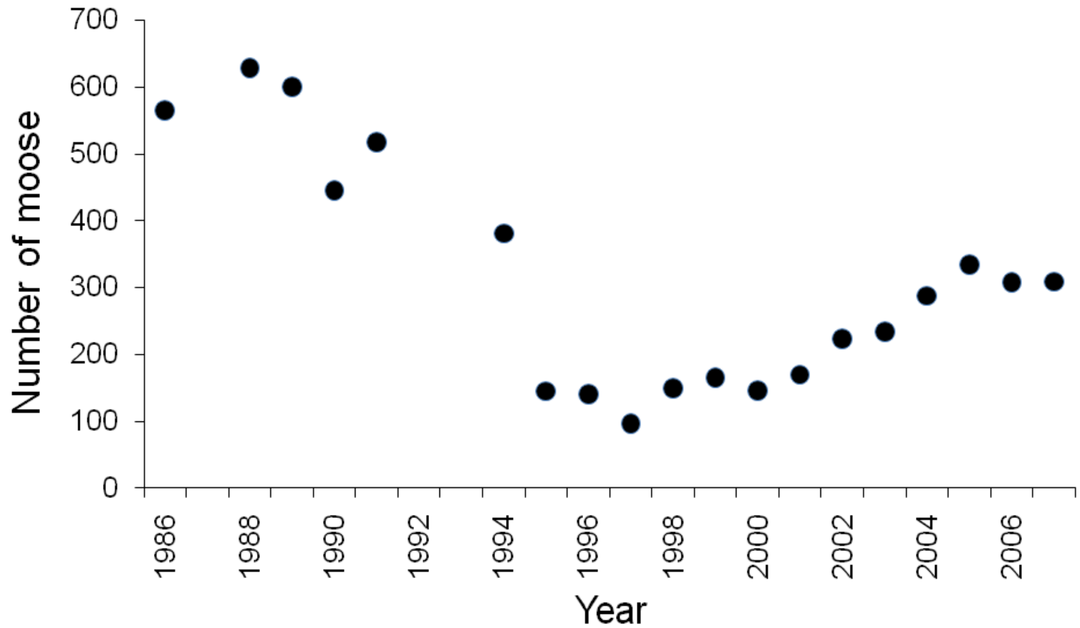


Figure 4-8. Moose surveys of the North Slope drainages between the Canning River and Accomplishment Creek.

Notes: 1986-1998 surveys were conducted in the fall and the 1999-2008 surveys were conducted in the spring (Lenart 2002, Lenart 2008).

Relatively few moose live east of the Canning River on the coastal plain and northern foothills of Arctic Refuge. In 2002–2008, 47–61 moose were observed during surveys of Unit 26C-north between the Sadlerochit and Egaksrak rivers (U.S. Fish and Wildlife Service, unpublished data). Moose on the upper reaches of the Kongakut and Firth rivers (north of the Brooks Range divide) are more numerous, but abundance here apparently also declined during the 1990s, as did moose numbers south of the Brooks Range divide along the Coleen and Sheenjek rivers (Figure 4-9).

In 1995-1996, a study of seasonal movements of moose in the upper reaches of Kongakut, Firth, Coleen, and Sheenjek rivers showed that 86 percent of collared moose wintering in these drainages moved to the Old Crow Flats in Yukon, Canada, where they spent the summer (Mauer 1998). In 2007, biologists from Yukon territories begin monitoring satellite-collared moose spending summers in the Old Crow Flats. Many moved to Arctic Refuge to winter on the Firth, Coleen, or Kongakut rivers. Others wintered north or southeast of Old Crow Flats (D. Cooley, Project Leader, Environment Yukon, pers. comm.).

Natural mortality factors affecting Arctic Refuge moose populations are poorly documented. Brown bears and wolves prey on moose, but predation rates are unknown. Moose are taken by subsistence hunters from Arctic Village and Kaktovik and by general hunters visiting the Refuge. Total harvest varied by region and declined over time as populations decreased in abundance. Because of concerns about small population size, subsistence harvest of moose in the northwestern portion of the Refuge is restricted, and there is currently no open season for general hunters in Unit 26C.

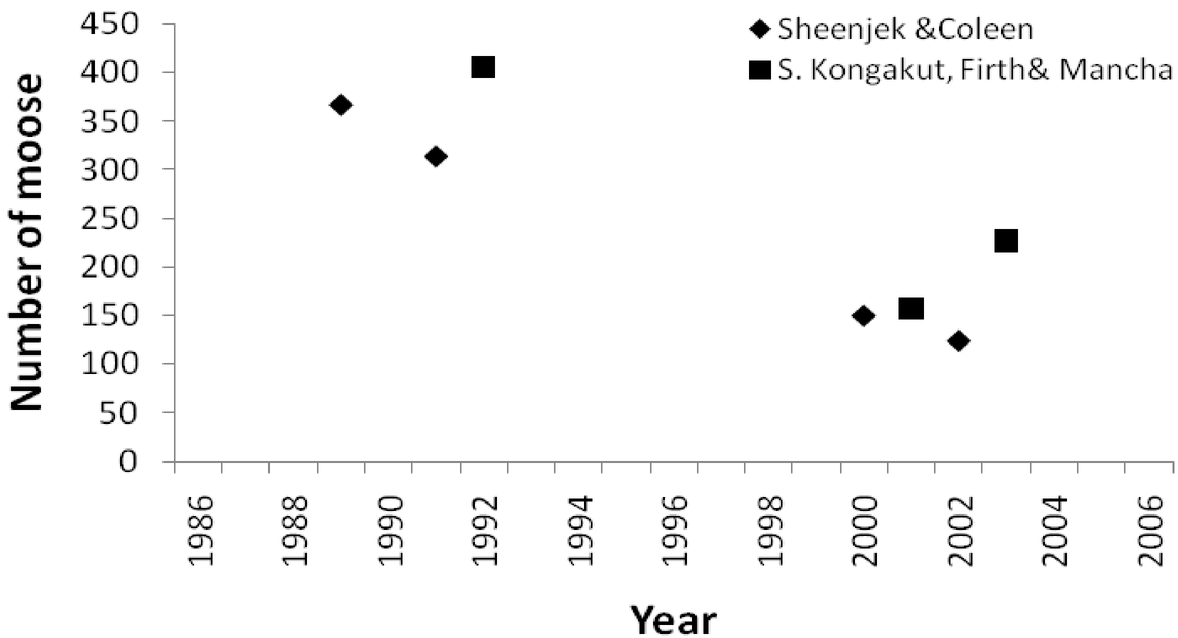


Figure 4-9. Moose counts along Sheenjek and Coleen rivers south of the Brooks Range Mountains and southern reaches of the Kongakut and Firth-Mancha drainages, Arctic National Wildlife Refuge, Alaska, 1989–2004.

Data source: U.S. Fish and Wildlife Service, Arctic Refuge.

Changes in climate that increase the length of the growing season may benefit moose if shrub habitats continue to increase in northern Alaska. Delach and Matson (2011) found that moose in Arctic Refuge are "not vulnerable/presumed stable" to climate change because their body configuration can cope with possible increases in snow and their use of early successional stages of vegetation will benefit if these plant communities increase as the climate warms.

Bears

Arctic Refuge is one of the few conservation areas in the world where all three species of North American bears occur. Polar bears use the northern edge of the Refuge, black bears occur only in southern regions in boreal forests, and brown bears are found throughout Arctic Refuge.

Polar bears (Ursus maritimus)

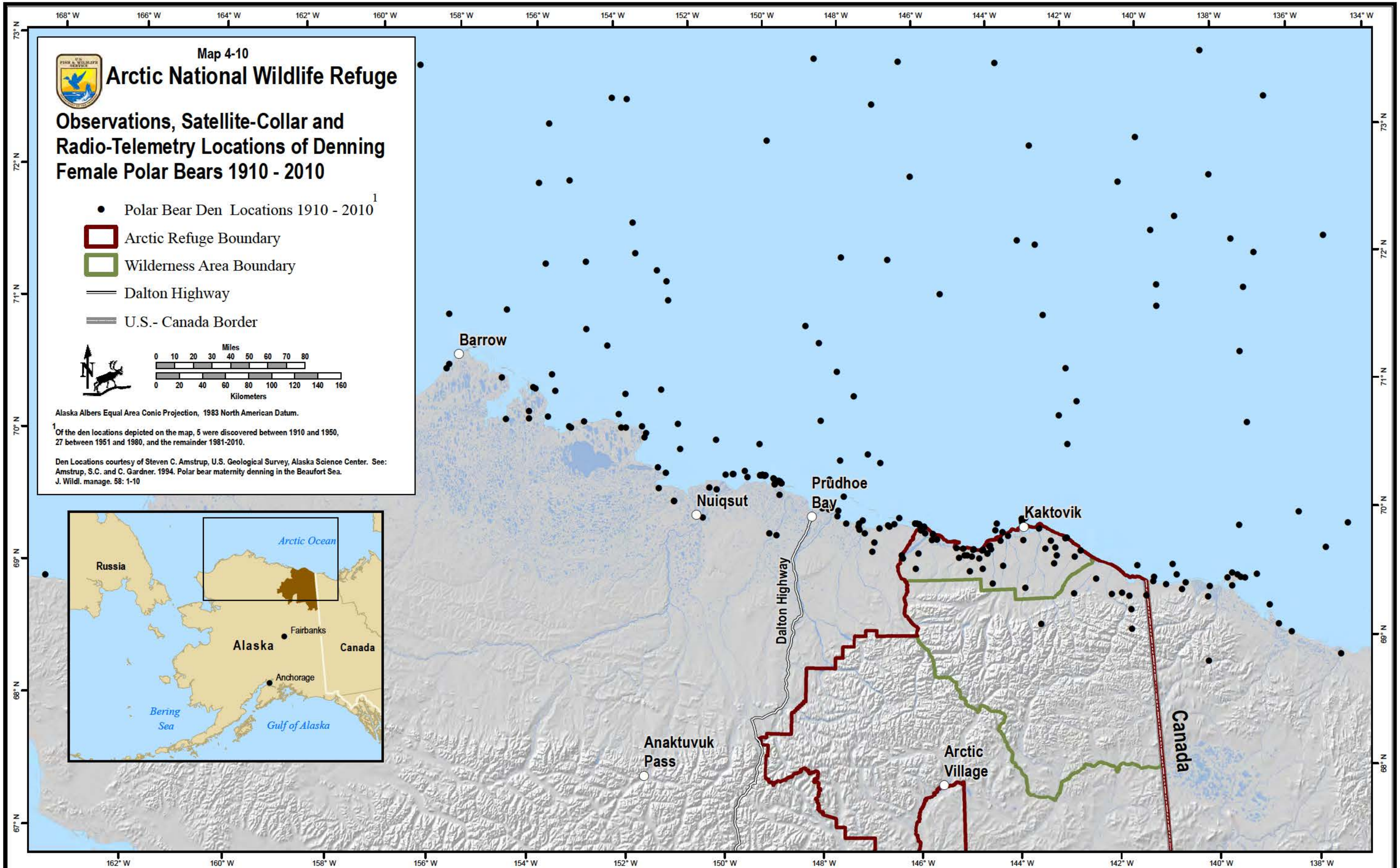
Polar bears are a relatively new species, having branched off the brown bear/grizzly bear lineage during the Late Pleistocene Epoch approximately 150,000 years ago (Lindqvist et al. 2010). Polar bears live throughout the arctic regions of the world and are classified as a marine mammal. The southern limit of their distribution is determined by the limit of arctic pack ice and annual land fast ice during winter (DeMaster and Stirling 1981). They are typically found on broken sea ice in areas with abundant ring seals *(Phoca hispida)* or bearded seals *(Erignathus barbatus)*, their principle prey (MacDonald and Cook 2009). Because of their strong association with ice seals, polar bears depend on sea ice for survival.

Polar bears first reproduce at age five or six. They mate in April and May, but—like other bear species—fertilized eggs do not begin to develop until September or October. One to three cubs are born in December in winter dens, which pregnant females excavate in snowdrifts offshore on stable pack ice or onshore in large drifts along drainages (Amstrup 2002). Males and non-pregnant females remain active throughout the winter on the pack ice.

Polar bears associated with Arctic Refuge are part of the southern Beaufort Sea stock, whose range extends from Icy Cape, west of Point Barrow, Alaska, to Pearce Point, east of Paulatuk, Canada (Brower et al. 2002). Polar bears in the southern Beaufort Sea spend most of their time in shallow waters over the continental shelf, in areas with greater than 50 percent ice cover, where they have access to ringed and bearded seals (Durner et al. 2006, Durner et al. 2009).

The coastal plain of Arctic Refuge has more potential terrestrial denning habitat for pregnant polar bears than other areas of arctic Alaska because it has uplands and hills and is bisected by streams and rivers. These features lead to formation of snow drifts that provide potential den sites (Durner et al. 2006). Sea ice forms earlier in the fall in northeastern Alaska, which may allow pregnant bears to access terrestrial habitats from the pack ice more readily (Lentfer et al.1980). Thinning sea ice has apparently contributed to a shift from denning on sea ice to denning on land in this region, as evidenced by a decline in the proportion of dens on pack ice from 62 percent in 1985–1994 to 37 percent in 1998–2004 (Fischbach et al. 2007). This shift emphasizes the importance of Arctic Refuge coastal plain to polar bears, as does the distribution of known polar bear dens in northern Alaska (Map 4-10).

Polar bears occur at low densities because they are long lived and have delayed sexual maturity, long intervals between reproductive events, and small litters (Lentfer et al. 1980, DeMaster and Stirling 1981). In the early 1960s, overhunting resulted in polar bear population declines in the southern Beaufort Sea (Amstrup et al. 1986). The Marine Mammals Protection


Map 4-10
Arctic National Wildlife Refuge
Observations, Satellite-Collar and Radio-Telemetry Locations of Denning Female Polar Bears 1910 - 2010
Polar Bear Den Locations 1910 - 2010[1]
Arctic Refuge Boundary
Wilderness Area Boundary
Dalton Highway
U.S.- Canada Border
Miles
0 10 20 30 40 50 60 70 80
0 20 40 60 80 100 120 140 160
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
[1]Of the den locations depicted on the map, 5 were discovered between 1910 and 1950, 27 between 1951 and 1980, and the remainder 1981-2010.
Den Locations courtesy of Steven C. Amstrup, U.S. Geological Survey, Alaska Science Center. See: Amstrup, S.C. and C. Gardner. 1994. Polar bear maternity denning in the Beaufort Sea. J. Wildl. manage. 58: 1-10
Russia
Arctic Ocean
Alaska
Fairbanks
Anchorage
Canada
Bering Sea
Gulf of Alaska
Barrow
Nuiqsut
Prudhoe Bay
Kaktovik
Dalton Highway
Anaktuvuk Pass
Arctic Village
Canada
168° W
166° W
164° W
162° W
160° W
158° W
156° W
154° W
152° W
150° W
148° W
146° W
144° W
142° W
140° W
138° W
136° W
134° W
73° N
72° N
71° N
70° N
69° N
68° N
67° N

Act of 1972 restricted harvest of Alaskan polar bears to Alaska Natives but allowed unlimited harvest—provided that it was not wasteful—and the sale of handicrafts made from bear parts (U.S. Fish and Wildlife Service 2010a). Following passage of the Marine Mammals Protection Act, the size of the southern Beaufort Sea polar bear population increased, and likely stablized during the 1990s (Amstrup et al. 2001). From 2001-2006, a negative rate of population growth (Hunter et al. 2007) and declining recruitment, survival (Regehr et al. 2010 and body condition and size (Rode et al. 2010) suggest that the southern Beaufort Sea population of polar bears is currently declining. The most recent population estimate for the southern Beaufort Sea is 1526 polar bears (95 percent CI = 1211-1841; C.V. = 0.106) (Regehr et al. 2006).

Polar bears were designated a Threatened species under the Endangered Species Act in May 2008 (73 FR 76249-76269). Under the Marine Mammal Protection Act, polar bears in the southern Beaufort Sea are classified as "Depleted" and designated as a "strategic stock" (U.S. Fish and Wildlife Service 2010b). Conservation concerns for this population include "loss of sea ice habitat due in part to climate changes in the arctic, potential overharvest, and current and proposed human activities including industrial activities occuring in the nearshore and offshore environment." (U.S. Fish and Wildlife Service 2010b, p 4). This shift emphasized the importance of the Arctic Refuge coastal plain to denning polar bears, which is also supported by the distribution of known polar bear dens in northern Alaska (Map 4-10).

Harvest of the southern Beaufort Sea polar bear population is currently managed under the authority of the Polar Bear Agreement between the Inuvialuit Game Council of Canada and the Iñupiat of the North Slope Borough of Alaska (Brower et al. 2002). Canada has a well regulated and controlled harvest, while harvest in Alaska is voluntary (Brower et al. 2002). The agreement provides for a Joint Commission and Technical Advisory Committee appointed by the commission, an annual quota, hunting seasons, and protection of bears in dens and females accompanied by cub-of-the-year.

A quota of 80 bears (40 each in Alaska and Canada) was set by the agreement in 1998 and reviewed in 2000 based on a population estimate of 1,800–2,000 (Amstrupt et al. 1986, Amstrup et al. 2001, Brower et al. 2002). In 2003–2007, an average of 54 polar bears were killed by subsistence hunters each year in the Beaufort Sea population in Alaska and Canada combined (Brower et al. 2002). Based on an estimated sustainable harvest rate of 1.5 percent of the total population size taken as females and a 2-males-to-1-female ratio in the harvest, 4.5 percent of the total population (63 of 1526 polar bears) could be harvested annually (76 FR 47021). This rate of harvest has been proposed for polar bear populations that are capable of natural growth at near maximimal rates (Taylor et al.1987). It may not be sustainable for populations experiencing limitations due to climate change or other effects. In July 2010, at the most recent Inuvialuit-Iñupiat Polar Bear Management Meeting, the quota for the southern Beaufort Sea population was reduced from 80 to 70 bears per year (76 FR 47021).

Marine Mammals Management division of the Service monitors the annual harvest of polar bears killed in Alaska, including animals taken from the southern Beaufort Sea population in and near Arctic Refuge. In Alaska, 117 polar bears were killed by subsistence hunters in 2005-2009. This was 40 fewer bears (157) than were killed in Alaska in 2000-2004 (76 FR 47021).

In 2010, the Polar Bear Specialists Group indicated that the five-year average harvest of polar bears in the southern Beaufort Sea was 44 polar bears per year with a quota of 80, the status of the population was reduced, the trend was declining, and the probability of future decline was moderate (40–60 percent) (Polar Bear Specialist Group 2010). The Potential Biological Removal level, as defined by the Marine Mammals Protection Act, indicates the maximum number of animals (excluding natural mortalities) that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population was estimated to be 22 bears per year for the southern Beaufort Sea population (U.S. Fish and Wildlife Service 2010b).

Final regulations developed by the Service (76 FR 47010-47054) authorized nonlethal, incidental unintentional take of polar bears during year-round oil and gas industry exploration, development, and production operations in the Beaufort Sea and the adjacent north coast of Alaska from August 3, 2011, to August 3, 2016. The analysis found that oil and gas activities would have a negligible impact on polar bears during this five-year year period (76 FR 47010-47054).

The probability of a large oil spill (greater than1000 barrels) in and near the Beaufort Sea is low (11 percent) according to Marine Management Service (U.S. Fish and Wildlife Service 2010b). This may increase as exploration and development moves offshore. Potential adverse impacts to polar bears from a large oil spill are of major concern (Federal Register Vol. 76 No. 149 page 47031). Polar bears are most vulnerable during the open water period when aggregations of bears at whale carcasses on shore take place (76 FR 470334). Amstrup et al. (2006) found a low probability that a large number of bears (25-60) would be affected by a large offshore oil spill. He estimated 0-27 polar bears could be oiled by a spill in the southern Beaufort Sea if the spill occurred during open water conditions in September or an estimated 0-74 bears could be oiled in October. If the subsistence harvest continues to average 54 bears per year and the annual sustainable harvest is now less than 81 bears, the death of a few dozen bears could result in population decline or slow recovery (U.S. Fish and Wildlife Service 2010b).

The Service also concluded that the probability of a large offshore oil spill in the next five years was low. If a spill did occur, the likelihood that oil would contact important areas or habitats used by bear habitats was also low, and, although individual bears may be affected, the effect on the polar bear population would be minimal. Thus “only small numbers of polar bears are likely to be affected by a large oil spell in arctic waters with only a negligible impact” to the southern Beaufort Sea population (76 FR 47036-47037).

People are interested in viewing polar bears in and near Arctic Refuge. In the fall, polar bears are attracted to remains of bowhead whales harvested by residents of Kaktovik. Congregations of bears feeding on whale bones near Kaktovik at the edge of Arctic Refuge provide opportunities for visitors and residents to see these large carnivores. The Service’s Marine Mammals Management division and Arctic Refuge staff cooperate to monitor the fall influx of bears near Kaktovik and assist the community in developing guidelines for polar bear viewing.

Critical habitat for polar bears was designated by the Service in December 2010 with the final rule effective on January 6, 2011 (75 FR 76086-76137). Designated habitat was 187,757 square mi (484,738 square km) in Alaska and adjacent territoral and U.S. waters.

Polar bears rely on sea ice for survival. Sea ice is declining throughout the Arctic as temperatures increase, melting periods lengthen, and freeze-up occurs later in the fall (Stroeve et al. 2007). Increased periods of open water reduce reflectance and cause additional warming of the Arctic Ocean, leading to further ice melt (http://iside.org/cryosphere/seaice/processes/albedo.html). Between 1985 and 2006, large losses of optimal polar bear habitat occurred in the southern Beaufort and Chukchi Seas (Durner et al. 2009). In the southern Beaufort Sea, these changes appear to be negatively affecting polar bears’ body condition, size, recruitment, and survival (Rode et al. 2010, Regehr et al. 2010). Hunter et al. 2010 suggests that this decline is due to sea ice habitat loss and that the population may face severe declines in the future if sea ice loss continues as forcasted. Delach and Matson (2011) state that polar bears are “extremely vulnerable” to climate change because of their dependence on ice and snow.

Brown (grizzly) bears (Ursus arctos)

This species occurs in North America, Europe, and Asia, although they have been reduced or exterminated by humans over much of their historic range. In Alaska, brown bears still occupy most of their historic range. They are frequently solitary, except for females with dependent offspring, aggregations at clumped food resources, and mating pairs. Brown bears breed between mid-May and July, although development of fertilized eggs is delayed until October. One to three cubs are born in winter dens during January (Churcher 1999).

In Arctic Refuge, the average female brown bear did not successfully reproduce until age nine years (Reynolds 1976, Reynolds and Hechtel 1980). In other areas of the Arctic, the mean age at first reproduction was greater than eight years (Reynolds and Hechtel 1984, Case and Buckland 1998). Average litter size of brown bears in arctic areas is two, and cubs can have a high mortality rate during their first year of life. Weaning does not occur until age two or three years. The interval between successful litters exceeds three years. The delayed age at first reproduction, long inter-birth intervals, small litters and high cub mortality result in low rates of reproduction for brown bears in northern latitudes.

Male and female brown bears are dormant in dens during the arctic winter. Heart rate and body temperature decline slightly, metabolic rate is reduced, and bears neither urinate nor defecate while in the den (Reynolds et al. 1986, Watts and Jonkel 1988).

Unlike polar bears, which den in snow cavities, brown bears in Arctic Refuge usually excavate earthen dens in the mountains on steep, south-facing slopes above rivers. They enter their dens during September and October, and emerge from late March through May. Inclement weather, especially snow storms, is considered a major factor in stimulating denning activity (Craighead and Craighead 1972, Reynolds et al. 1976). Because arctic soils are coarse, the top layer must be frozen before dens can be successfully excavated. Dens generally collapse with spring thaw, so reuse of dens is rare (Garner and Reynolds 1986). Adult males generally enter dens later and emerge later than females with cubs of the year. In Arctic Refuge, brown bears spend more than half their lives in winter dens (Reynolds et al. 2010).

Brown bears are opportunistic omnivores. In Arctic Refuge, grizzlies eat a variety of foods depending on seasonal availability. In March-May, after emerging from winter dens, they dig roots of *Hedysarum* plants and kill or scavenge ungulates. They use habitats ranging from shrubby riparian corridors, lowlands, foothills and upland mountain slopes with moist herbaceous tundra and sparsely vegetated areas along rivers and high mountain ridges.

Brown bears eat ungulate carcasses primarily in April and May before green vegetation emerges. Satellite-collared brown bears consumed more caribou than moose or muskoxen (Reynolds et al. 2007). Stable isotope analysis of brown bear blood serum collected over a 30-year period showed that arctic brown bears eat primarily vegetation and that consumption of meat did not increase over time (Reynolds et al. 2006).

Brown bears living in and near Arctic Refuge prey on caribou and moose calves and are a predator of muskoxen (Reynolds et al. 2002b). Arctic ground squirrels and microtine rodents, when they are abundant, are important prey items for bears. Bears north of the Brooks Range divide did not shift their distribution in response to the presence of calving caribou. Annual variation in snow melt patterns appears to be a more important determinant of bear distribution (Young et al. 2002).

On the Sheenjek River in the southern part of the Refuge, brown bears consume spawning salmon (Lenart 2007d). North of the Brooks Range, however, bears have little access to fish, and few observations of bears fishing have been reported. Stable isotope analyses suggest little use of marine-based resources (Reynolds et al. 2006). However, brown bears have been observed feeding and displacing polar bears at whale carcasses in Kaktovik, Barter Island (S. Miller, Wildlife Biologist, Service's Marine Mammals Management, pers. comm.).

Brown bear densities in northern Alaska are lower than densities areas in southern and southeastern Alaska where bears have access to salmon (Miller et al. 1997) In unit 26B in and near Arctic Refuge, brown bear densities were 18 bears per 386 mi^2 (18 bears per 1000 km^2) in 1999–2003 (Reynolds et al. 2009). By contrast, on Kodiak Island, bear densities were 308 bears per 386 mi^2 (308 bears per 1000 km^2) (Van Daele 2007).

In Arctic Refuge, brown bears are more abundant in the foothills and mountains of the Brooks Range than on the coastal plain (Young et al. 2002, Lenart 2007d). Lenart (2007d) estimated there were 390 brown bears in the foothills and mountains between the Canning River and the U.S. Canada border (Game Management Unit 26C) and 269 brown bears in the northwestern Refuge and adjacent areas (Unit 26B). Population trends and distribution of brown bears south of the Brooks Range are not well known.

An average of 36 brown bears were killed per year by general hunters in Units 25A, 26B, and 26C in and near the Refuge during 1993–2006 (Lenart 2007d). The number of brown bears taken by subsistence hunters is unknown.

Because of their wide ranging distribution and diverse use of habitats, brown bears in Arctic Refuge are likely to be less affected by a changing climate than other species. Delach and Matson (2011) found that brown bears in Arctic Refuge are "moderately vulnerable" to climate change because bears can move and disperse over long distances .

American black bears (Ursus americanus)

In Arctic Refuge, this species is only found in boreal forests of the southern uplands and lowlands (MacDonald and Cook 2009). Like brown bears, American black bears are omnivorous—eating plants, young ungulate, and other resources. They breed in early summer, delay implantation of the fertilized egg until November, and give birth to tiny young in winter dens. American black bears have 2–3 cubs, but from 1–6 cubs have been observed (Rogers 1999). Habitats used by black bears in Arctic Refuge likely include open and closed spruce forests and mixed forest of spruce and birch. But little is known about the distribution, population trends and mortality factors of American black bears in Arctic Refuge. Because of their wide distribution and omnivorous habits, black bears may not be negatively affected by climate change. If the boreal forest expands northward, black bears may increase their range in northern Alaska.

Other Carnivores

Carnivores play important roles as predators and scavengers in the ecological balance of Arctic Refuge. Furbearing species are also important to trappers and hunters. In communities near the Refuge, furs are used for clothing and handicrafts, and are a source of income. Many people visiting the Refuge hope to see carnivores such as brown bears, wolves or wolverines.

Wolves (Canis lupus)

Wolves were formerly distributed throughout the Northern Hemisphere, but their range has been greatly reduced by humans. Wolves still occupy most of their historic range in Alaska, however, including the arctic and subarctic regions. The wolf is a social species, usually living in packs of 5–10 animals. At high latitudes, wolves breed once a year during April. Altricial pups are born about two months later and are weaned about nine weeks after birth. Wolves feed on a variety of prey but are primarily predators of ungulates (Mech 2002).

Wolf packs often occupy territories that are distinct from those of neighboring packs. Wolves move a few miles to 45 mi (72 km) per day at speeds of about five mph (8 kmh) (Mech 1999). Individual wolves may travel great distances. One radio-collared wolf from Arctic Refuge moved 479 mi (770 km) from its last location in Arctic Refuge (Garner and Reynolds 1986).

Wolves are found throughout Arctic Refuge. North of the Brooks Range divide between the Canning River and the U.S.-Canada border, packs were associated with 11 different dens, which were more likely to be found in the mountains or foothills than on the coastal plain (Young et al. 2002). In this region of the Refuge, only about 20-40 wolves were present.

During the caribou calving period, wolves were generally associated with den sites and killed relatively few caribou (Young et al. 2002). Caribou are the primary prey species for wolves, followed in importance by sheep and moose. Small mammals, birds, and ground squirrels are also taken on an opportunistic basis. Wolves studied in northern portion of the Refuge did not follow caribou to their winter ranges but tended to remain in pack territories all year (Young et al. 2002). Wolves in northern Alaska ate caribou from spring to fall but switched to Dall's sheep, moose, and small game during winter (Stephenson 2006).

On the North Slope of Alaska, wolves were more abundant prior to aerial wolf hunting and predator control practices of the mid-1950s. Though the practices were outlawed by 1970, the abundance of wolves did not return to historic levels. Reported harvest of wolves in Units 25A, 26B, and 26C averaged 39 per year from 1997 to 2005. Known harvest likely underestimates the number of wolves killed, particularly in Units 26B and 26C, as many furs are used locally and not sealed (Stephenson 2006). Wolf populations are also affected by dynamics of food supplies, rabies epidemics, and competition with other wolves (Stephenson 2006).

Wolves are generally less abundant in northern Alaska than in interior Alaska, where moose densities are higher. A 2003 aerial wolf survey in the foothills and mountains of Unit 26B between the Itkilik and Canning rivers indicated a density of about 4.8 wolves per 1000 square mi (Stephenson 2006). Numbers of wolves and wolf population trends in Arctic Refuge are not currently known.

Delach and Matson (2011) found that wolves in Arctic Refuge were "not vulnerable/presumed stable" to climate change because of their ability to use a diversity of habitats and their ability to disperse.

Wolverines (Gulo gulo)

This large member of the weasel family ranges widely over large distances and live in many habitats from sea level to mountain tops. Wolverines live throughout Alaska but are more numerous in the mountains and foothills of the Brooks Range than on the coastal plain (MacDonald and Cook 2009).

Breeding occurs from early spring through late fall. After a period of delayed implantation, two or three kits are born in snow dens between February and April. Natal dens are generally abandoned by mid-May. Although most of their food is carrion, wolverines also prey on ground squirrels, ptarmigan, snowshoe hares, and even caribou (Whitman 2002).

Very little is known about population trends or abundance of wolverines in Arctic Refuge although biologists record sightings of wolverines and other carnivores during the course of field work on many species. In the early 1980s, 11 wolverine sightings were made during intense field studies north of the Brooks Range (Mauer 1985b). In 28 years of annual spring surveys for muskoxen and moose between the Canning River and US-Canada border, three wolverines were seen. During radio-tracking flights in the Brooks Range in 2006-2009, one pair was observed. Less field work has been carried out south of the Brooks Range and less is know of wolverine densities in these regions.

Wolverines are an important furbearer species in the eastern interior of Alaska, including southern areas in Arctic Refuge (Szepanski 2007). An average of 25 wolverines per year were harvested in regions in or near the Refuge during 1996–2006. Most of these were taken south of the Brooks Range in Unit 25A (Szepanski 2007). Because wolverines taken by local residents are frequently used for clothing and may not be sealed, estimates of harvest are likely biased low.

Delach and Matson (2011) stated that wolverines in Arctic Refuge are “highly vulnerable” to effects of climate change because of “natural barriers to species range shift” and “dependence on snow.” Wolverines have natal dens in areas where snow cover persists until mid May. If changes in climate result in the loss of persistent snow cover and summer temperatures, the extent of wolverine habitats may be reduced (Copeland et al. 2010).

Arctic foxes (Vulpes lagopus)

This species lives in northern areas of the Refuge from the arctic sea ice to the Brooks Range mountains. Arctic foxes often spend winters on sea ice, feeding primarily on the carrion of seals killed by polar bears. In summer, primary prey are lemmings and voles, although they also take bird eggs and nestlings (Anderson 1999). Arctic fox populations vary widely depending on the availability of food such as lemmings (MacDonald and Cook 2009). Rabies is endemic in arctic fox populations in Alaska (Garner and Reynolds 1986, Ballard et al. 2001).

Arctic foxes are monogamous. In northern Alaska, breeding occurs in March through early April, and pups are born in May or June. Litter size is highly variable (from 2–20), and the number of pups weaned depends on vole and lemming populations (Anderson 1999). Denning occurs on land during summer, primarily near the coast.

Residents of Kaktovik trap arctic foxes during winter in moderate numbers, but harvest levels are not known. Red foxes, whose range extended into high latitudes during the 20th century, are dominant over and likely outcompete smaller arctic foxes (Selas et al. 2010). They also kill arctic foxes (Pamperin et al. 2006).

Arctic foxes are adapted to the cold arctic climate (Underwood and Reynolds 1980, Anderson 1999). Climate change may negatively affect arctic foxes because of their association with sea ice and polar bears in winter. Delach and Matson (2011) found that arctic foxes in Arctic Refuge are "extremely vulnerable" to changes in climate due to potential habitat loss, its dependence on ice and snow, and possible loss of prey species.

Red foxes (Vulpes vulpes)

This fox is the most widely distributed carnivore in the world. Red foxes live in diverse habitats, hunting and scavenging a wide variety of resources. Red foxes breed from late December through late March. An average of five pups are born 6 weeks later, which are raised by both parents (Seidensticker 1999). Red foxes occur throughout the Refuge, but they are most common in the riparian areas in the mountains and foothills of the Brooks Range (MacDonald and Cook 2009).

In northern Alaska, the range of red foxes may be expanding into the range of arctic foxes (Pamperin et al. 2006). The larger body size of red fox gives them a competitive advantage (Selas et al. 2010), and red foxes have been observed killing arctic foxes (Pamperin et al. 2006). As the climate becomes warmer, red foxes could benefit by the expansion of boreal forest habitats in Arctic Refuge. Delach and Matson (2011) found that that red foxes in Arctic Refuge are likely to increase their populations with climate change.

Canada lynx (Lynx canadensis)

Canada lynx are well adapted to living in snow, as are their primary prey, the snowshoe hare (*Lepus americanus*). Lynx are usually solitary. Breeding occurs during March and April, and an average of three kittens are born in May or June (Tumlison 1999).

The most important lynx habitats in Arctic Refuge are south of the Brooks Range in spruce and mixed forests and woodlands with dense understories of shrubs (MacDonald and Cook 2009). In times of prey scarcity, lynx range into tundra areas and have been observed as far north as the arctic coast.

Reported harvest of Canada lynx, red fox, mink, and American marten from Game Management Units south of the Brooks Range peaked in 1996. Mink harvest peaked again in 2004, and the number of harvested lynx continued to increase between 2003 and 2005 (Szepanski 2007). North of the Brooks Range divide, four Canada lynx were taken in 2003, and three Canada lynx were taken in 2006 (Szepanski 2007).

Canada lynx were classed as "highly vulnerable" to climate change based on its dependence on snow and forest habitats, and its dependence on a single prey species; however, the certainty of this vulnerability is low (Delach and Matson 2011).

Rodents and Hares

Rodents occupy a wide diversity of habitats on Arctic Refuge. Many are important in the food webs of the tundra and boreal forest ecosystems. High variability in rodent and hare abundance influences numbers and distribution of predators and scavengers and affects vegetation communities on which rodents and hares depend. Climate change could have positive or mixed effects on rodents and hares in Arctic Refuge. An increase in the length and warmth of the growing season could increase access to green forage for all herbivores. However, if wet graminoids tundra is replaced by dryer shrubbier tundra, singing voles (*Microtus miurus*), collared lemmings (*Dycrostonyx groenlandicus*), hares (*Lepus* sp.), and porcupines (*Erethizon dorsatum*) could benefit, while brown lemmings (*Lemmus trimucronatus*) and root (tundra) voles (*Microtus oeconomus*) may not (Martin et al. 2009). Delach and Matson (2011) found that collared and brown lemmings and root (tundra) voles were "extremely vulnerable" to climate change because of their "sensitivity to temperature change." Alaska marmots (*Marmota browerii*), arctic ground squirrels (*Spermophilus parryii*), singing voles, and northern bog lemmings (*Synaptomys borealis*) were "highly vulnerable"and snow shoe hares, northern-red backed voles (*Myodes rutilus*), meadow voles (*Microtus pennsylvanicus*), red squirrels, (*Tamiasciurus hudsonicus*) and porcupines were considered to be not "vulnerable/presumed stable." Inouye et al. (2000) found that Alaska marmots are likely to be affected by a warming climate because they live in mountain habitats that may change and because they are endemic to northern Alaska and could be rare. Climate change that results in more incidents of freezing rain or icing conditions in winter could affect rodents and hares, especially small species like lemmings and voles that are active all winter and depend on insulating layers of snow for warmth and protection from predators (Merritt 2010).

Alaska marmots (Marmota broweri)

This large squirrel is endemic to Alaska and occurs in some mountain areas in Arctic Refuge. Its distribution, status, and natural history are not well known. Marmots live in rocky alpine areas of tundra in scarcely vegetated scree type habitat. Alaska marmots are further discussed in the section on Endemic Species.

Arctic ground squirrels (Spermophilus parryii)

This medium-sized rodent is found throughout Alaska in habitats ranging from tundra, meadows, river banks and lakeshores (MacDonald and Cook 2009). In Arctic Refuge, it occurs in tundra regions of well-drained soils where burrows can be constructed. Moist sedge-Dryas tundra and moist sedge tussock tundra habitats are used by Arctic ground squirrels. In the Arctic Refuge, ground squirrels are s most numerous in the foothills and mountains of the Brooks Range (MacDonald and Cook 2009). Arctic ground squirrels are the northernmost hibernator in North America, spending up to nine months in winter dens (Buck and Barnes 1999). Arctic ground squirrels are an important food resource for brown bears and foxes.

Lemmings and Voles

Collared lemmings are found from the arctic coastal plain to the mountains of the Brooks Range frequently in moist sedge-willow tundra and moist sedge-tussock tundra in association with cotton grass (*Eriophorum vaginatum*). Of all the microtines, this species is best adapted to sub-freezing temperatures, ice and snow. In winter the coat of the collared lemming turns white and develops an enlarged claw for digging through snow.

Brown lemmings occupy a wider geographic range than collared lemmings and are found throughout Alaska. They are most abundant at higher latitudes and are the most common microtine on the coastal plain of Arctic Refuge. Brown lemmings live in wet sedge grass (graminoids) tundra.

Singing voles are the most common microtine in the Brooks Range and are less frequently found in the foothills and rarely on the coastal plain. Singing voles live in well-drained sites at the edge of swales or banks near early successional stages of vegetation and running water.

Root voles *(Microtus oeconomus)* are found throughout Alaska. In Arctic Refuge, they are abundant and widespread from the coastal plain and foothills to the north and south slopes of the Brooks Range. Root voles occupy a variety of open herbaceous habitats ranging from wet graminoids tundra to grass-forb meadows and bogs.

The northern red-backed vole (*Myodes rutilus*) is found primarily in the Brooks Range and along major river valleys. It lives in areas with overhead protection from rocks or vegetation such as scarcely vegetated scree, dwarf shrub, and woodland habitats. (MacDonald and Cook 2009).

Lemming and vole populations on the Refuge tend to fluctuate widely (Batzli and Pitelka 1983). When brown lemmings or other microtines are abundant, they have substantial effects on local plant communities and provide food resources for many other species, including brown bears, arctic and red foxes, least weasels (*Mustela nivalis*), and other mammalian and avian predators. Lemming "highs" cause shifts in predator distribution as species move in to take advantage of this abundant food resource.

Snowshoe hares (Lepus americanus)

This species occasionally occurs in boreal forests in the southern portion of the Refuge in riparian willow stands (MacDonald and Cook 2009). Hare sign observed in the mountains and northern foothills is likely also that of snowshoe hares. However, two other species of northern hares have been documented east and west of the Refuge and may occur on the Refuge itself,

although their presence has not been documented. Alaskan hares (*Lepus othus*) historically occurred as far east as the Colville River, about 100 miles west of Arctic Refuge (Best 1999a). Arctic hares (*Lepus arcticus*) are found in Northwest Territories, Canada, about 100 miles east of Arctic Refuge (Best 1999b).

Snowshoe hares are active year-round and can produce 2–5 litters of 1–8 young each per year. Young hares are born fully furred, grow rapidly, and are weaned within a month (Murray 1999). Snowshoe hare populations vary widely from year to year, often increasing over several years and then declining rapidly. At high densities, snowshoe hares are an important resource for medium to large predators. Lynx populations are closely tied to cycles of snowshoe hare populations (Tumlison 1999).

Endemic species

Two species of mammals occur only in Alaska, and both have been found on Arctic Refuge.

Alaska marmots (Marmota browerii)

This large squirrel lives in mountains north of the Yukon River, including the Brooks Range in Arctic Refuge (Gunderson et al. 2009). Its status is poorly understood (MacDonald and Cook 2009). Alaska marmots subsist on large amounts of low quality forage and choose den sites in bolder fields or rock outcroppings. Hibernation begins in September and ends in June, and members of a colony den together. Adult females produce only one litter per year, and sexual maturity is reached at several years of age.

Distribution of Alaska marmots is very patchy and scattered. Many details of the natural history of this species are unknown (Hoffmann 1999).

Alaska tiny shrews (Sorex yukonicus)

This shrew is a newly described species endemic to Alaska (Dokuchaev 1997). Little is known about the distribution and natural history of this tiny animal, which is the smallest shrew in the world. It appears to be widespread but rare in Alaska and occupies a wide range of forested and non-forest habitats, including riparian scrub (MacDonald and Cook 2009). A specimen was found dead on the Canning River delta in 2004, confirming that the species occurs on the Refuge (C. Villa, Refuge Operations Specialist, Arctic National Wildlife Refuge, pers. comm.).

4.3.7.4 Mammal-related Management Issues

Arctic Refuge is responsible for implementing Federal subsistence hunts pursuant to regulations adopted by the Federal Subsistence Board. Refuge staff distributes permits to local communities for the subsistence harvest of Dall's sheep, moose, and muskoxen in Unit 26C and Dall's sheep in the Arctic Village Management Area (Unit 25A). The number of permits issued typically depends on the population status of the species being hunted. Consequently, it is essential for Federal and State managers to have reliable, up-to-date information about population status and trends in order to properly plan for conservation of local species while allowing for subsistence and general hunting to the extent possible. The most effective means for obtaining information relating to population numbers and trends includes a combination of aerial surveys, ground counts, radio tracking (such as collaring), and habitat assessment by way of remote sensing and ground studies.

While Dall's sheep is an important subsistence species in this area, it is at the northern extent of its range and particularly vulnerable to overharvest. For that reason, improved understandings of population numbers and trends, seasonal movements, and distribution throughout the Refuge are needed. It will also be important to coordinate any sheep survey efforts on the Refuge with those in surrounding areas to enhance understandings of regional population trends.

Moose are another species in Arctic Refuge upon which local subsistence hunters are heavily reliant. Just as in the case of Dall's sheep, the moose populations on the Refuge have the potential to be overharvested if there is insufficient data for managers to make well-informed decisions. Consequently, in addition to developing base information about moose population trends and distribution, it will be important to conduct research that allows Federal and State managers to better understand patterns of movement and interaction between moose populations in the region.

For Federal managers to make appropriate decisions with regard to all of the ungulate populations on the Refuge, it will be necessary to develop an improved understanding of the local predator-prey relationships that impact those populations. To this end, monitoring of grizzly bears and wolves will be necessary. Information gathered will be used to better understand the dynamics of large predators living near the northern edge of their range as well as to clarify the nature of the relationships between these predators and their ungulate prey.

In the last two decades, caribou, sheep, muskoxen, and moose populations have fluctuated in Arctic Refuge, with some showing prolinged periods of decline. Similar declines occurred west of the Refuge, but most ungulates in those areas have since shown signs of recovery. Understanding the full range of factors that drive ungulate populations is essential for understanding and predicting population trends, and for managing subsistence harvests. The Refuge staff continues to participate in cooperative studies with ADFG, the Yukon Territory government, and others to ensure that these species will be conserved now and into the future.

4.4 Human Environment

4.4.1 Cultural and Historical Context

Over 530 archeological and historic and paleontological sites have been recorded within the boundaries of Arctic Refuge (ADNR Alaska Heritage Resources Survey 2001). These sites do not exist in isolation but in the context of a remarkable record of more than 10,000 years of human use of the land (Reanier 2003). At least seven prehistoric and two historic Native cultural traditions are represented on Arctic Refuge. Cultural resources on the North Slope and coastal plain are on or near the surface of the tundra and tend to be oriented along river corridors and coastal beaches. This means that many cultural resource sites on the Refuge are vulnerable to erosion and other natural forces, and to a lesser extent, from public use of Refuge lands and waters.

4.4.1.1 Archaeological and Historical Resources of Arctic National Wildlife Refuge

Currently, 212 archeological and 188 historical sites have been recorded within the boundaries of Arctic Refuge. Access to many areas of the Refuge is difficult and costly, requiring fixed-wing aircraft and substantial legwork. If the locations of known archaeological sites were plotted on a map, they would appear in clusters, reflecting the areas and extents of the surveys conducted. While the individual characteristics of the sites recorded within the boundaries of Arctic Refuge are unique, their nature can be generalized into several categories, which include:

- Coastal settlements, consisting of semi-subterranean driftwood or whalebone houses, in some cases associated with cemeteries and/or additional structures. Post-contact and pre-contact houses are present along the coast of the Beaufort Sea.
- Inland settlements, consisting of semi-subterranean driftwood or whalebone houses, also in some cases associated with cemeteries and/or additional structures. This is the least known type of site on the Refuge.
- Tent ring complexes, consisting of arrangements of stones used to secure skin tents to the ground, often with associated hearths in and outside of the ring. These features are found along river corridors on elevated terraces and likely relate to seasonal caribou hunting by coastal people. In some cases, these complexes are situated near or adjacent to caribou drive lines or fences.
- Caribou drive lines and fences are found on the north and south sides of the Brooks Range. These linear arrangements of stone cairns (in the north) and spruce (in the south) were used to funnel the movements of caribou herds into corrals where they were dispatched by hunters. The development of this type of large-scale procurement strategy required considerable levels of social organization to plan, create, and execute.
- Lithic scatters, consisting of surface and subsurface collections of artifacts and debris resulting from the procurement, preparation, and manufacture of stone tools. In many cases, lithic typological and technological comparisons are the only way of assigning an age to a site.
- Historic cabins built by indigenous peoples, early explorers, and trappers that offer insights into the early contact period.
- Prospecting and mining sites established during the late 19th and early 20th centuries document historic mineral exploration of the Refuge.

- Graves and cemeteries are sometimes associated with other types of archaeological and historic sites but may also be found in isolation.

4.4.1.2 Area History

The Arctic and its people, particularly the Eskimos, have fascinated Europeans since Frobisher's voyages in 1576. In the 1920s, archaeological research in the Bering Strait region delineated several proto-Eskimo cultural traditions. Most subsequent research in Alaska has focused on the west and northwestern coasts. Due to remoteness and a lack of development activity, very little work has occurred in the eastern Alaska arctic. Arctic Refuge Eskimo prehistory is based on broad regional patterns developed elsewhere.

The prehistory of interior Alaska, south of the Brooks Range, is very poorly known due to limited fieldwork, largely a result of challenging topography, vast distances, and difficult access. Interior sites also lack the flamboyant material culture of coastal sites (Shinkwin 1977, Workman 1996). Finally, most interior research focuses on the earliest settlement of the Americas to the near total neglect of later periods. With few excavated sites to draw on, regional culture history sequences for Arctic Refuge must be inferred from sites sometimes long distances from the Refuge.

Prehistory: the earliest period

The unglaciated Arctic coast served as a migration route for early nomadic hunters who migrated to America from Asia across the Bering Land Bridge. During the Itkillik glaciation, extensive valley glaciers prohibited human occupation of the Brooks Range. As the ice front retreated, by 10,000 B.C., people gradually penetrated the foothills. The area south of the Brooks Range remained ice-free during the last glaciations and was a route for entry of immigrants into the New World. Bones that were possibly modified by humans from Old Crow Flats in theYukon Territory may date to as old as 27,000 years ago.

Paleoindian Tradition (13,700–9,800 years ago)

Paleoindian refers to the first widespread and well-attested Native American cultural tradition. Paleoindian includes the well-known Clovis, Folsom, and Plano traditions in mid-continental North America. Characteristic artifacts include iconic fluted projectile points, edge-ground lanceolate projectile points, and other bifaces, multiple spurred gravers, and scrapers (Kunz and Reanier 1994, Kunz and Reanier 1995), all with exquisite technical workmanship. In Alaska, Paleoindian sites are almost all surface finds. Fluted points have been found in the Nenana and Tanana River valleys; on the North Slope (Reanier 1995, Kunz et al. 2003); in the Brooks Range and its northern foothills; and in Yukon Territory, Canada. Most known sites command impressive views of the surrounding landscape and appear to have been hunting lookouts and weapon repair stations. Paleoindian societies probably consisted of small mobile bands of big-game hunters focused on capturing now extinct Pleistocene mega-fauna: mammoths, horses, and bison. As the environment transformed at the end of the Pleistocene and large mammals disappeared, the Paleoindian tradition vanished from the north (Kunz et al. 2000).

The Putu Site, on the eastern slope of the Sagavanirktok Valley, excavated in the 1970s (Alexander 1987), was the first Alaskan site to produce fluted projectile points. Recent re-examination of the site questions the postulated 11,500-year-old date and raises the possibility that the tradition persisted in the Brooks Range until 8,800 years ago (Reanier 1995). The Mesa site, south of Barrow in the foothills of the Brooks Range, is the best documented site of this period (Kunz and Reanier 1994, Kunz and Reanier 1995). Radiocarbon samples from 30 hearths have produced dates ranging between 11,660 and 9,330 years ago. Other Paleoindian tradition sites include Bedwell (Sagavanirktok River), Hilltop (Atigun River Gorge), and Tuluaq Hill (Noatak River) (Kunz 1982, Kunz and Reanier 1994, Kunz and Reanier 1995, Reanier 1995, Rasic and Gal 2000, Kunz et al. 2003).

American Paleoarctic Tradition: 11,800–8,000 years ago

Overlapping with the Paleoindian tradition, the American Paleoarctic tradition (Anderson 1968) is the oldest, well-documented, Alaska-wide cultural tradition. The American Paleoarctic tradition is a loose technological construct (Anderson 1968, Anderson 1970, West 1981, Dumond 1987), with numerous variants distinguished by differences in frequencies of specific artifact types. Particular emphasis is placed on the presence or absence of microblades. Some of these variations include the Northwest Microblade Complex, the Nenana Complex, the Denali Complex, the Chindadn Complex, and the Sluiceway Complex. Many researchers consider them to be variations of a single tradition (Clark 1981, Clark 2001, Dumond 2001, Holmes 2001). Recent discoveries at the Nogahabara Sand Dunes on the Koyukuk Refuge support the concept that these traditions are a single with assemblage differences representing functional variation rather than distinct cultural groupings (Daniel Odess, pers. comm., 2005). Questions regarding the relationship between the American Paleoarctic tradition and its ancestral groups in Siberia, and the relationship of Paleoarctic and PaleoIndian peoples are hotly debated.

Wedge-shaped microblade cores, a variety of blades and microblades, and burins for working bone are hallmarks of the Paleoarctic tradition. The technology has clear antecedents in older sites from eastern Siberia (West 1996). The tradition is widespread, found across the North Slope and extending east through the Yukon, in the Koyukuk and Tanana river regions, Bristol Bay, the eastern Aleutians, southeast Alaska, and coastal and interior British Columbia. The sites appear to represent the camps of small bands of big-game hunters. Although the occasional horse, elk, moose, and musk ox has been found in sites, the economy was heavily dependent on caribou. Since caribou numbers appear to have been low at that time, making a living in north Alaska may have been quite challenging.

Paleoarctic sites on the North Slope include the Gallagher Flint Station near Galbraith Lake (Dixon 1975), the Lisburne Site on Iteriak Creek (Bowers 1982, Bowers 1999), Kurupa Lake (Schoenberg 1995), Kealok Creek (Reanier 2003), Tunalik (Gal 1982), and the Putuligayuk River delta overlook site at Prudhoe Bay (Lobdell 1985). Dated sites on the North Slope are younger than sites further south, suggesting a later arrival of this tradition to the far north. Kealok Creek site is one of the oldest Paleoarctic sites on the North Slope, at approximately 9,800 years old.

Prehistory: The middle period

Northern Archaic Tradition: 8,000–3,000 years ago

An unfilled gap appears in the sequence before the appearance of the forest-adapted Northern Archaic tradition about 6,000 years ago. The Northern Archaic tradition is a series of related cultures widely distributed across Alaska (Anderson 1968). Less is known about this tradition than any other in Alaska. Although there is an apparent gap, the tradition clearly derives from the Paleoarctic tradition, adding leaf-shaped spear points, large bifaces, end and side scrapers, tchi-thos (boulder spall scrapers), notched pebble axes, cobble choppers, and notched stone net sinkers to the Paleoarctic toolkit of microblades and side notched points.

First described from Cape Krusenstern and Onion Portage, Northern Archaic sites are known from Anaktuvuk Pass (Campbell 1961) and Kurupa Lake (Schoenberg 1995). Unlike earlier traditions, most sites are found in interior Alaska. Sites are found as far east as the Mackenzie River and south to Ugashik Lakes on the central Alaska Peninsula. On the coastal plain, sites are clustered around the mouth of the Colville River, at the Putuligayuk River Delta Overlook site (Lobdell 1985, Lobdell 1995), Kuparuk Pingo (Lobdell 1986, Lobdell 1995), Lisburne, and Kuna. South of the Brooks Range sites around Old John Lake on Arctic Refuge belong to the Northern Archaic tradition. Northern Archaic sites are absent from southeast Alaska and the Yukon-Kuskokwim basin.

During Northern Archaic times, the modern boundaries of the boreal forest were established and modern environmental conditions reigned. Environmental change from the dry Pleistocene steppe to wet tussock tundra probably reduced human mobility. The economic focus was on interior, terrestrial resources, notably caribou. Net sinkers signal a major shift in subsistence from big-game hunting to a mixed hunting and fishing economy. The geographic distibution of Northern Archaic largely corresponds to the modern distribution of western Athabascans and the tradition is likely ancestral to the modern people of the area.

Arctic Small Tool Tradition: 5,000–2,400 years ago

The Arctic Small Tool tradition is generally thought to be the earliest of the archaeological traditions that leads directly to modern day Eskimo peoples. As the name implies, it is typified by diminutive and beautifully made flaked stone tools. Among these are end and side blades (attached to an antler base to make composite projectile points), microblades, and mitten-shaped burins. The Arctic Small Tool tradition expanded across the Arctic from Alaska to Greenland, a surface distance of nearly 5,000 miles, in less than 500 years. They were the first people to inhabit the high arctic and occupied a much more extensive area than did the earlier Paleoindians or any subsequent Eskimo culture.

The Arctic Small Tool tradition appears rather abruptly and is associated with a climatic shift occurring at the end of the Holocene Warm Period. The tradition has several component cultures, but only the Denbigh Flint Complex is found in northern Alaska. Denbigh sites are common throughout the Brooks Range and extend south to the Kobuk River. A variant is found far to the south on the northern Alaska Peninsula (Dumond 1984). Excavated Denbigh sites in northern Alaska include Croxton, Punyik Point, Kurupa Lake, Mosquito Lake, and the Gallagher Flint Station, all lying along the northern edge of the Brooks Range. The average age of the Denbigh occupation at these sites is 4,000–3,400 years ago. Dates at Mosquito Lake and Gallagher Flint Station indicate occupation as late as 2,400 years ago (Kunz 1977). The Walakpa site near Barrow also contains Denbigh materials dated to around 2,400 years ago (Stanford 1971, Stanford 1976). Dates from the Putuligayuk River indicate this tradition lasted to around 2,000 years ago on the North Slope (Lobdell 1985). These slightly later assemblages contain—in addition to typical Denbigh materials—small, contracting stem, edge-ground, end blades.

The economy was broadly based with equal reliance upon maritime, land, and riverine resources. Their technology was geared towards caribou hunting even in coastal sites where seals were hunted (Giddings and Anderson 1986). People lived in caribou skin tents in the summer. More substantial shallow semi-subterranean houses exist and probably indicate winter occupation. These houses measure about 8 by 10 feet in size. A willow framework arched over the excavation and supported a roof of sod blocks sheathed by caribou skins (Kunz 2006). Denbigh people, like their earlier predecessors, made most of their stone tools from chert. However, they also exploited the Batza Téna obsidian source, on the Koyukuk Refuge's Indian River. Use of Batza Téna obsidian is evidence of their mobility, large population, and established trading networks.

Prehistory: the late period

Iñupiat Ancestors

Beginning about 2,000 years ago, people on the Arctic coast became more reliant on marine resources. Strong continuity in stone and organic tools suggests direct descent from earlier Arctic Small Tool tradition people.

Birnirk Culture (1,600–1,000 years ago)

The type site for this maritime based culture is Birnirk (Piåniq) at the base of the Barrow spit. Birnirk developed out of the Old Bering Sea, and Okvik cultures centered on St. Lawrence Island in the Bering Sea. Sites appear along the coast from Kotzebue to Barrow (Giddings and Anderson 1986), and include Walakpa (Stanford 1976), Point Hope (Larsen and Rainey 1948), and Cape Krusenstern (Giddings and Anderson 1986).

Birnirk houses and artifacts document a lifeway nearly identical to those of the historic Iñupiat (Ford 1959, Carter 1966, Stanford 1976). The people lived in substantial settlements in semi-subterranean winter houses. They were accomplished hunters of seal, walrus, and caribou, and occasionally hunted whales. They also harvested fish and waterfowl.

The tool assemblages include beautifully carved and decorated ivory harpoon heads. Flaked stone side and end blades, and ground slate tools such as ulus, were common. Bone, ivory, and antler were used to make numerous implements, including harpoon heads, tool handles, and composite tool parts. Although skin boats have likely been an important item in every Arctic culture's toolkit, the increased emphasis on marine resources suggests an increase in use, and possibly in size, of skin boats. Birnirk people were part of an elaborate interaction sphere involving contacts throughout Bering Straits, intercontinental trade, and warfare (Mason 1998).

Thule (1,000–400 years ago)

By 1,000 years ago, in response to climate moderation and technological advances related to whaling, the Birnirk culture had transformed into the Thule Culture. Thule people spread from northwest Alaska across northern Canada to Greenland, arriving during the same warm period that allowed the Norse to settle Greenland. Thule expansion rivals the Arctic Small Tool tradition colonization 3,000 years earlier.

Climate warming changed sea ice conditions to allow access to the bowheads through open water whaling. Technological changes included new harpoon types; development of specialized bone, antler, and ivory whale hunting tools; refinement of large open skin boats; and the invention of the dragfloat.

Other aspects of Thule culture are almost identical to that of their Birnirk ancestors. The toolkit contained flaked stone end and side blade insets, ground stone implements, and pottery. Reliance on whales allowed, and required, populations to aggregate in larger settlements and led to dramatic changes in social and political organization. Settlements consisted of single room dwellings of logs and sod arranged around a larger, multi-roomed dwelling occupied by the lead whaling family. Thule sites are found at Barrow, Walakpa (Stanford 1976), Point Hope (Larsen and Rainey 1948), Cape Prince of Whales, and Cape Kruzenstern (Giddings and Anderson 1986).

Athabascan Ancestors

Athabascan prehistory is a lifeway adapted to the boreal forest. There is no single identifiable prehistoric Athabascan tradition. Regional variability and adaptation are hallmarks of this tradition. Researchers disagree over how far into the past Athabascan people and cultures can be traced. Some see a recognizable Athabascan cultural pattern beginning with major environmental and adaptive changes that preceded the Northern Archaic tradition. Others believe the earlier people (Paleoindian/Paleoarctic) are related to American Indian groups now found further south, and Athabascan cultures represent a later migration. Drawing on linguistic evidence, Krauss and Golla (1981) suggested that 3,000 years may have elapsed since the numerous modern Athabascan languages diverged from a common language centered in Alaska.

Physically, there is an apparent gap in the archaeological record between Northern Archaic tradition sites and Athabascan components of the last 2,000 years. The gap is likely the result of limited field work, buried sites, erosion, cultural values prescribing behaviors that limit creation of visible sites, and periodic depopulation and resettlement (Moodie et al. 1992, West and Donaldson 2002). Complicating the picture in eastern Alaska, a major volcanic eruption 1,900 years ago in the Wrangell Mountains deposited the White River ash layer. Following this eruption, groups around Kluane and Aishihik lakes moved to the northwest, and Kavik points, tchi-thos, and other generalized Athabascan tradition implements appeared in the Brooks Range.

The Klo-Kut site, mid-way along the Porcupine River in Canada, provides the longest unbroken record of prehistoric Athabascan occupation, spanning 1,500 years and culminating in a historic Athabascan village (Morlan 1973). The earliest Athabascan tradition phase, identified by Le Blanc (1984) is Old Chief, extending from ca. 900 B.C. to A.D. 700. Old Chief exhibits relationships to Itkillik at Onion Portage, Minchumina Lake, and the Taye Lake phase in southwest Yukon. Artifacts include notched projectile points, and the assemblages lack microblades.

The later Klo-Kut Phase begins about A.D. 700 and continues through the arrival of European traders. Workman's Aishihik Phase is an equivalent Phase determination. The assemblage is closely related to the upper component of Dixthada, Kavik, and other sites throughout Alaska and western Canada (Shinkwin 1979). Artifacts include small, tapered-stem projectile points, groundstone hide and wood working tools, bone implements, and use of copper. Microblades are increasingly rare but never totally disappear from the record. Sites are larger than those of the earlier Northern Archaic and Paleoarctic peoples and contain semi-subterranean houses and cache pits. (Clark 1981).

Early North Alaska History

Modern Iñupiat

People of the Thule culture are directly ancestral to the modern Iñupiat of northern Alaska. Again, environmental change stimulated cultural change. An apparent decline in the number of whales around AD 1400 caused settlements around Kotzebue Sound to contract and houses to become smaller. Whaling continued at Point Hope and Barrow, where villages continued to grow in size and population. Eastward towards the MacKenzie delta, settlements were small with between one and four houses. People in these smaller communities relied on a broader range of resources, especially fish. The toolkit remained the same as in Birnirk and Thule times with the exception of the whaling technology. Asian and European trade items, chiefly iron, entered Alaska in the 17th century through trade networks across Siberia. Foreign trade goods are not common until the mid-1800s.

Two distinct but interrelated groups of Iñupiat make their homes on the North Slope. The Tagiugmiut have been primarily dependent on a marine economy based on the harvest of sea mammals; the bowhead whaling complex has been the focal point of their social and cultural development. Kaktovik residents primarily descend from this group of Iñupiat. The Nunamiut occupy the inland zone of the North Slope and rely on caribou. The two groups have strong cultural, social, and economic ties (Worl Associates 1978).

Barter Island has been an important trading site since aboriginal times. A large prehistoric village existed on the island, but in cultural memory, the site has always best been known as a trading center for Iñupiat from east and west along the coast and from inland areas (Jacobson and Wentworth, 1982). The Iñupiat who ultimately established permanent residence on the island after the turn of the century have close ties with relatives at Inuvik in Canada (Worl Associates 1978). Additional information on the history of Barter Island is found in Jacobson and Wentworth (1982).

The historic period in northern Alaska begins with the arrival of the European explorers who began the written record. Sir John Franklin's expedition sailed westward from the Mackenzie River, reaching the Return Islands just west of Prudhoe Bay in August 1826 before turning back (Franklin 1828). That same year, Beechey's expedition sailed north from the Bering Strait in H.M.S. Blossom, under the command of Thomas Elson, reaching Point Barrow only five days after Franklin's expedition left the Return Islands (Beechey 1831).

In about 1898, whaling vessels began rounding Point Barrow and sailing east to hunt in the Beaufort Sea. The whalers chose to allow their vessels to become frozen in protected shore ice where they remained over winter in order to be on the Beaufort whaling waters early in the open water season. The ships served as bases for inland exploration and stopped at many points along the Arctic coast where coastal and inland indigenous people traded for Euro-American goods.

Modern Gwich'in

Written history south of the Brooks Range began about 1844 when Hudson's Bay Company traders descended the Porcupine River to its confluence with the Yukon River in search of trade routes. Alexander Hunter Murray established a Hudson's Bay Company trading post, called Fort Yukon, at the confluence in 1847. The fur trade quickly dominated the region's economy and established what is considered today as a traditional vocation for Natives on the South Slope. The traders were followed into the region by the first missionaries in the early 1860s.

Prior to the introduction of rifles, caribou fences were used in harvesting caribou. Men, women, and children cooperated to build fences that could be several miles long. They funneled migrating caribou into semicircular corrals lined with snares. Once caribou entered the corrals, hunters dispatched snared and trapped animals using spears or bows and arrows. The use of caribou fences ended as rifles became more available in the late 1900s. Mckennan described the use and construction of these structures during his ethnographic work in the region (McKennan 1965). In the early 1970s, researchers located and mapped the remains of late prehistoric and historic caribou fences in northeastern Alaska and the adjacent Yukon Territory (Warbelow et al. 1975, Roseneau 1973, Andrews 1977). Dendrochronological dating of selected fences placed the earliest year of construction at approximately A.D. 1800, with most construction falling between approximately A.D. 1830 and A.D. 1860 (Blazina-Joyce 1989).

After Alaska was purchased by the United States from Russia in 1867, the Hudson's Bay Company was forced to vacate its holdings. The Fort Yukon post moved up the Porcupine River to Canadian soil at Old Rampart. Hudson’s Bay Company holdings operations were assumed by the Alaska Commercial Company.

In the late 1800s, gold prospectors explored the South Slope but found little evidence of gold. Prospectors were followed by geologists, methodically searching for signs of valued minerals and petroleum. These expeditions opened the door to direct Euro-American contact with Native people in interior northeastrn Alaska. It is important to note that European and Asian goods, especially tobacco, iron, and copper, had reached northern Alaska through Native trade routes long before these expeditions (Murdoch 1892).

Commercial whaling and the trade that ensued linked Native peoples to the larger economy. Western trade goods entered the Native trade networks, and goods were exchanged along the coast at annual trade fairs such as the one at Niåliq at the mouth of the Colville River or at trading posts set up by white traders along the Arctic coast.

The presence of Europeans, especially during the commercial whaling period that began in the 1850s, increased the availability of useful items such as metal and firearms, both of which became part of Iñupiat material culture. However, their presence also exposed the Native peoples to a host of European diseases against which they had no resistance. Diseases such as smallpox and influenza decimated northern populations, and by the end of the 19th century had caused major population shifts. By 1914, less than half of the Native residents of the Barrow area were descendents of its original inhabitants (Jenness 1957, Stefansson 1913).

From the close of World War I to about 1931, fox trapping was a second connection to the larger western economy (Spencer 1959). During the 1920s, fueled by the fashion industry, white fox pelts sold for about $50. By 1931, prices were down to $5 or less per pelt, and most trappers returned to traditional subsistence practices out of necessity. Mirroring the fox trapping experience was reindeer herding. Reindeer were introduced to Alaska in 1898, and beginning about 1915, after the collapse of commercial whaling, large herds were developed by the people of Wainwright, Barrow, and Barter Island (Spencer 1959). Herders struggled with problems such as disease, predation by wolves, and stampedes to which numerous animals were lost. As with fox trapping, reindeer herding ultimately ended with the collapse of the market for meat and hides in the early 1930s.

Until the late 1930s, the Gwich’in occasionally traveled to Barter Island to trade with the Iñupiat. The Gwich’in were known for trading babiche (moose or caribou hide cut into strips), wolverine skins, and spruce tree pitch with the Barter Island Iñupiat for seal oil, seal skins, tea, rifles, and ammunition. The first rifles acquired by the Nets'aii Gwich'in reportedly came from Iñupiat traders who had acquired them from whalers.

4.4.1.3 Contemporary Villages and Communities

The Iñupiat and Athabascan people of the region have used the lands and resources of the Refuge for many centuries. Although social, cultural, and economic changes have been occurring throughout this period, recent decades have brought an ever accelerating pace of change. Currently, only the Iñupiat community of Kaktovik located on Barter Island along the shore of the Beaufort Sea is located within the boundaries of Arctic Refuge. The Gwich'in Athabascan villages located on the south side of the Brooks Range near the Refuge include Arctic Village, Chalkyitsik, Fort Yukon, and Venetie (Map 4-1). These villages share similar languages, heritages, and traditonal homelands, which encompass large portions of the Refuge. To the west of the Refuge, along the Dalton Highway corridor, are the communities of Wiseman and Coldfoot. Coldfoot is predominantly a non-Native conmmunity, and Wiseman has a small percentage of Alaska Natives. Arctic Village and Kaktovik are the villages that are the most heavily dependent on the Refuge for subsistence use because of their immediate proximity to the Refuge. Residents of Chalkyitsik, Fort Yukon, and Venetie also use Refuge lands to lesser extents (K. Whitten, ADFG, pers. comm.). More information on contemporary subsistence use is found in sections 4.4.3.8 through 4.4.4.3. In addition, several families living outside the villages depend heavily on the natural resources for subsistence.

4.4.1.4 Cabins

Currently the Refuge has 15 cabins under permit, and 3 cabins for which a permit has expired and the permit holders have not requested renewal. All the cabins were all permitted for trapping activities. While cabins determined to be abandoned or in trespass may be disposed of in accordance with regulations at 50 CFR 36.33(b)(2), the Refuge does not plan to remove existing cabins not under permit unless their use causes safety, liability, or other substantial problems. In that case, the Refuge will follow the appropriate NEPA process, and if the cabin is in designated Wilderness, congressional notification will be provided.

4.4.2 Transportation and Access

4.4.2.1 Aircraft Access to Communities

Primary year-round access to the local communities and the Refuge is by aircraft. Each of the villages in or near the Refuge has an airport. All airports are State-owned, except for those in Arctic Village and Venetie, which are owned by the Venetie Tribal Government. The community runways range from 2,000 feet long at Wiseman to 5,810 feet long at Fort Yukon; all are gravel surfaced, and few have runway lights. Frequency of air service varies, but several communities have regularly scheduled air service, and commercial air operator services are also available.

4.4.2.2 Roads

There are no roads on Arctic Refuge lands. The nearest highway is the James Dalton Highway (also known as the Haul Road). It provides access to the North Slope for transport of materials, equipment, supplies, and visitors. The highway was opened to public use as far as Deadhorse in 1994, and has since experienced steady increases in visitor use. The highway serves as a major access corridor to Refuge lands and drainages. The Refuge boundary is approximately three quarters of a mile away from the highway at Atigun Gorge, a popular access location to the Refuge. Adjacent drainages are also easily accessible from the road. The Dalton Highway Corridor Management Area was established in 1980 and amended in 1985. The Management Corridor encompasses an area five miles east and west of the Dalton Highway. Alaska Statute prohibits the use of off-road-vehicles within five miles of the highway right-of-way in this area. The highway is maintained by the State of Alaska Department of Transportation and Public Facilities.

4.4.2.3 Easements and Rights-of-Way

ANCSA Section 17(b) Easements

Section 17(b) of the ANILCA of 1971 authorizes the Secretary of the Interior to reserve easements on lands conveyed to Native corporations to guarantee access to public lands and waters. Easements across Native lands include linear easements (e.g., roads and trails) and site easements. Site easements are reserved for use as temporary campsites and to change modes of transportation The map depicting ANCSA 17(b) Trail and Site Easements and State claimed Revised Statute 2477 Routes is located in Appendix E-2 on page E-5.

The Service is responsible for administering those public easements inside and outside Refuge boundaries that provide access to Refuge lands. Service authority for administering 17(b) easements is restricted to the lands in the easement and to the purpose of the easement. The size, route, and general location of 17(b) easements are identified on maps filed with conveyance documents. Conveyance documents also specify the terms and conditions of use, including the acceptable periods and methods of public access. Hunting and fishing are not prohibited uses of 17(b) easements. Currently, there are nine campsites, two landing areas, one streamside, and 11 trail easements established to access Arctic Refuge. If necessary to protect access to public lands and waters, additional easements may be reserved whenever lands are conveyed to Native corporations.

Revised Statute 2477 Right-of-Way Claims

The State of Alaska identifies numerous claims to roads, trails, and paths across Federal lands under Revised Statute 2477 (RS 2477), a section of the Mining Act of 1866 that states "The rights-of-way for construction of highways over public lands, not reserved for public uses, is hereby granted." RS 2477 was repealed by Section 706 (a) of the Federal Land Policy and Management Act of 1976, subject to valid existing rights.

Assertion and identification of RS 2477 rights-of way neither establishes the validity of these claims nor the public's right to use them. The validity of all RS 2477 rights-of-way may be determined either via demonstration that these rights were perfected prior to the enactment of the Federal Land Policy and Management Act of 1976 or through appropriate judicial proceedings. In Alaska Statute 19.30.400, the State of Alaska has identified the following six route(s) on Arctic Refuge it claims may be asserted as RS 2477 rights-of-ways (see Table 4-9 and Appendix E).

Table 4-9. Asserted RS 2477 Rights-of-Way

Trail Number	Name
476	Circle-Chalkytsik Yukon Border
560	Rampart House-Demarcation Point
1648	Gordon-U.S. Border (coastal)
1649	Simpson Cove-Tamayariak
466	Nation River-Rampart House Trail
85	Christian-Arctic Village Trail

ANILCA Title XI, Sections 1110(a) and (b) Access Requirements

Under Sections 1110(a) and 1110(b) of ANILCA, the Service must provide certain types of access across Refuge lands, subject to reasonable regulations. Section 1110(a) requires that the Refuge permit transportation access across Refuge lands for traditional activities and for travel to and from villages and home sites. Under Section 1110(b), when the State or a private party owns surface or subsurface land interests that are effectively surrounded by Refuge lands, the Service must provide "adequate and feasible access for economic and other purposes" to the property but subject to reasonable regulations to protect the natural and other values of the lands.

4.4.2.4 Airplane Access

The primary means of access into and out of the Refuge by non-local visitors is by aircraft, which can only land where topography and surface conditions or lake size are appropriate. Light aircraft equipped with either wheels, skis, or floats are used, depending upon the season. During summer months, wheel planes can land on some river gravel bars, beaches along the Beaufort Sea coast, and other flat areas to access more remote regions of the Refuge. Floatplanes can access some of the larger lakes, such as the Lake Peters and Lake Schrader area in the Brooks Range; however, they are more commonly used on the South Slope lakes than the North Slope region of the Refuge.

4.4.2.5 Snowmobile Access

ANILCA allows the public use of snowmobiles to access the Refuge during periods of adequate snow cover. Snowmobiles (locally referred to as snowmachines) are a common mode of transportation in and around the communities near the Refuge. They are also commonly used for travel between communities, for checking traplines, hunting, gathering firewood, and for other subsistence activities. The frozen river systems of the Refuge and the Beaufort Sea provide travel routes between villages during the winter months. Today, most winter travel is accomplished with snowmobiles, although dog sleds were more common in the past. A few individuals in communities near the Refuge still maintain and use dog teams. Today many dog teams are used for racing rather than subsistence hunting or trapping.

It is difficult to access the Refuge from the Dalton Highway by snowmobile because (with some exceptions) motorized vehicles are prohibited within five miles of the highway by Alaska Statute 5 AAC 92.530.7. Those exceptions include access to private property or mining claims, access to areas for research, or transiting from one side of the corridor to the other. This ban extends from the Yukon River Bridge to just south of Prudhoe Bay.

4.4.2.6 Subsistence Access

ANILCA Title VIII, Section 811

Title VIII Section 811 of ANILCA specifies that rural residents engaged in subsistence uses will have reasonable access to subsistence resources on public lands. Section 811 requires the Refuge permit the use of “snowmobiles, motorboats, dog teams, and other means of surface transportation traditionally employed for such purposes by local residents, subject to reasonable regulation.” The Refuge manager can restrict the use of certain types of transportation on Refuge lands under the procedures set forth in 50 CFR 36.12.

Other Access

ANILCA Title XI Section 1110(a) addresses access for traditional activities and for travel to and from villages and home sites (see ANILCA Title XI in Section 4.4.2.3). While not specific to subsistence, Section 1110(a) is applicable to some subsistence users. Snowmobiles, motor boats, and foot travel provide primary means of access to traditional subsistence camps and harvest areas. Small aircraft are occasionally used to access remote or distant traditional camps, allotments, or harvest areas. Local rivers and coastal waters are major travel ways for subsistence users during ice-free months and in the winter. Residents also travel overland by snowmobile during the winter.

Lands conveyed to KIC; Doyon, Limited; North Slope Regional Corporation; and Native allotments in the Refuge are private lands, and access is generally limited to the corporation shareholders and their descendants, or the allotment family and friends. Subsistence hunting and fishing on these private lands is subject to Alaska State hunting regulations.

4.4.2.7 Off-Road Vehicle Access

General use of off-road vehicles is prohibited by Federal regulation (43 CFR 36.11) on national wildlife refuges in Alaska except on established roads, parking areas, and routes designated by the agency. Off-road vehicles, as defined in 50 CFR 36.2, include air boats and air-cushion vehicles along with motorized wheeled vehicles. No routes or areas have been designated for off-road vehicles in the Refuge.

Title VIII Section 811(b) of ANILCA and Alaska national wildlife refuge regulations in 50 CFR 36.12 allow the "use of snowmobiles, motorboats, dog teams and other means of surface transportation traditionally employed by local rural residents engaged in subsistence uses." Off-road vehicles as defined in 50 CFR 36.2 have not been determined to be a traditional means of subsistence access for Arctic Refuge. However, in Chapter 2, Objective 4.6, we propose a historical access study to help identify what are the traditional means of access to what are now Refuge lands and waters.

Alaska Statute 19.40.210 prohibits the use of off-road vehicles (including snowmobiles) for any purpose within five miles of the right-of-way of the Dalton Highway north of the Yukon River if the use begins or ends in the 10-mile-wide corridor. The Dalton Highway runs within about 1,000 ft (300 m) west of Arctic Refuge at its closest point. This statute precludes off-road vehicles from accessing the Refuge from the Dalton Highway at present, though there have been recent attempts to remove the prohibition. If the prohibition is lifted, off-road vehicle use in the corridor could increase substantially, potentially resulting in illegal off-road vehicle use on the Refuge.

4.4.2.8 Boat Access

Boats are used for fishing, sightseeing, hunting, and travel between villages. Motor boat use by visitors occurs primarily for fishing and hunting on the south side of the Refuge in the Porcupine River drainage. However, a few motorboats are used for polar bear viewing along the Arctic coast near Barter Island and on rivers accessible from the Dalton Highway. Non-motorized inflatable boats and kayaks, which can traverse the shallow and rocky stretches, are used mainly by non-local visitors. Rafts are the most common means of travel for river floaters, although kayaks and canoes are sometimes used.

Motorized boats are an important means of travel for local residents conducting subsistence activities and for travel between villages. Residents from villages south of the Brooks Range predominantly use boats to reach the Refuge. Summer season access is available from late May to early October via East Fork of the Chandalar and Porcupine rivers and their larger tributaries to the south. Boats are also used along the Beaufort Sea coast for subsistence hunting, fishing, and gathering. Heavy and bulky goods are delivered by barge to Fort Yukon via the Yukon River and its tributaries, and by barge to Kaktovik via the Beaufort Sea.

4.4.3 Description of the Socioeconomic Environment

The geographic area considered for describing socioeconomic effects generally consists of the communities in and near the Refuge. Socioeconomic effects outside of this area are expected to be minimal because of the area's geographic isolation. Local residents in and near the Refuge principally reside in seven communities: Arctic Village, Chalkyitsik, Coldfoot, Fort Yukon, Kaktovik, Venetie, and Wiseman. All the affected communities except Kaktovik are located in the Yukon-Koyukuk census Area, which encompasses a large area of 148,258 mi^2 (38,398 km^2) between the Yukon Territories, Canada, and the lower Yukon River in Alaska. Kaktovik, which sits on the northern border of the Refuge, is the only community to belong to a different census area, the North Slope Borough.

The six communities in the Yukon-Koyukuk census area are not incorporated in an organized borough, and the State of Alaska legislature has oversight of education, planning, and zoning in this unincorporated region. Cities and tribal organizations typically provide community services while the State provides education through Regional Educational Attendance Areas. Fort Yukon is the only one of these communities that has a sales tax (three percent).

Refuge lands currently are used most heavily by Kaktovik and Arctic Village residents; residents of Fort Yukon, Venetie, and Chalkyitsik use Refuge lands to a lesser extent (K. Whitten, ADFG, pers. comm.). Kaktovik, an Iñupiat community, is located on Barter Island onthe shore of the Beaufort Sea. The communities of Arctic Village, Chalkyitsik, Fort Yukon, and Venetie are all Athabascan villages located on the south side of the Brooks Range. The communities of Coldfoot and Wiseman, located along the Dalton Highway east of the Refuge, are primarily non-Native communities. The following community summaries are taken in large part from the State of Alaska Department of Commerce, Community, and Economic Development's Community Database Online[3].

Arctic Village

This village is located on the east bank of the East Fork of the Chandalar River, six mi (10 km) southwest of the junction of the Junjik River in the Brooks Range. It is adjacent to the southern Refuge boundary and is approximately 100 air mi (160 km) north of Fort Yukon and 290 mi north of Fairbanks. Arctic Village has always been a traditional community of Neets'aii Gwich'in Athabascans. Living a highly nomadic life, they traditionally used seasonal camps

[3] Alaska Community Database Community Information Studies, Department of Commerce, Community, and Economic Development, State of Alaska. Accessed on February 23, 2012, at http://www.commerce.state.ak.us/dca/commdb/CF_CIS.htm

and semi-permanent settlements such as Arctic Village, Venetie, Christian, and Sheenjek in pursuit of fish and game.

In the early 1900s, family groups began to gather more permanently at several locations with the first permanent residents settling at the present Arctic Village site in 1909. In 1943, the Venetie Indian Reservation was established due to the combined efforts of residents of Venetie, Arctic Village, Christian Village. and Robert's fish camp to protect their land for subsistence. When ANCSA was passed in 1971, Venetie and Arctic Village opted to take title to the 1.8 million acres of land in the former reservation. Representatives from Arctic Village and Venetie serve as members of the Native Village of Venetie Tribal Government.

The community is not located on the road system and access to Arctic Village is by aircraft. The Venetie Tribal Government owns and operates the 4,500-foot-long by 75-foot-wide gravel landing area approximately one mile south of the village. Like most rural Alaska village landing areas, there are no Federal Aviation Administration approved instrument approach procedures or facilities, and air service is occasionally interrupted by adverse weather conditions. Local transportation is by all-terrain vehicles, snowmobiles, motor boats, dog teams, and by walking.

The washeteria and school are the only facilities with running water. The village provides water to the school, which uses 17,000-gallon and 7,000-gallon holding tanks. When these tanks run dry, their primary source of water is the Chandalar River. None of the homes are plumbed, and other offices such as the health clinic and Village Council haul their own water. Outhouses or honey buckets are used by most residents. A number of housing upgrades have been made in recent years, and feasibility studies are underway to examine alternatives for a safer water source, washeteria improvement, and relocation of the landfill south of the landing area. The village uses a small solar-powered system to provide some of their electricity, and the remainder is provided via a new generator complex.

Chalkyitsik

The community of Chalkyitsik is located on the Black River approximately 21 miles from the southern Refuge boundary; it is 45 mi (70 km) northeast of Fort Yukon and 170 air mi (270 km) from Fairbanks. The community's location near the interface of the Yukon Flats and upland areas to the east allows access to a variety of wild plant and animal resources. Traditionally, Chalkyitsik was a Dr'aanjik Gwich'in (Black River) village, though today it is a mix of Gwich'in people from the Black River, Yukon Flats, Chandalar, and Porcupine River areas (Nelson 1973).

Access to Chalkyitsik is primarily by aircraft through use of a State-owned 4,000-foot-long by 90-foot-wide gravel runway. The Alaska Department of Transportation and Public Facilities anticipate that an airport improvement project will take place in the near future under the Aviation Improvement Program (Alaska Department of Transportation and Public Facilities 2010). The village is also accessible by small river boat. Chalkyitsik received cargo by barge at one time, but the service is no longer provided.

Residents use all-terrain vehicles, snowmachines, motor boats, dog teams, and foot travel for fishing, hunting, gathering, and recreation. No roads connect Chalkyitsik with other villages, although there is a winter trail to Fort Yukon.

Water is drawn from a well under the Black River, and it is treated, and stored in a 100,000-gallon tank. Residents haul water from the new water treatment plant/washeteria/clinic building and use honey buckets or outhouses for sewage disposal. No homes are plumbed. The village provides water to the school. A feasibility study was completed to provide piped water and a sewer system to the school and 10 homes on the west side, and a landfill relocation study is under way (Alaska Department of Commerce, Community and Economic Development, Alaska Community Database).

Coldfoot

The orginal settlement of Coldfoot, intially called Slate Creek, was located along the middle fork of the Koyukuk River near Slate Creek approximately 69 miles from the Refuge boundary. The settlement began around 1898 when thousands of prospecting miners flooded to the area in search of gold. The name was changed when a group of prospectors got "cold feet" about wintering in the district and headed south. At its height, Coldfoot had one gambling hall, two roadhouses, seven saloons, a number of brothels, and a post office. Mail was delivered once a month arriving from Fort Yukon in the winter by dogsled and in the summer arriving by foot. By 1912, the miners relocated to the richer ground in what is now known as Wiseman, 13 miles north. Many of Coldfoot's original buildings were brought to Wiseman as construction material or used for firewood.

In the early 1970s, during the construction of the Trans-Alaska Pipeline, Coldfoot started coming back to life when a bustling pipeline camp was established not far from the original town site. Truckers found that Coldfoot was a convenient halfway place to stop along the haul road between Deadhorse to the north and Fairbanks to the south. The haul road, now known as the Dalton Highway, was opened to public travel in 1994 and has since experienced steady increases in road travelers. Electricity is provided by individual generators, and residents use household wells and septic tanks. There are no schools or health clinics in the community. Volunteers provide emergency services using highway and air access.

Most employment is in government and services to road travelers. There is a restaurant, a gas and service station, a recreational vehicle park and dump station, a motel, a State trooper and State fish and wildlife office, a BLM field office, and an Arctic Interagency Visitor Center. The State-owned gravel airport is 4,000-feet-long by 100-feet-wide, providing scheduled commercial and private aircraft access. A local commercial air operator provides charter air services to the surrounding area based from the airport.

Fort Yukon

Fort Yukon is located at the confluence of the Yukon and Porcupine rivers, approximately 63 miles from the southern Refuge boundary, and about 140 air mi (225 km) northeast of Fairbanks and is the largest village of the Kutchin or Gwich'in Athabascan people. The community has historically served as a meeting place for the Gwich'in Athabascan and neighboring peoples. Its location on the Yukon River makes it an important transportation center, as well as an important area for harvesting fish resources.

In 1847, Alexander Murray established Fort Yukon as a Canadian outpost in Russian territory. The Hudson's Bay Company, a British trading company, operated at Fort Yukon from 1846 until 1869. The fur trade of the 1800s, the Klondike gold rush, and the establishment of the fort and trading post spurred economic activity, providing some opportunities for Native and non-Native residents in the region. A White Alice radar site and an Air Force station were established during the 1950s. More recently, Fort Yukon continues to serve as an important trading, supply, transportation, and administration center for the region.

Fort Yukon is not connected to the road system, however the community is accessible year-round by air and boat during the summer months. Heavy cargo is brought in by barge from the end of May through mid-September to a river off-loading area. Residents use riverboats and skiffs for recreation, hunting, fishing, and other subsistence activities. The State owns a 5,810-foot-long by 150-foot-wide lighted gravel landing area that is currently undergoing major improvements. Floatplanes use Hospital Lake, which is adjacent to the airport and the Yukon River for access. The community has about 17 miles of local roads and a city transit bus system, providing transport throughout the town. Snowmobiles and dog sleds are used on area trails or the frozen river during winter.

Water is drawn from two wells and is treated and stored in an 110,000-gallon tank. Approximately half of all homes are plumbed and are served by a combination of piped water, water delivery, and individual household wells. Residents use a flush/haul system, septic tanks, honey buckets, and outhouses for sewage disposal. The piped water system and household septic tanks were installed in 1984. The city has received funds to begin repairs to the piped water system and to construct a piped gravity sewer system to serve 250 residents and businesses.

Kaktovik

Kaktovik is an Iñupiat community located on Barter Island on the shore of the Beaufort Sea. Until the late 19th century, Barter Island was a major trade center for the Iñupiat and was especially important as a bartering place for Iñupiat from northeastern Alaska and Inuit from Canada. In 1923, a trading post was established on the island that provided a location for resident trappers to trade furs and obtain supplies.

Reindeer were introduced to the area in the 1920s, which—along with fur trade—provided more sustained economic activity. After World War II, the military selected Barter Island as

the location for the first Distant Early Warning Line System. The availability of military-related jobs and the opening of a school attracted more people to settle permanently in Kaktovik in the 1950s. The City of Kaktovik was incorporated as a second class city in 1971.

Economic opportunities in Kaktovik are limited, by standards of the contiguous United States because of the community's isolation (the Distant Early Warning Line System is now mostly automated, and the Kaktovik station usually only has two civilian contractors in residence), but compared to other communities in the region, a variety of economic opportunities exist in Kaktovik. Most of the private employment is for the provision of services, either for the North Slope Borough or the City of Kaktovik. The majority of jobs are with the local government, which includes the local school district. Part-time seasonal jobs, such as construction projects, also provide some employment for local residents. KIC employs a number of individuals and is involved in local business. Tourism has begun to develop on a small scale as a result of Kaktovik's proximity to the Refuge and increasing interest in viewing polar bears, observing traditonal whale harvest activities, and participating in other recreational opportunities.

Air travel to Kaktovik provides the only year-round access. The 4,800-foot Barter Island Airport is owned by the U.S. Air Force and operated by the North Slope Borough. The Air Force plans to transfer this landing area to the borough or Kaktovik in the near future, and the State of Alaska is planning to construct a new air strip in a more suitable location (the current air strip is low gravel spit and subject to fog and flooding). An environmental impact assessment was completed for this project in January 2009 (see Appendix C). Marine and land transportation provides seasonal access through barges and small boats in the summer and snowmachines in the winter.

The North Slope Borough provides all utilities in Kaktovik. Water is derived from a surface source and is treated and stored in a 680,000-gallon water tank. A newly constructed piped water and sewer system provides flush toilets, showers, and plumbing for most residences. The borough provides electricity and subsidizes diesel fuel for the community. The Harold Kaveolook School (pre-school through grade 12, and adult education) is an important focus of the community. Health care is provided by health aides, visiting physicians, and other specialists at the Tom Gordon Health Clinic. Emergency services, including a fire station housing an ambulance, a fire engine, and a water tender, are provided by volunteers and borough professionals.

Venetie

Venetie is located on the Chandalar River approximately 22 miles from the southern boundary of the Refuge and is about 45 mi (70 km) northwest of Fort Yukon and 140 air mi (225 km) north of Fairbanks. It is an original Neets'aii Gwich'in village, founded in 1895 by a man named Old Robert who chose Venetie because of its plentiful fish and game.

In 1899, the U.S. Geological Survey noted about 50 Natives living along the Chandalar River, some in small settlements of cabins about seven miles above the mouth of the River, but most in the mountainous part of the country beyond the Yukon Flats. By 1905, Venetie was a settlement of a about six cabins and 25 or 30 residents. The gold rush to the Chandalar region in 1906–1907 brought a large number of miners. A mining camp of nearly 40 cabins and a store was established at Caro, upriver from Venetie, and another store was located near the mouth of the East Fork. By 1910, the Chandalar was largely played out and Caro almost completely abandoned.

In 1943, the Venetie Indian Reservation was established, due to the combined efforts of the residents of Venetie, Arctic Village, Christian Village, and Robert's Fish Camp, who worked together to protect their land for subsistence use. At about this same time, a school was established at Venetie, encouraging additional families to settle in the village. Eventually, a landing area, post office, and store were built, and the use of seasonal camps declined during the 1950s and 60s. The Reservation was revoked by ANCSA. Under Section 19(b) of ANCSA, Venetie and their cultural neighbors in Arctic Village chose to not participate in ANCSA and instead took the lands of the former Venetie Indian Reservation in fee.

Access to Venetie is almost exclusively by air. The Native Village of Venetie Tribal Government owns and operates the 4,100-foot-long by 65-foot-wide gravel landing area. The Chandalar River provides access by boat from May to October, but there is no barge service due to shallow water. Motor bikes, four-wheelers, trucks, snowmobiles, and dog teams are used for local travel.

Water is drawn from a well near the Chandalar River and then treated and stored in a tank. Residents haul water and use honey buckets. A circulating water utilidor system and 49 household service connections were constructed in 1980, but the east loop froze in 1981 and the west loop in 1982. Twenty-nine individual household septic tanks installed in 1980 also froze during their first winter of operation. Currently, only eight homes have functioning plumbing. A flush/haul system is under construction in Venetie; four homes are currently served. The Stanley Frank Washeteria and Water Treatment Plant use a small solar-powered system to provide some electricity.

Wiseman

Wiseman is located on the middle fork of the Koyukuk River at the junction of Wiseman Creek in the Brooks Range; it is approximately 56 miles from the Refuge boundary. It lies 13 miles north of Coldfoot on the Dalton Highway, about 260 miles northwest of Fairbanks. Prior to white settlement, the Wiseman area was inhabited by the Dihai Kutchin and was in a region of contact between Nunamiut, Kobuk, and Selawik Eskimos to the north and west, and Koyukon Indians to the south.

Wiseman was established in 1907 to accommodate the needs of the growing number of gold miners and prospectors drawn to the placer rich creeks of this Koyukuk valley. Primarily a trading community, Wiseman once supported a population of about 250 residents and maintained a post office, general store, roadhouse, Pioneer Hall, telegraph office, and school. This is one of the few communities founded by non-Natives north of the Yukon River and is the furthest north “gold rush” settlement in the Brooks Range still in existence today.

Supplies were brought up the Koyukuk River to Wiseman Creek by horse-drawn barge, where a new town developed in 1907. A log post office operated from about 1909 to 1956, with mail and supplies freighted or flown in. A territorial school operated from 1934 to 1941. By 1974, the 414-mile pipeline "haul road" was constructed, which passes near Wiseman.

The school, operated in the Community Center, was closed in November 2002 because it was unable to meet the State's minimum enrollment. There are 30 original cabins from the 1920s still in use; 70 percent are used seasonally. Wiseman is situated between Arctic Refuge to the east and the Gates of the Arctic National Park and Preserve to the west. Subsistence hunting, fishing, and trapping sustain year-round residents.

Self-employment, seasonal visitor service jobs, seasonal highway maintenance jobs, and seasonal work at the Arctic Interagency Visitor Center in nearby Coldfoot or with the NPS provide some employment opportunities for Wiseman residents. Several residents sell handcrafted items and furs. A State-owned 2,000-foot-long by 30-foot-wide gravel landing area is available but is not consistently maintained.

4.4.3.1 Population

In 2010, the largest community in Arctic Refuge's Yukon-Koyukuk census area was Fort Yukon, with a reported total population of 583 persons. Kaktovik had the second highest population of 239 persons. With the exception of Coldfoot and Wiseman, which have seasonal populations, Chalkyitsik had the smallest population (69) in 2010 of all seven communties.

Since 1970, all communities, with the exception of Chalkyitsik, have experienced population growth. Kaktovik's population growth led the group, increasing by 94.3 percent over the 40 year period. Only Chalkyitsik had a population decline. Since 1970, Chalkyitsik's population has decreased by 47 percent. The decline in population is consistent with the overall Yukon-Koyukuk Census area's decline in population of nearly 21 percent.

Table 4-10 shows the population estimates for all seven communities from 1970 through 2010, along with the census areas and the State. These trends are also illustrated in Figure 4-10. Compared to the State's population increase of 135 percent between 1970 and 2010, the North Slope Borough also experienced a notable increase in population. Its population increased by 173 percent. A portion of this increase is likely due to the development and expansion of the oil industry's operations in the area. The table also shows that since the 2000 Census, every community experienced a decline in population over the last decade. Figure 4-10 illustrates the trend in population for the communities.

Table 4-10. Population by selected region

Region / Community	1970	1980	1990	2000	2010	Percent Change 1970–2010
Arctic Village	85	111	96	152	152	78.82
Chalkyitsik	130	100	90	83	69	-46.92
Coldfoot	-	-	-	13	10	nc
Fort Yukon	448	619	580	595	583	30.13
Kaktovik	123	165	224	293	239	94.31
Wiseman	-	8	33	21	14	nc
Venetie	112	132	182	202	166	48.21
Yukon-Koyukuk Census Area	7,064	7,873	6,713	6,551	5,588	-20.89
North Slope Borough	3,451	4,199	6,043	7,385	9,430	173.25
State of Alaska	302,583	401,851	550,043	626,932	710,231	134.72

"nc" indicates no change; - (a dash) indicates no data available

Sources:

1. Alaska Census Data, Alaska Department of Labor and Workforce Development. Available at http://labor.alaska.gov/research/census. Retrieved on 2/13/2012.

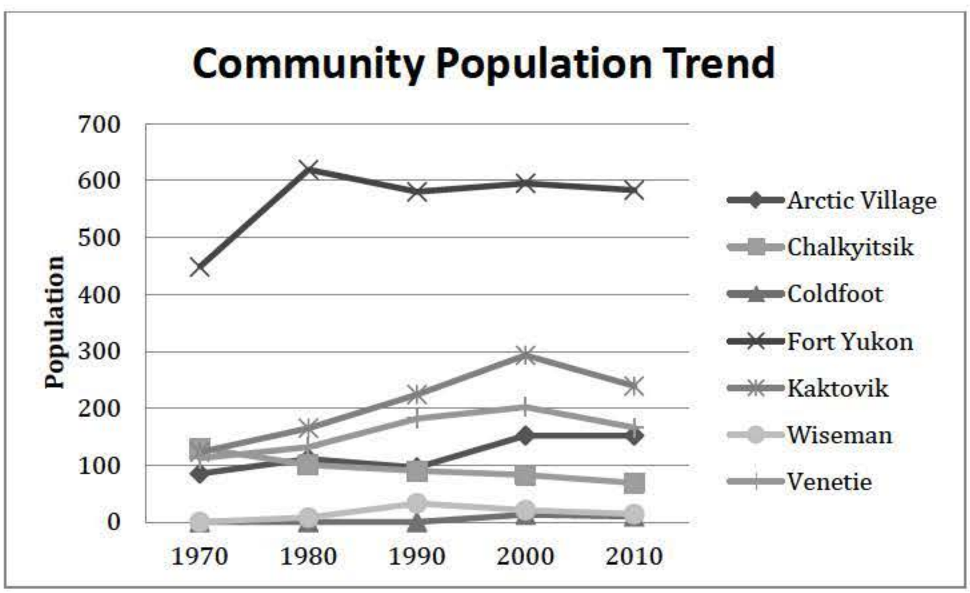


Figure 4-10. Population trends for communities nearest to Arctic Refuge.

4.4.3.2 Population Projections

Figure 4-11 shows the forecasted change in total population for the Yukon-Koyukuk census area and the North Slope Borough, respectively. The figure shows that over the next 25 years, the total population of the North Slope Borough is expected to grow 30 percent, from 6,807 individuals in 2006 to 8,867 in 2030. By contrast, the population for the Yukon-Koyukuk census area is forecast to decline by 13 percent, from 5,860 total individuals in 2006 to 5,111 individuals by the end of 2030. Both populations, however, are projected to remain very small (i.e., less than one percent) of the entire population of Alaska.

Table 4-11 shows the underlying dynamics for the projected changes in population. Both regions are forecast to experience a net loss in future years due to emigration out of the area. The forecasted growth in the North Slope Borough's population, however seems to be attributable to a much higher number of expected births. The number of births in the North Slope Borough far exceeds the number of individuals forecasted to leave the area, while the number of births in the Yukon-Koyukuk census area is only slightly greater than the number of emigrants.

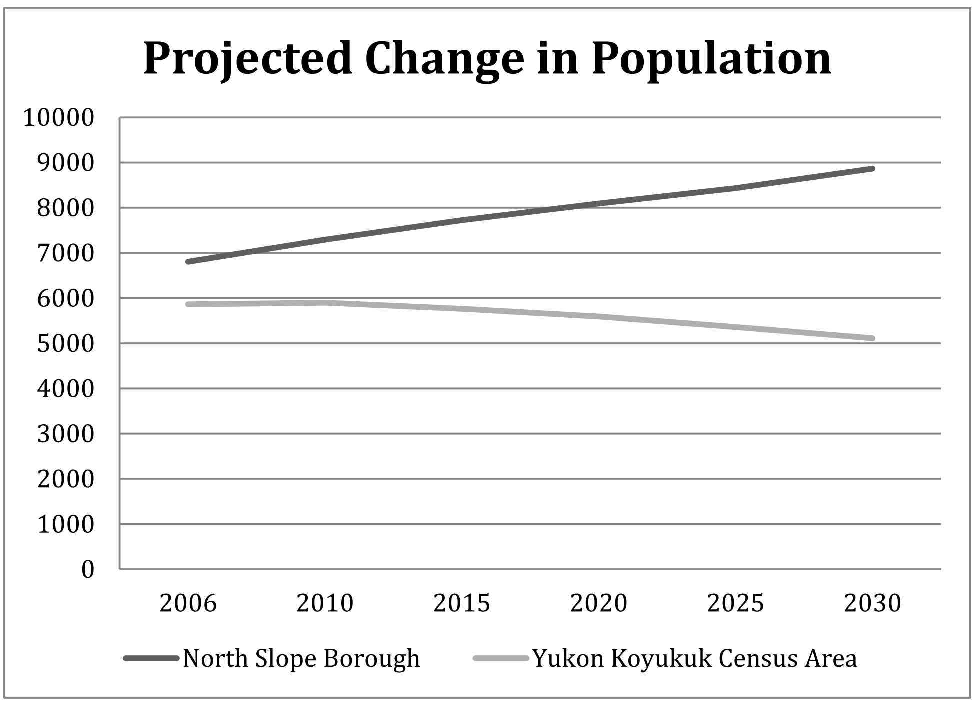


Figure 4-11. Projected change in population. Source: Alaska Department of Labor and Workforce Development 2007.

Table 4-11. Projected births, deaths, and net migration 2006-2030. North Slope Borough and Yukon-Koyukuk census area.

Census Area	2006–2010	2010–2015	2015–2020	2020–2025	2025–2030
	Average Annual Births				
North Slope Borough	159	183	189	187	196
Yukon-Koyukuk Census Area	81	99	101	92	78
	Average Annual Deaths				
North Slope Borough	44	43	47	50	55
Yukon-Koyukuk Census Area	50	49	50	52	53
	Average Annual Net Migration				
North Slope Borough	6	-54	-68	-69	-55
Yukon-Koyukuk Census Area	-21	-77	-85	-87	-75

Source: Alaska Department of Labor and Workforce Statistics 2007

4.4.3.3 Demographics

Table 4-12 provides a general overview of the demographic composition of the communities. Most communities, with the exception of the very small Dalton Highway communities of Coldfoot and Wiseman, have a very high proportion of Alaska Natives relative to the percentages in the State. The proportion of residents that are Alaska Native range from a low of 85.5 percent in Chalkyitsik to a high of 91.6 percent in Venetie. The median age for the State of Alaska is 33.8 years, which is higher than that for all communities with the exception of Coldfoot. Of this group, the median ages for Arctic Village, Chalkyitsik, and Wiseman are all less than 30 years.

Table 4-12 also shows the percentage of residents that are under 18 years, between 18 and 64 years of age, and 65 years and older. While the State average for working age adults (18-64 years) is 65.9 percent of the total population, only Coldfoot has a population percentage greater than the State average in this range (70.0 percent). Conversely, the communities all have a higher percentage of residents under 18 years of age than the State average, with the exception of Coldfoot. Arctic Village and Venetie have a higher percentage of adults over the age of 65 than the State average. The communities of Arctic Village, Coldfoot, Fort Yukon, Kaktovik, and Venetie all have a higher percentage of males living in their communities than the State average of 52.0 percent.

Table 4-12. Socioeconomic characteristics of communities nearest to Arctic Refuge

Region/Community	Median Age	Under 18	18-64	65 and Over	Male	Alaska Native
Arctic Village	29.0	28.3%	64.5%	7.2%	56.6%	88.8%
Chalkyitsik	27.5	34.8%	55.1%	10.1%	50.7%	85.5%
Coldfoot	43.0	20.0%	70.0%	10.0%	60.0%	10.0%
Fort Yukon	33.7	28.6%	63.3%	8.1%	55.7%	89.2%
Kaktovik	30.5	30.1%	61.9%	7.9%	52.3%	88.7%
Wiseman	28.5	28.6%	64.3%	7.1%	50.0%	0.0%
Venetie	30.5	31.9%	61.4%	6.6%	60.2%	91.6%
North Slope Borough	35.1	23.9%	71.9%	4.3%	62.6%	54.1%
Yukon-Koyukuk Census Area	35.3	27.8%	62.0%	10.2%	54.2%	71.4%
Alaska	33.8	26.4%	65.9%	7.7%	52.0%	14.8%

Source: Alaska Department of Labor and Workforce Development 2010

4.4.3.4 Households and Housing

Similar to the population profiles, household numbers are greatest in Fort Yukon (246) and least in Coldfoot (6) and Wiseman (5). The U.S. Census defines a household as all of the people who share a housing unit. According to the Census, a household could consist of a single person. Groups of people sharing a housing unit, even if they are unrelated, would be counted as a single household. In contrast a family is a group of two people or more (one of whom is the householder) related by birth, marriage, or adoption and residing together. The percentage of family households in the communities ranges from a low of 17 percent in Coldfoot to a high of 80 percent in Wiseman. These communities, however, are extremely small. The range for the remainder of the communities is 53 percent family households in Fort Yukon to a high of 72 percent in Kaktovik. The State average is 66 percent. Fort Yukon also has the highest proportion of family households with children headed by a female. Over 40 percent of the family households with children under 18 are headed by a female in this community. This is roughly double the state-wide percentage. Arctic Village also has a very high proportion of family households with children headed by a female (67 percent). Median household incomes ranged from a low of $9,583 in Venetie to a high of $61,250 in Coldfoot. Of the larger communities, Kaktovik reported the second highest median household income ($46,458).

Most of the population of Alaska lives in urban areas with utilities and services. The villages near Arctic Refuge are isolated rural communities. According to the 2000 Census, the housing characteristics for communities nearest to Arctic Refuge are vastly different from those typical of the State[4]. For example, the majority of homes in the State are heated with natural gas that is brought into the home via utility infrastructure. This is not the case for Arctic Refuge communities. The majority of homes in Arctic Village, Chalkyitsik, and Venetie heat with wood. The major heating fuel source for Kaktovik homes is fuel oil, which is also the primary heating fuel source for homes in Fort Yukon. Only Kaktovik shows that some homes heat with utility gas, and only the community of Wiseman heats with bottled gas, which is their primary heating source.

[4] At the time this research was conducted (February 2012), Census 2010 Tables DP-4 were not yet available.

In general, the homes in communities near Arctic Refuge are less densely occupied than those of the State. On average, there are 2.4 residents per household across the State. Only the communities of Arctic Village and Venetie have averages in this vicinity. Kaktovik has more residents per household than the State average at 3.3. The remainder of the communities have far fewer residents per household.

Homes in communities in and near the Refuge are different from the typical Alaska home in several other categories: the vast majority of homes in these communities lack complete plumbing and kitchen facilities; a large number of them lack telephone service; and most were provided through Housing and Urban Development programs.

Table 4-14 provides a summary of select housing characteristics for the communities nearest to Arctic Refuge and for the State.

Table 4-15 provides an overview of select characteristics associated with each community's estimated annual civilian workforce over the five-year period 2006 through 2010. The U.S. Census Bureau defines the labor force to include all people not in the military both employed and not employed, 16 years and over. Of the seven communities, Fort Yukon has the greatest number of people in the workforce (270) followed by Kaktovik (220). Coldfoot, Wiseman, Chalkyitsik, and Arctic Village had the smallest number of individuals in the workforce. Coldfoot and Wiseman are waypoint communities along the Dalton Highway and are a frequent stopping point for travelers. Both communities (Coldfoot and Wiseman) reported no unemployment, which is most likely attributable to the extremely small workforces and populations in these communities.

Median worker earnings were all lower than the State average. Community earnings ranged from a low of $7,045 for a worker in Venetie to a high of $20,000 in Fort Yukon. Both Arctic Village and Venetie appear to have the most struggling economies of all the communities. They have the lowest median household incomes and the highest percentage of their residents living beneath the poverty line. Unemployment in Venetie is nearly 50 percent of the total workforce.

At the time the surveys were taken ten percent of all Alaskan residents lived below the poverty line. All communities and regions in the area of Arctic Refuge reported higher estimated population levels living beneath the poverty level. The percentage of community residents living in poverty ranged from 11.5 percent in Chalkyitsik to 34.9 percent in Arctic Village.

4.4.3.5 Commercial Economy

The economies of the communities in the vicinity of Arctic Refuge are not very diverse. State and local government agencies, including the school districts, provide for nearly 70 percent of the employment. Only the communities of Coldfoot and Wiseman have greater percentages of workers in the private sector than in the public sector. Both of these communities have a very small number of individuals in the labor force compared to the other Refuge communities.

Fort Yukon and Kaktovik have relatively diversified employment bases. Both communities report employment in every major private industrial sector. While both communities report the greatest number of employees working for local governments, other industrial sectors with relatively large number of employees include the trade, transportation, and utilities sector and construction for Fort Yukon and the finance and professional services sector for Kaktovik. The communities of Coldfoot, Fort Yukon, and Kaktovik are unique in that they are the only communities that showed employment in the natural resources sectors of agriculture, forestry, fishing and hunting, and mining.

Table 4-13. Household characteristics of communities nearest to Arctic Refuge

Region/Community	Total Households	Average Household Size	Family Households	Percent Family Households	Family Household with Child under 18	Female Family Head with Child under 18	Median Household Income
Arctic Village	65	2.3	37	57	21	14	$22,500
Chalkyitsik	24	2.9	16	67	9	5	$41,250
Coldfoot	6	1.7	1	17	1	-	$61,250
Fort Yukon	246	2.4	130	53	66	27	$30,500
Kaktovik	72	3.3	52	72	26	5	$46,458
Wiseman	5	2.8	4	80	1	-	$23,750
Venetie	61	2.7	41	67	19	6	$ 9,583
North Slope Borough	2,029	3.3	1,443	71	803	222	$33,712
Yukon-Koyukuk Census Area	2,217	2.5	1,318	59	642	229	$68,517
Alaska	258,058	2.7	170,750	66	85,121	17,577	$32,384

Source: Alaska Department of Labor and Workforce Development 2010

- (a dash) indicates no data available

Table 4-14. Housing characteristics of communities nearest to Arctic Refuge compared to the State of Alaska

Characteristic	Community							
	Arctic Village[1]	Chalkyitsik[1]	Coldfoot	Fort Yukon[1]	Kaktovik	Venetie	Wiseman	State of Alaska
Total housing units	66	63	13	316	90	80	29	260,978
Average residents per unit	2.3	1.3	1.0	1.9	3.3	2.5	0.7	2.4
Type of heating fuel								
Utility gas	0.0%	0.0%	0.0%	0.0%	2.3%	0.0%	0.0%	45.9%
Bottled, tank, or LP gas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	42.9%	2.2%
Electricity	0.0%	0.0%	0.0%	0.8%	2.3%	0.0%	0.0%	10.2%
Fuel oil, kerosene, etc.	20.8%	34.4%	100.0%	60.8%	95.5%	4.5%	28.6%	35.8%
Coal or coke	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%
Wood	79.2%	65.6%	0.0%	38.4%	0.0%	95.5%	28.6%	3.7%
Solar energy	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lack complete plumbing	89.6%	100.0%	0.0%	54.0%	67.0%	100.0%	71.4%	6.3%
Lack complete kitchen	89.6%	100.0%	50.0%	54.0%	14.8%	93.9%	100.0%	5.6%
No telephone service	16.7%	15.6%	0.0%	24.9%	18.2%	18.2%	42.9%	3.0%

Source: U.S. Census Bureau 2000, Profile of General Demographic Characteristics, Table DP-4 [Note: At the time the Plan was updated (February 2012), Table DP-4 for the 2010 Census were not yet available.]

[1] These communities are in a census designated place (CDP), which is a statistical geographic entity representing a closely settled, unincorporated community that is locally recognized and identified by name.

Table 4-15. Estimated annual workforce characteristics (2006–2010) for communities nearest to Arctic Refuge

Community	Characteristics				
	Median Earnings for Workers ($)	Civilian workforce	Percent of civilians unemployed[1]	Percent older than 16 yrs not in labor force[2]	Percent of all persons below poverty line
Arctic Village	15,625	38	13.7	47.9	34.9
Chalkyitsik	9,432	32	25.5	31.9	11.5
Coldfoot[3]	NA	5	0.0	0.0	0.0
Fort Yukon	20,000	270	14.6	32.0	20.6
Kaktovik	10,040	220	7.4	52.4	13.3
Wiseman[3]	NA	10	0.0	16.7	10.5
Venetie	7,045	91	49.1	14.2	24.1
Yukon-Koyukuk Census Area	15,865	2,739	15.5	35.9	23.6
North Slope Borough	20,592	4,354	15.7	36.2	11.8
State of Alaska	32,389	380,443	9.6	28.0	9.9

Source: U.S. Census Bureau 2010. Data in tables reflect sampling averages; margins of error are not reported.

[1] All civilians 16 years old and over are classified as unemployed if they (1) were neither "at work" nor "with a job but not at work" during the reference week, and (2) were actively looking for work during the last 4 weeks, and (3) were available to accept a job. Also included as unemployed are civilians who did not work at all during the reference week, were waiting to be called back to a job from which they had been laid off, and were available for work except for temporary illness.

[2] The labor force includes all people classified in the civilian labor force, plus members of the U.S. Armed Forces (people on active duty with the U.S. Army, Air Force, Navy, Marine Corps, or Coast Guard). The civilian labor force consists of people classified as employed or unemployed.

[3] The ACS did not sample anyone over 16 years of age (i.e., working age adults). Median Earnings were not reported for Coldfoot. Wiseman earnings reflect CPI adjusted Census 2000 findings. All other data obtained from Census 2000.

Table 4-16 shows the total number of jobs by industry sector for each community along with the percentage of total jobs for all communities combined. In general, community employment is highly dependent on local and state government jobs. The top private sector jobs are in the trade, transportation, and utilities sector and in construction. There are no manufacturing or wholesale trade jobs in any of the communities.

Table 4-17 shows the net change in employment by industry sector for each Arctic Refuge community. Most communities, with the exception of Arctic Village, lost jobs in the natural resources sector. Retail trade jobs increased across the board for the communities, in contrast to the overall State experience. Other sectors with considerable increases included educational, health and social services, and public administration jobs.

Table 4-16. 2010 Employment by industry sector (number of individuals) for communities nearest to Arctic Refuge

2010 Workers by Industry	Arctic Village	Chalkyitsik	Coldfoot	Fort Yukon	Kaktovik	Venetie	Wiseman	Total	Percent of Total
Natural Resources and Mining	-	-	2	2	1	-	3	8	1.1%
Construction	2	1	1	16	1	42	-	63	9.0%
Trade, Transportation, and Utilities	1	-	1	27	4	1	-	34	4.8%
Information	1	-	-	13	-	-	-	14	2.0%
Financial Activities	-	-	-	1	22	-	-	23	3.3%
Professional and Business Services	-	-	-	5	13	-	1	19	2.7%
Educational and Health Services	3	3	-	15	1	5	-	27	3.8%
Leisure and Hospitality	2	5	8	5	4	2	-	26	3.7%
State Government	-	2	1	8	-	-	1	12	1.7%
Local Government	69	26	-	149	96	65	-	405	57.6%
Other	3	2	-	59	-	7	1	72	10.2%
Total	81	39	13	300	142	122	6	703	100.0%

Source: Alaska Department of Labor and Workforce Development 2010

Table 4-17. Number of people changing their type of employment between 1990 and 2000 in communities nearest to Arctic Refuge; numbers in parentheses indicate a decrease in number for that type of employment

Industry	Arctic Village[1]	Chalkyitsik[1]	Coldfoot	Fort Yukon[1]	Kaktovik	Venetie	Wiseman	Alaska (% change)
Agriculture, forestry, fishing, and hunting and mining	2	(2)	-	(8)	(2)	(2)	-	-21.7
Construction	-	-	2	3	(12)	4	-	26.9
Manufacturing	-	-	-	-	-	-	-	-36.7
Wholesale trade	-	-	-	(4)	-	-	-	-2.9
Retail trade	1	2	3	6	10	3	-	-17.6
Transportation and warehousing, and utilities	3	2	-	-	5	2	-	34.3
Information	(3)	2	-	(2)	(5)	-	-	-0.4
Finance, insurance, real estate, and rental and leasing	-	2	-	2	4	-	-	15.6
Professional, scientific, management, administrative, and waste management services	2	-	-	5	3	-	-	110.1
Educational, health, and social services	1	(3)	-	12	23	(7)	5	50.2
Arts, entertainment, recreation, accommodation, and food services	2	-	-	3	6	1	5	684.2
Other services (except public administration)	(2)	5	-	(8)	-	(3)	-	-43.6
Public administration	11	(2)	-	58	6	11	-	-1.0
Total	17	6	5	67	38	9	10	14.7
Percent Change	61	55	nc	39	48	26	nc	

Source: U.S. Census Bureau 2000, Profile of General Demographic Characteristics, Table DP-3. [Note: At the time the Plan was updated (February 2012), Table DP-3 for the 2010 Census were not yet available.]

[1] These communities are in a census designated place (CDP), which is a statistical geographic entity representing a closely settled, unincorporated community that is locally recognized and identified by name.

4.4.3.6 Commercial Recreation Opportunities on the Refuge

Visitors use the Refuge for many recreational activities, including river floating, hiking, backpacking, camping, mountaineering, hunting, fishing, and wildlife observation and photography. There is no direct visitor registration system, thus the Refuge has no specific means by which to monitor the number of visitors, activities, and lengths of stay for individuals entering the Refuge on their own. The Refuge does, however, require commercial service providers to have special use permits to operate on the Refuge. These permits are primarily obtained by commercial guides (recreation and hunting guides) and by air operators who fly visitors onto the Refuge. The remainder of this section discusses the approximate economic benefits to the area resulting from these services. See section 4.4.5 for a comprehensive summary of visitor use of the Refuge.

Guided Hunting on the Refuge

General hunters are attracted to the Refuge to pursue big-game animals, including caribou, Dall's sheep, grizzly bear, and moose. With few exceptions, non-Alaska residents are required by law to hire a guide to hunt sheep, brown bear, and mountain goats (goats don't occur on Arctic Refuge). Non-Alaska resident aliens—people who are not citizens of the United States—must hire a guide to hunt any big-game species (State of Alaska hunting regulations).

There are 16 geographically separate exclusive hunt guide use areas identified for the Refuge (Map 4-11), which are awarded through a competitive permitting process. Several of Arctic Refuge's hunting guide permittees have permits for two guide use areas, resulting in a total of 11 hunting guide service providers on the Refuge. One of the guide use areas, ARC12[5], remains vacant because it surrounds Arctic Village and includes the Arctic Village Sheep Management Area, which is reserved for federally qualified subsistence users from the villages of Arctic Village, Venetie, Kaktovik, and Chalkyitsik for sheep hunting. ARC10a is not open to big-game guiding due to its proximity to the Dalton Highway and the associated high concentration of visitors (hunters and recreationists).

Most guided hunters pursue multiple species during a 9- or 10-day hunt. However, Arctic Refuge data reflect that over the past several fall hunting seasons, an average of 97 animals were harvested by an average of 85 hunters annually (Arctic Refuge 2011). Therefore, although hunters target multiple species on a guided hunt, each hunter harvests one animal on average.

Depending on the unit hunted, the primary target species is usually a Dall's sheep, moose, or grizzly bear. Other hunted species may include caribou, black bear, or wolf. The Refuge receives the highest number of general hunters between August and September. Although the Refuge is open to hunting some species beyond these months, weather and other factors typically restrict general hunting to these times.

The typical price for a 10-day guided Dall's sheep or grizzly bear hunt is around $14,500. That price includes air transportation to and from the Refuge; one client to one guide hunting service; food and shelter during the hunt; equipment use; and field care of game meat and trophies. Additional expenses incurred by the hunter include lodging before and after the hunt, license and tag fees, meat processing, and shipping of meat and trophies. Hunters should

[5] ARC## (e.g., ARC12) are unique identifiers for exclusive commercial hunt guide use areas in Arctic Refuge. ARC stands for "Arctic Refuge" and is not an acronym.

budget an additional $2,500–$3,500 for these expenses, depending on whether they intend to have their taxidermy work conducted in Alaska. Additionally, guides are typically paid a gratuity, which may average about $1,000. Based on these assumptions, the direct economic impact to the State economy per guided hunt would be about $18,500[6].

Based on the average number of guided hunt clients during the fall season (85) and an average hunt cost of $18,500, the direct economic impact to the State would be approximately $1.57 million. These expenditures support additional jobs in the State as the dollars are spent on other goods and services by the recipients (i.e., indirect economic impacts) before the dollars ultimately leave the State for purchases of imported goods and services. Based on previous research conducted by the Service concerning the economic impacts associated with visits to national wildlife refuges, a dollar circulates approximately 0.6 times before leaving the State. Thus, a direct expenditure of $1.57 million would result in a total economic impact to the State of approximately $2.5 million.[7]

Special Use Permit System

Commercial operators who are permitted to work on the Refuge support visitors as air operators or recreation guides. While Refuge visitors are not required to obtain permits to enter the Refuge, commercial operators must obtain special use permits to operate in the Refuge. Table 4-18 summarizes the combined number of permits issued for commercial recreation and air transportation in the Refuge. The total number of permits issued has steadily increased since 1980 (Figure 4-12, Section 4.4.5.3). These permit numbers reflect air operations; recreational guiding (which includes backpacking, base-camping and/or day hiking, river rafting, polar bear viewing, and dog mushing); educational pursuits; and guided sport fishing permits. During the past 10 years, the annual number of permitted air operators has grown from about 10 to 14, and the number of permitted recreational guiding businesses has grown from 16 to as many as 28.

There are no quotas for the number of commercial air operator or recreational guiding permits that may be issued each year. These permits are non-competitive; the businesses simply must complete the application process and agree to abide by the conditions of their permit. Each permit is validated for use in the area specified by the permittee. In other words, permits are not issued by location, and there are no Refuge recreational units. There are no limits to the number of people an air operator may taxi to the Refuge. Similarly, there are no limits to the number of trips a recreational guide may offer; however, recreational guides may not have more than one guided group in the same river drainage at any given time. At the end of the permit period, permittees are required to report their use of the Refuge (i.e., number of clients, dates, locations, type of use, etc.).

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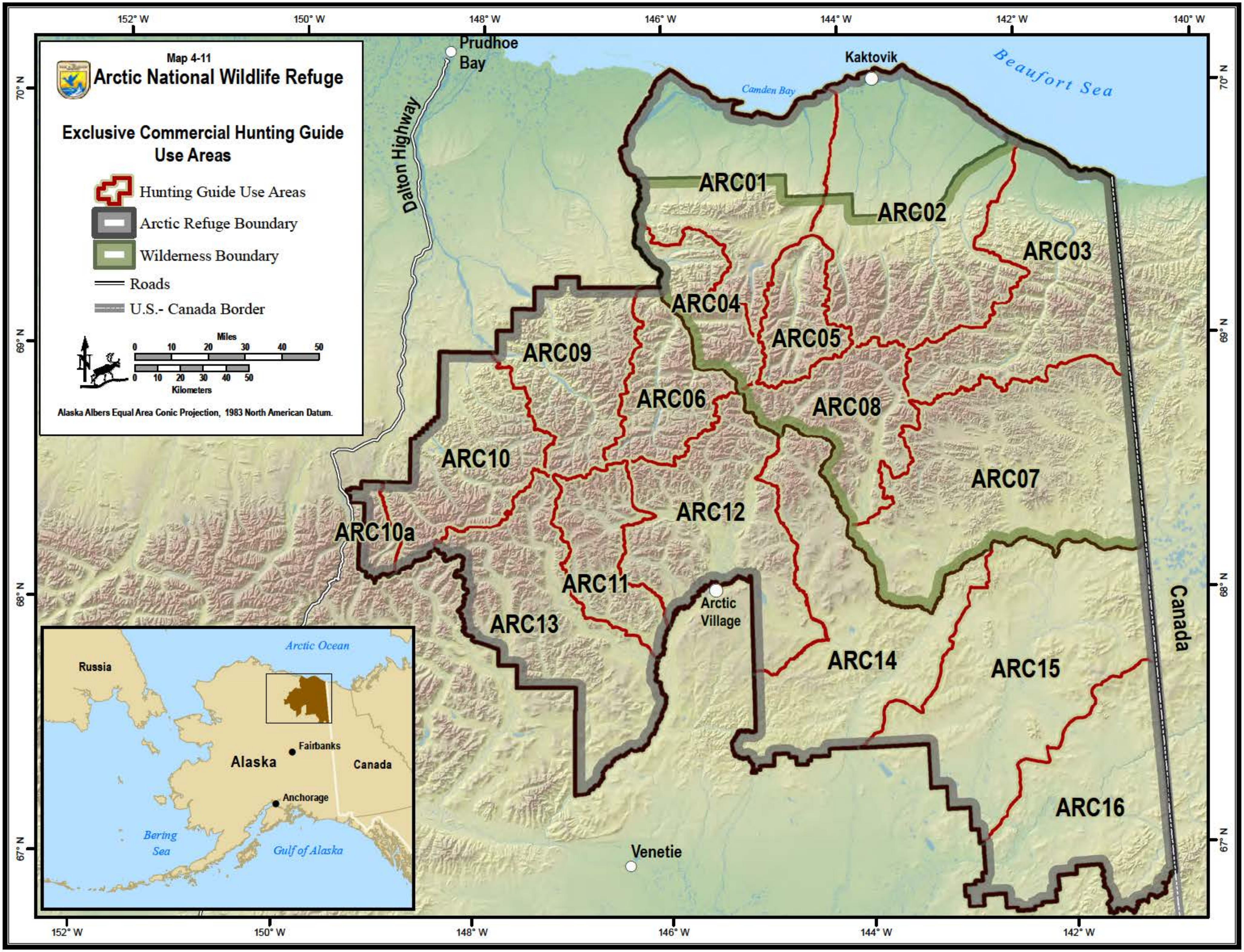
[6] Hunters also incur an additional expense for air transportation to the State. However, only part of the airfare would be expected to directly benefit the State economy because a large portion of the cost would flow to corporate offices for operational expenses. Most of the major airlines serving Alaska are headquartered out of state.

[7] Caudill, J. and E. Carver, Banking on Nature, U.S. Fish and Wildlife Service, Division of Economics, 2006. $2.5 million = (1.6 multiplier * $1.57 million).

Table 4-18. Commercial recreation and air operations permits

Year	Number of Special Use Permits Issued		
	Recreation	Air Operations	Total Permits
1980	7	-	7
1981	8	-	8
1982	7	-	7
1983	14	-	14
1984	10	-	10
1985	9	-	9
1986	14	-	14
1987	12	3	15
1988	18	3	21
1989	21	8	29
1990	17	12	29
1991	16	12	28
1992	15	14	29
1993	17	10	27
1994	19	9	28
1995	16	9	25
1996	14	11	25
1997	14	9	23
1998	17	11	28
1999	16	11	27
2000	16	8	24
2001	22	10	32
2002	21	10	31
2003	25	11	36
2004	24	11	35
2005	28	11	39
2006	27	10	37
2007	22	12	34
2008	22	13	35
2009	25	14	39

Source: Arctic Refuge Special Use Permit Files



Map 4-11
Arctic National Wildlife Refuge
Exclusive Commercial Hunting Guide Use Areas
Hunting Guide Use Areas
Arctic Refuge Boundary
Wilderness Boundary
Roads
U.S.- Canada Border
Miles
0 10 20 30 40 50
0 10 20 30 40 50
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
Prudhoe Bay
Dalton Highway
Kaktovik
Camden Bay
Beaufort Sea
ARC01
ARC02
ARC03
ARC04
ARC05
ARC06
ARC07
ARC08
ARC09
ARC10
ARC10a
ARC11
ARC12
ARC13
ARC14
ARC15
ARC16
Arctic Village
Venetie
Canada
152° W
150° W
148° W
146° W
144° W
142° W
140° W
70° N
69° N
68° N
67° N
Russia
Arctic Ocean
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska

Commercial Air Operator Services

On Arctic Refuge, there are two types of air transportation services offered: air-taxis and air transporters. Air-taxis may fly in hunters, but hunters are incidental to their air-taxi business, and hunters are charged the same hourly rate as their other clients (river rafters, backpackers, etc.). When a client hires the service of an air-taxi, the hunter decides the drop-off and pick-up locations. Transporters offer fly-in services to hunters, and they directly target the business of hunters through advertisements. The transporter may be responsible for determining the hunting location, and a fixed rate is paid by each client to the transporter for all transportation services needed, including that of gear and game meat. Transporter fees are typically higher than air-taxi fees. Because of this, the economic impacts of non-hunting recreationists and hunters need to be evaluated differently.

Non-hunting Recreational Guiding

Accurate commercial recreational guiding trip cost averages across the entire Refuge are very difficult due to the number of variables in trip length and location, and are approximations on extrapolated data. There is an average trip cost for guided non-hunting recreation on or to the Kongakut River. Based on information provided on permittees' websites, the average cost of a guided nine-day Kongakut River trip, including food, equipment, and roundtrip transportation from Fairbanks, is $4,125.00 per person. Considering our limited basis for estimation, the costs on the Kongakut River trips is being used to approximate non-hunting guided recreation cost for Arctic Refuge. From 2001 to 2009, an average of 989 commercially-supported people visited the Refuge each year. Of these visitors, 56 percent were guided, and 44 percent were non-guided. Therefore, guided non-hunting recreation on the Refuge contributes approximately $2,124,375 to the State's economy annually[8].

Commercially-Supported Non-guided Non-hunting Recreational Visitation

Though air-taxi operators charge a fixed hourly rate, air-taxi costs vary widely depending on the point of origin, the destinations, the number of people in the party, the amount of gear, and the type of aircraft used, accurate estimates of commercially supported, non-guided, non-hunting recreational visitation are difficult to make. On average, air-taxi services cost between $1,000 and $1,500 per person.This would mean the 344 non-guided, non-hunting visitors[9] contributed between $344,000 and $516,000 to the State economy annually for air transportation to and from the Refuge[10].

Non-guided Hunting Visitation

When hunters use the services of a transporter, the cost of air transportation to and from the Refuge tends to be much higher than an air-taxi. Transporters charge a rate per person rather than an hourly rate, and may consider points of origin, the destinations, and the type of

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[8] 989 x 0.56 = 554, 554 x 0.93 = 515, 515 x $4,125 = $2,124, 375

[9] 989 x 0.44 = 435, 435 x 0.79 = 344

[10] 344 x $1,000 = $344,000; 344 x $1,500 = $516,000

aircraft used when establishing their rates for individuals. Based on permittees' websites, the lowest per person rate is $1,750, and the highest per person rate is $4,995[11].

Hunters comprise about 28 percent of Refuge visitation annually. Between 2001 and 2009, there was an average of 989 visitors each year, meaning about 277 of those visitors were hunters; of those hunters, 25 percent, or 69 individuals, were guided. Therefore, on average, 208 non-guided hunters contribute between $364,000[12] and $1,038,960[13] to the State economy annually for air transportation to and from the Refuge.

When combining the economic contributions to the State economy of guided non-hunting and non-guided visitation (all types), it is important to realize this total is likely a low estimate, since additional expenses in Alaska incurred by most visitors likely include hotel stays, food, and travel to Fairbanks before and after their trip.

4.4.3.7 Economic Impact of Refuge Management Activities

Refuge operations entail the hiring of permanent and seasonal employees for research, management, visitor services, maintenance, law enforcement, and aviation services. To conduct these activities, the Refuge has a budget for salaries and supplies (Table 4-19). Local Arctic Refuge communities and the city of Fairbanks, where the Refuge headquarters is located, benefit from these expenditures in terms of jobs created and associated income and economic output. The Refuge spends money on a variety of goods and services in a manner similar to any other business. Likewise, Refuge employees spend their salaries in the community on a variety of consumer goods and services.

These direct expenditures are only part of the total picture. Those businesses and industries that supply local retailers where purchases are made also benefit from these expenditures. For example, if a Refuge employee and her family decide to go out for dinner in Fairbanks, the restaurant keeps the total bill. The restaurant in turn pays a food wholesaler who in turn pays a food processor. The food processor then spends a portion of this income to pay businesses supplying the food processor. In this fashion, each dollar of local expenditures can affect a variety of businesses at the local, regional, and State level. Consequently, Refuge budget expenditures can substantially affect economic activity, employment, and household income.

In fiscal year 2011, Arctic Refuge budget expenditures totaled $3,286,004. Non-salary expenditures totaled $1,221,865, or 37 percent of the total budget. Salaries, including personnel benefits, totaled $2,064,139, which represents 63 percent of the total budget. Between 2005 and 2009, the total Refuge budget saw modest annual increases to its base budget. In 2010 and 2011, Refuge budgets declined slightly, decreasing by 1.4 percent in 2011 from the 2009 level.

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[11] These figures represent a range of charges from the public websites of air transporters authorized to operate in the Refuge in 2010.

[12] 208 x $1,750 = $364,000

[13] 208 x $4,995 = $1,038,960

Rent, communications, and utilities are paid primarily to Government Services Administration for the Refuge's Federal building office space. Approximately $4,000 is paid to the North Slope Borough annually for the Refuge's Kaktovik bunkhouse utilities (electric and water), and approximately $10,000 is paid to KIC annually for the Refuge's Kaktovik bunkhouse heating fuel. Arctic Refuge currently employs 23 permanent full-time and part-time staff members, one term full-time staff member, and two temporary, intermittent employees. These employees range from a GS-0325-05 Refuge clerk to a GS-485-14 Refuge manager. All of these employees are based in Fairbanks.

The Refuge also employs two temporary, intermittent GS-1001-07 Refuge information technicians. These employees are based in Arctic Village and Kaktovik.

Generally, three to five temporary, seasonal employees are hired each year to support summer biological field work. These employees are hired through the Delegated Examining Unit, with job opportunities announced on the USA Jobs website every January. They are hired as GS-4 to GS-7 Biological Science Technicians. Based on the 2011 budget, their salary costs range from $16.17 per hour for the GS-4 to $22.42 per hour for the GS-7, including a 16.46 percent locality pay and 10.56 percent Alaska Cost of Living Adjustment.

Each year, between 5 and 11 high school students in remote Refuge communities are hired for summer Youth Conservation Corps projects in their villages. In 2011, students were paid the Alaska minimum wage of $8.00 per hour, and the student leaders were paid $10.00 per hour. In 2011, 10 students worked for 20 days for a total cost of $15,432.00.

Table 4-19. Total Arctic Refuge budget (2005 – 2011)

Description	2005	2006	2007	2008	2009	2010	2011
Full-time permanent employees	$ 1,176,952	$ 1,238,014	$ 1,238,191	$ 1,314,740	$ 1,392,474	$ 1,334,105	$ 1,400,887
Personnel benefits	$ 595,964	$ 631,273	$ 624,457	$ 674,680	$ 706,583	$ 617,967	$ 663,252
Travel and transportation	$ 65,095	$ 81,619	$ 109,517	$ 115,552	$ 141,896	$ 180,377	$ 116,682
Transportation of supplies, material, etc.	$ 13,459	$ 10,700	$ 35,102	$ 25,883	$ 43,672	$ 46,909	$ 64,081
Rent, communications, and utilities	$ 329,092	$ 347,464	$ 281,854	$ 271,445	$ 383,814	$ 415,713	$ 428,403
Printing and reproduction	$ 504	$ 222	$ 3,063	$ 2,233	$ 311	$ 1,617	$ 1,715
Other contractual services	$ 158,521	$ 253,553	$ 469,633	$ 337,064	$ 411,702	$ 297,939	$ 326,300
Supplies and materials	$ 198,442	$ 163,562	$ 248,159	$ 202,378	$ 173,570	$ 208,168	$ 163,502
Equipment	$ 68,023	$ 52,604	$ 58,577	$ 36,121	$ 26,360	$ 25,940	$ 50,937
Land and structures	$ 5,000	$ 174,801	$ -	$ 1,650	$ 41,698	$ 53,052	$ 2,105
Grants and contributions	$ 10,000	$ -	$ 55,006	$ 61,403	-	$ 139,567	$ 68,130
Total	$ 2,621,052	$ 2,953,812	$ 3,123,559	$ 3,043,149	$ 3,322,080	$ 3,321,354	$ 3,286,004

Source: Alaska Region Division of Finance, March 1, 2012

Contracts with Alaska-based vendors are primarily used for aviation fuel, volunteer lodging, maintenance projects, and field equipment that costs more than $3,000 (boats, motors, etc.). Other large purchases are made using established DOI contracts for computers, animal satellite tracking or radio-collar equipment, etc.

To estimate the impacts of Refuge budget expenditures on employment, income, and economic output, 2011 Refuge budget expenditures were used in conjunction with an economic modeling method known as input-output analysis. This analysis estimated the total economic activity generated by the Refuge, including the number of jobs and job-related incomes associated with these expenditures. The Refuge employs people, and pays them wages that they spend part or all of in various communities for goods and services that add economic value. The following estimates assume that all Refuge budget expenditures take place in the combined area of Fairbanks, North Slope, and the Yukon-Koyukuk census areas. Table 4-20 summarizes the economic impacts of the Refuge budget expenditures[14].

Table 4-20. Economic impacts associated with 2011 Arctic Refuge budget expenditures

Budget	Direct Expenditure	Total Output	Total Jobs	Multipliers	
Salary Only	$ 2,064,139	$3,327,630	25.35	Output	1.61
Non-Salary	$1,221,865	$1,969,787	15.00	Jobs/$million	12.28
Total	$3,286,004	$5,297,418	40.35		

Source: Calculations conducted by the Division of Economics, U.S. Fish and Wildlife Service using Minnesota IMPLAN Group, Inc. software on March 15, 2012.

4.4.3.8 Subsistence Harvest, Barter, and Trade Economies

Past Subsistence Barter and Trade Economies

Hunting, fishing, and gathering activities traditionally constituted the economic base of life for Alaska Native peoples. Native trade networks for the barter and exchange of goods and resources were in existence long before European and Euro-American contact along Alaska's coast and throughout the interior regions. Introduction of western trade goods did not become common in the Native trade networks until the mid-1800s (Wentworth 1979).

South of the Brooks Range, Hudson's Bay Company traders descended the Porcupine River to the Yukon River in search of trade routes. This led to the establishment of the Hudson's Bay Company trading post at Fort Yukon in 1847 (Wilson 1947). The fur trade quickly expanded to become a dominant element in the region's economy and established what is considered today a traditional vocation for rural residents.

[14] Economic effects include the direct, indirect, and induced effects of Refuge spending. Direct effects are production changes associated with the immediate effects of changes in final demand (in this case, changes in Refuge budget expenditures); indirect effects are the production changes in those industries that supply the inputs to industries directly affected by final demand; and induced effects are changes in regional household spending patterns caused by changes in regional employment (generated from the direct and indirect effects).

North of the Brooks Range, whaling vessels began rounding Point Barrow and sailing east to hunt in the Beaufort Sea in 1854. Some whalers permitted their vessels to become frozen in protected shore ice where they remained during winter in order to begin whaling early in the open water period of the Beaufort Sea. These whaling ships also stopped along the Arctic coast and traded with coastal and inland Native peoples. Gwich'in Indians from south of the Brooks Range occasionally traveled north to Barter Island to trade with the Iñupiat until the late 1930s (Wentworth 1979). Commercial whaling, fur trapping, and the trade that ensued linked Native peoples to the larger economy. Western trade goods entered the Native trade networks and were exchanged along the coast at annual trade fairs or at trading posts.

Modern Mixed Subsistence-Market Economies

Title VIII of ANILCA recognizes the customary and traditional uses by rural Alaska residents of wild, renewable resources for direct personal consumption as food, shelter, fuel, clothing, tools, or transportation. It also recognized the traditional sharing and barter of subsistence resources for personal and family consumption, for making and selling of handicraft items out of non-edible byproducts of fish and wildlife resources, and for the practice of customary trade.

The Alaska Federation of Natives (2005) describes subsistence as:

- The hunting, fishing, and gathering activities which traditionally constituted the economic base of life for Alaska's Native peoples and which continue to flourish in many areas of the State today. Subsistence is a way of life in rural Alaska that is vital to the preservation of communities, tribal cultures, and economies. Subsistence resources have great nutritional, economical, cultural, and spiritual importance in the lives of rural Alaskans.
- Subsistence, being integral to our worldview and among the strongest remaining ties to our ancient cultures, is as much spiritual and cultural, as it is physical.

Subsistence is part of a rural economic system, referred to as a "mixed subsistence-market" economy, characterized by mutually supportive "market" and "subsistence" sectors (Wolfe and Ellanna 1983). Families invest money in small-scale, efficient technologies to harvest wild foods such as gillnets, fish wheels, guns and ammunition, traps, camp gear, motorized skiffs, all-terrain vehicles, and snowmobiles. Modern mixed subsistence-market economies require cash income sufficient to allow for the purchase of this equipment, as well as for the operational supplies of fuel, oil, mechanical parts, and the maintenance of such equipment. Subsistence is not oriented toward sales, profits, or capital accumulation but is focused toward meeting the self-sustaining needs of families and small communities (ADFG 2000). Participants in this mixed economy in rural Alaska augment their subsistence harvests by cash employment. Cash from firefighting, trapping, commercial fishing, oil and gas industry jobs, construction jobs, Alaska Permanent Fund or Native corporation dividends, and/or wages from the public sector supplement their subsistence pursuits. The combination of subsistence and commercial-wage activities provides the economic basis for the way of life so highly valued in rural communities (Wolfe and Walker 1987).

Subsistence harvest levels can vary widely from one community to the next, and sharing of harvest is common in rural Alaska between individuals and communities (ADFG Community Subsistence Information System). Federal regulations define barter as the exchange of fish or wildlife or their parts taken for subsistence uses for other fish, wildlife or their parts or for other food or for non-edible items other than money. An example of modern barter activities would be the intercommunity exchange of subsistence resources between the communities of Kaktovik and Anaktuvuk Pass. Under this exchange, muktuk and whale meat is sent to Anaktuvuk Pass from Kaktovik, and caribou is sent from Anaktuvuk Pass to Kaktovik. Caribou is a much more variable resource for Kaktovik than for Anaktuvuk Pass, and Anaktuvuk Pass does not have access to bowhead whales or other marine mammals. However, this exchange is not barter in the strictest sense because in years when Kaktovik does not harvest a whale, they still receive caribou from Anaktuvuk Pass and vice versa. Most of the food acquired by harvest and trade is exchanged and redistributed at public functions and feasts such as major holidays of Thanksgiving, Christmas, Easter, and the Fourth of July (HDR 2011).

South of the Brooks Range, an example of different geographic abundance and availability of fish and wildlife resources and the subsequent sharing and exchange of resources would be Arctic Village and Venetie's better access to caribou and sheep resources from the Brooks Range and Fort Yukon and Beaver's better access to various runs of salmon and moose from the Yukon River region. These are just a few of the resources that are bartered and shared between these villages especially in time of shortage of one species or the other (J. Bryant, Community Liaison, Arctic Refuge, pers. comm.). On a much larger scale and scope, there are many more customary and traditional resources of the Gwich'in and Koyukon people that are important for barter, trade and exchange such as, but not limited to, furs such as wolverine, lynx, marten, and beaver; berries such as blueberries and salmon berries; plants and herbs such as Labrador tea; whitefish such as grayling; waterfowl; and small game such as ground squirrel. Additionally the list of villages which participate in this barter and trade in the southern regions include, but are not limited to, Chalkyitsik, Circle, Birch Creek, Stevens Village, and Old Crow, Canada.

Customary trade is defined by Federal law and regulations as the exchange of cash for fish or wildlife resources to support personal and family needs, so long as the trade does not constitute a major commercial enterprise. Customary trade of edible fish and wildlife resources is highly regulated by Federal and State regulations. Examples of customary trade include the sale of a small portion of a rural Alaskan resident's subsistence caught salmon prepared as salmon strips to another rural resident for their personal consumption or the sale of fur from trapped furbearers.

Another common practice involves the making and selling of handicrafts items out of non-edible byproducts of fish and wildlife that have been taken for subsistence. Non-edible parts of subsistence resources are used to make many functional and/or artistic items. Hides and pelts are used to make bedding, clothing, slippers, mukluks, hats, dolls, drums, and masks. Ivory, bone, and antler are carved for knife handles, needle cases, and figurines. Jewelry and decoration for clothing and other artistic crafts are made from many items, such as ivory, baleen, antler, and feathers (ADNR 2008).

In recent years, the cost of fuel in villages, often exceeding $8.00 a gallon, has negatively impacted subsistence use activities. Subsistence harvesting is conducted closer to villages to reduce travel fuel costs. If travel to distant harvest areas is necessary, several families or hunters may combine funds for the purchase of fuel and travel with fewer boats or snowmachines. Often a resident in the village with a job will purchase fuel or ammunition for a family member or household who does not have income, and the resulting harvest is shared amongst them.

4.4.4 Subsistence Uses

Arctic Refuge encompasses much of the traditional homelands of both the Iñupiat and Gwich'in peoples and their ancestors. As described in section 4.4.1.2, archeological records indicate early man use sites exist on Refuge lands along Arctic coastal areas as well as areas south of the Brooks Range which remained ice free during the glaciation periods providing important immigration routes from Asia to the Americas. Over 70 archeological and historical sites have been documented in the northern region representing a long, rich and vibrant history of Iñupiat or their ancestors use. A prehistoric Iñupiat village existed on Barter Island and area has served as an important trading site since aboriginal times for Iñupiat from the east and west along the coast and from inland areas to the south including the Gwich'in people. It is clearly evident that Arctic Refuge is a treasure cultural landscape for both the Iñupiat and Gwich'in people. Their contemporary use sites are often shared with millennia-old archeological sites continuing the living link between past and present. Hall and McKennan (1973) located numerous prehistoric sites at Old John Lake near Arctic Village during their survey with artifacts similar to those found at Anaktuvuk Pass, which have been dated at 4500 B.C. Archeological sites near Chalkyitsik included artifacts dating from approximately 4000 B.C. to 2000 B.C. and microblades possibly indicating a date as early as 10,000 years B.C. (Mobley 1982).The subsistence way of life encompasses much more than just a way of obtaining food or natural materials. It involves traditions that are important mechanisms for maintaining cultural values, family traditions, kinships, and passing on those values to younger generations (Alaska Federation of Natives 2010). It involves the sharing of resources with others in need, showing respect for elders, maintaining a respectful relationship to the land, and conserving resources by harvesting only what is needed. Subsistence is regarded as a way of life, a way of being, rather than just an activity (Alaska Federation of Natives 2010).

Presently, six communities (Arctic Village, Chalkyitsik, Fort Yukon, Kaktovik, Venetie, and Wiseman) are in or relatively close to Arctic Refuge and use the Refuge for subsistence purposes. Residents of Arctic Village and Kaktovik utilize the Refuge most frequently due to their close proximity in or adjacent to the Refuge. Residents of Fort Yukon, Venetie, Chalkyitsik, and Wiseman use Refuge lands to a lesser extent (Service 1988a). In addition, the following communities have geographic or cultural ties to Arctic Refuge and its subsistence resources: Beaver, Circle, Birch Creek, and Stevens Village in Alaska, and Old Crow in Canada. In general, communities harvest the subsistence resources most available to them, concentrating their efforts along rivers or coastlines or in the mountains, depending on the season and availability of resources at particularly productive sites (HDR 2011).

Determining when and where a subsistence resource will be harvested is a complex activity due to variations in seasonal distribution of animals, migration patterns, extended cyclical variation in animal populations and ever changing and complex hunting regulations. Human factors such as timing constraints (due to employment or other responsibilities), equipment (or lack thereof) to participate, and hunter preference (for one resource over another or for one sort of activity over another) are important components in determining the overall community pattern of subsistence resource harvest.

4.4.4.1 Subsistence Management

One of the purposes of ANILCA and for Arctic Refuge is to provide the opportunity for local rural residents engaged in a subsistence way of life to continue to do so (ANILCA Section 101(c) and Section 303 (2)(B)(iii)). Subsistence uses are defined in ANILCA 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 non-edible 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."*

ANILCA recognizes that the continued opportunity for subsistence uses on public lands is essential to Native physical, economic, traditional, and cultural existence, and to non-Native physical, economic, traditional and social existence (ANILCA Section 801). In recognizing the importance of Native and non-Native rural residents' subsistence needs, ANILCA established a rural priority for the subsistence uses of fish and wildlife over other consumptive users in times of scarcity (ANILCA Section 802).

Case and Voluck (2002) identify three elements of subsistence in ANILCA: economic and physical reliance on natural resources, cultural or social value of subsistence activities, and customs and traditions of Alaska Natives. For most rural residents, subsistence activities follow seasonal cycles and are linked to social and cultural traditions. The traditions of celebrations and sharing are woven into the fabric of the community, forming a complex network of social, psychological, and spiritual life. The term "customary and traditional use" describes the physical acts of hunting, fishing, and gathering evident in cultural and social values. The values are handed down from one generation to the next, linking the past and forming a basis for the future (Case and Voluck 2002).

Arctic Refuge boundaries encompass private Native allotments and lands conveyed to ANCSA groups and Federal lands. Subsistence hunting, fishing and trapping in the Refuge is regulated under a dual management system by the Federal government and the State of Alaska, which sometimes overlap, depending on where the harvest occurs. The reason for the dual State and Federal management of subsistence in Alaska is described by the Service (2008b) as follows:

> *"ANILCA, passed by Congress in 1980, mandates that rural residents of Alaska be given a priority for subsistence uses of fish and wildlife. In 1989, the Alaska Supreme Court ruled that ANILCA's rural priority violated the Alaska Constitution. As a result, the Federal government manages subsistence uses on Federal public lands and waters in Alaska—about 230 million acres or 60 percent of the land in the State. To help carry out the responsibility for subsistence management, the Secretaries of the Interior and Agriculture established the Federal Subsistence Management Program."*

Federal subsistence law is based on Title VIII of the 1980 ANILCA Act and regulations found in 36 CFR 242.1 (applies to U.S. Forest Service) and 50 CFR 100.1 (applies to DOI). The Federal Subsistence Board creates regulations for subsistence hunting, fishing, and trapping on Federal public lands, unconveyed ANCSA lands, and federally reserved waters in Alaska. Federal public land does not include the privately held Native allotments and ANCSA conveyed lands. State subsistence law is based on Title 16 of Alaska Statute 16 and Title 5 of the Alaska Administrative Code, Chapter 99. The Alaska Board of Fisheries and the Alaska Board of Game create regulations for subsistence fishing, hunting, and trapping on all Alaskan lands and waters, as well as lands conveyed to ANCSA groups. Regulations created by these Federal and State boards use proposals, information, and comments from the public, Federal Subsistence Regional Advisory Councils, local advisory committees, tribal governments and Native organizations, agencies, and other interests.

ANILCA Subsistence Management on Federal Public Lands

The Federal Subsistence Management Program initiated in 1990 utilizes public meetings and Federal Subsistence Regional Advisory Councils to provide opportunities for discussions on subsistence regulations and for development and review of proposals. Members of the public, the Subsistence Regional Advisory Councils, local advisory committees, tribal governments and Native organizations, agencies, and organizations may make recommendations to the Federal Subsistence Board for consideration. The North Slope Subsistence Regional Advisory Council represents rural users for the region north of the Brooks Range, including the community of Kaktovik, and the Eastern Interior Subsistence Regional Advisory Council represents users south of the Brooks Range.

In 1999, the Federal Subsistence Management program assumed management of Federal subsistence fisheries on Alaska rivers and lakes and limited marine waters in and adjacent to Federal public lands. This was directed by the 9th Circuit Court in the Katie John case and meets the requirements of the rural subsistence priority in ANILCA Title VIII. The Federal Subsistence Board publishes Federal regulations for subsistence hunting and fishing on Federal public lands every two years. The Federal Subsistence Regional Advisory Councils, State of Alaska representatives, and public play an active role in the regulatory process.

ANILCA directs that the utilization of public lands in Alaska is to cause the least adverse impact possible on rural residents who depend upon subsistence uses of resources; it also mandates that the use must be consistent with management of fish and wildlife in accordance with recognized scientific principles and the purposes for which the area was established. Subsistence management on Refuge lands is a complex, at times controversial, and often politically sensitive issue.

ANILCA contains many other provisions supporting continued opportunity for subsistence. For example, Section 811 ensures that subsistence users can access public lands by snowmobile, motorboat, and other traditionally employed means of surface transportation, subject to reasonable regulations. Section 810, directs that the land managers evaluate the effects of a proposed activity on their lands to determine whether the activity would "significantly restrict" subsistence uses. If it was determined that a proposed activity would probably result in significant adverse effects to subsistence resources or use, the land manager would follow requirements identified in Section 810 before making a final decision on the proposal.

Subsistence Use of Migratory Birds

As early as 1916, migratory bird treaties with Canada and Mexico failed to recognize Alaska's traditional spring and summer subsistence harvest. The Migratory Bird Treaty Act of 1918 (16 U.S.C. 703-712), as amended, established a Federal responsibility for the conservation of migratory birds. After years of negotiations, treaties were amended in 1997 to recognize this customary and traditional harvest. An allowance for the Secretary of the Interior to establish seasons for the taking of birds and the collection of their eggs by "indigenous inhabitants" of Alaska for their own nutritional and other essential needs was created (16 U.S.C. 712).

The Alaska Migratory Bird Co-management Council was established, which included representatives from the Alaska Native community, the ADFG, and the U.S. Fish and Wildlife Service acting as equal partners. The council's primary purpose is to develop recommendations for subsistence migratory bird harvest regulations. Eleven regional management bodies were created to provide local input to the council on the bird list, regional season dates, methods and means, and other annual regulatory recommendations. Alaska subsistence spring and summer migratory bird harvest season runs from April 2nd through August 31st. Migratory bird hunting from September 1st through March 10th is managed under separate Federal regulations in 50 CFR Part 20 and State regulations in 5AAC 85.065.

Subsistence Use of Marine Mammals

The Marine Mammal Protection Act of 1972, as amended (16 U.S.C. 1361-1421h; 50 CFR 13, 18, 216, and 229, as amended) established a Federal responsibility for conservation of marine mammals. The Service is responsible for management of polar bears, sea otters, and Pacific walrus. The act established a moratorium on the taking and importation of marine mammals and products made from them. Alaska Natives who take marine mammals for subsistence purposes, however, were exempt from the moratorium.

Polar bear management requires international coordination between the United States, Russia, and Canada, as well as a cooperative working relationship with Alaska Natives, who

may harvest polar bears for subsistence purposes as outlined under the Marine Mammal Protection Act. The Service monitors harvest through local taggers in 15 communities hired through the Marking, Tagging, and Reporting Program. Taggers gather important information from hunters about polar bears harvested around their community, including the date and location of harvest, and the sex, age, and condition of the bear. Harvest levels in Alaska have remained stable during the past 20 years in the southern Beaufort Sea but have declined in the Chukchi and Bering Seas (Service 2009).

4.4.4.2 Contemporary Village Subsistence Use

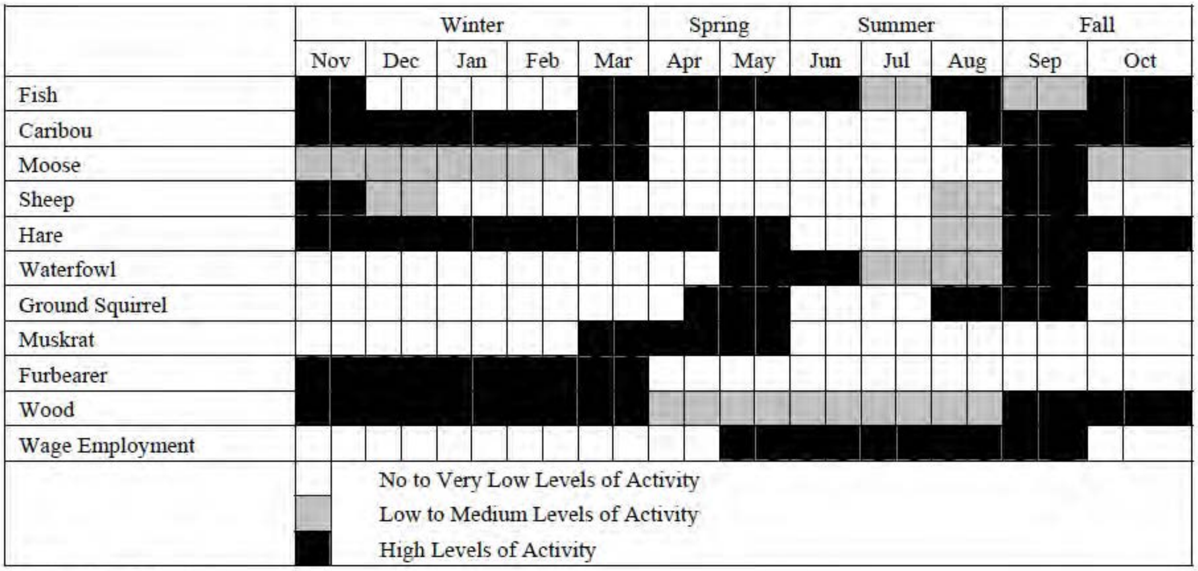
Arctic Village

Reverend Albert Tritt, a Neets'aii Gwich'in born in 1880, wrote that his people led a nomadic life, traveling to the Arctic Coast, Rampart, Old Crow, the Coleen River, and Fort Yukon in the 1880s and 1890s. In the early 1900s, family groups began to gather more permanently at several locations, with the first permanent residents settling at the present Arctic Village site in 1909 (Caulfield 1983). This village is located adjacent to the Refuge on the east bank of the East Fork of the Chandalar River, 6 mi (10 km) southwest of its junction with the Junjik River in the Brooks Range. This location is important for its proximity to nearby fishery resources, availability of timber for firewood and cabin logs, ready access to Dall's sheep on the nearby mountains, and—most importantly—for its access to the Porcupine caribou herds annual migration routes. For the northern Gwich'in people, caribou is still the most important food and cultural resource and is often referred to as their "source of life," providing as much as 80 percent of their diet by weight in some years (ADFG Community Subsistence Information System). The Porcupine caribou herd annual migration between the Porcupine River drainage and the Arctic North Slope has provided for the Gwich'in people for hundreds—even thousands—of years. In addition to being people of the mountains, the northern Gwich'in refer to themselves as "caribou people" (Caulfield 1983). For the Gwich'in people, the Porcupine caribou herd's calving grounds on Arctic Refuge's coastal plain is considered sacred ground, a birthing place for thousands of caribou each year (Gwich'in Nation 1988).

Arctic Village residents generally harvest resources near the community from either tribal reservation lands or Arctic Refuge lands. Residents hunt and fish on Old John Lake, the Chandalar, Sheenjek, Junjik, and Wind rivers, and on Red Sheep Creek. The most recent representation of a seasonal round of subsistence activities for Arctic Village is based on observations and interviews representing the period 1970 to 1982 (Table 4-21) (Caulfield 1983).

Spring begins with the break-up of the river ice in late May to early June, and once the ice thins, nets are set for whitefish, pike, grayling, and suckers; muskrats and waterfowl were hunted in the lakes. Summer begins with fishing by hook and line, as well as nets for whitefish, pike, grayling, suckers, and lake trout. By mid-August, migrating caribou pass nearby, and berries become ripe enough for picking, processing, and storing. Fall begins in mid- to late September. Caribou hunting continues during the fall and through the winter; moose are hunted in September. Fishing with gillnets through the ice begins, and it continues until the ice becomes too thick, when emphasis changed to jigging through the ice. Residents hunt sheep in the nearby mountains in September and November, and fur trappers return to their traplines to set and run them through March (Caulfield 1983).

Table 4-21. Annual cycle of subsistence activities for Arctic Village, 1970–1982



Source: Caulfield 1983.

Arctic Village Subsistence Harvests

Subsistence resource harvest data collected by the ADFG from 1993–1997, and by the Council of Athabascan Tribal Governments for moose, bear, and wolf harvest data in 2001 and 2002, are summarized in Appendix J of the Yukon Flats National Wildlife Refuge Environmental Impact Statement for the Proposed Land Exchange (Service 2010c). Total subsistence harvest for residents of Arctic Village during this time period was 10,000 to 21,000 pounds, with caribou and moose constituting more than 90 percent of the harvest by weight in most years (ADFG Community Subsistence Information System). Other important species included whitefish and, in some years, Dall's sheep and ducks. Andersen and Jennings (2001) reported 437 birds harvested in Arctic Village for the 2000 harvest year.

Arctic Village Subsistence Use Areas

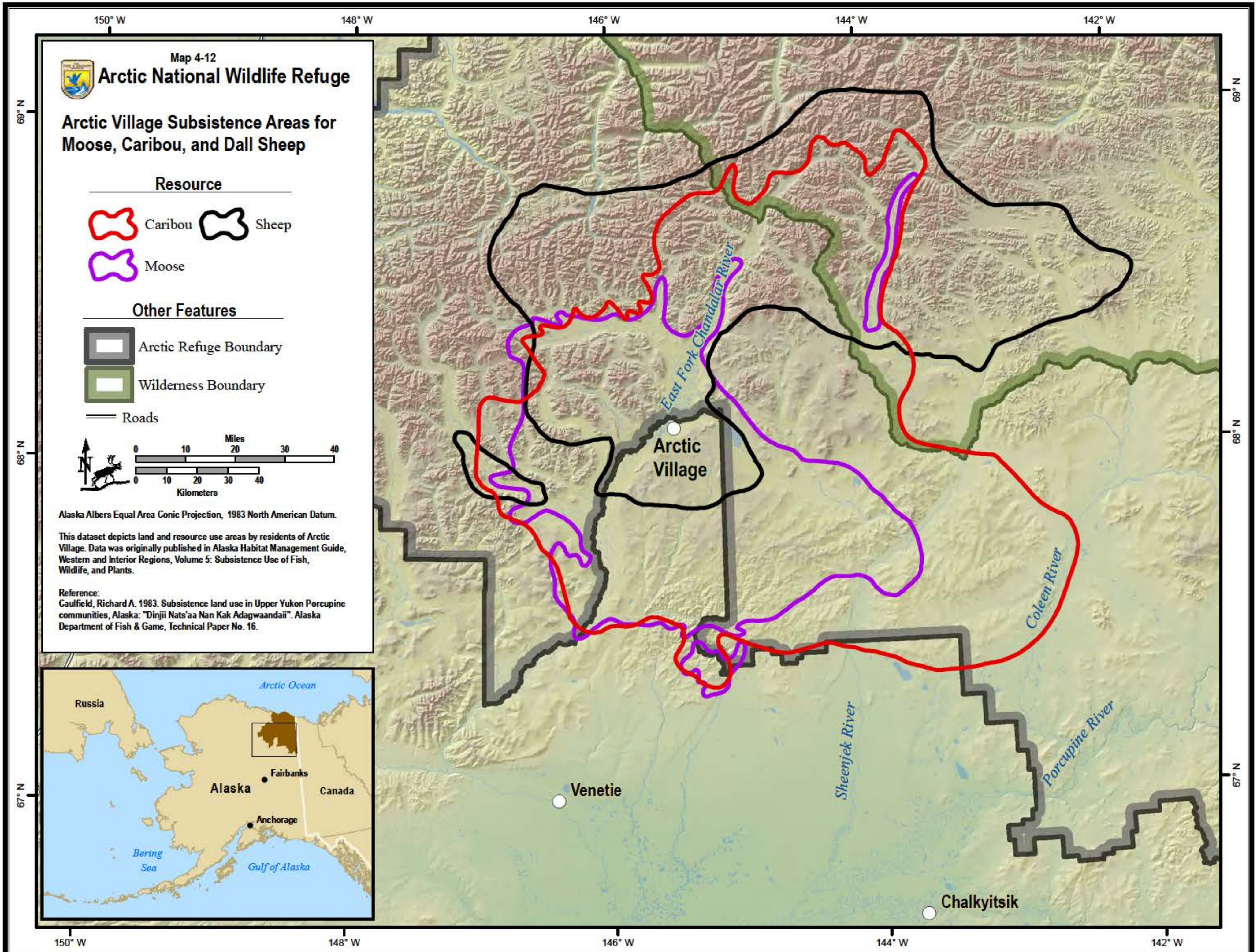
Arctic Village subsistence harvest areas shown on Maps 4-12, 4-13, and 4-14 are based on data collected by Caulfield (1983). These data are based on 1980 interviews documenting 11 respondents' lifetime subsistence use areas. This data may not represent the full range and extent of Arctic Village residents' contemporary use areas for resource harvesting. Harvest and use areas may have changed over time due to factors such as fluctuating populations of fish and wildlife resources, changing migration patterns, availability of resources, shifting climate and changes in habitat, and the impact of high fuel prices.

Map 4-12 includes lifetime subsistence use areas for caribou hunting, moose hunting, and sheep hunting. Map 4-13 depicts lifetime subsistence use areas for fishing, wildfowl hunting, and wood fuel and structural materials gathering. Map 4-14 includes lifetime subsistence use areas for bear hunting, furbearer hunting and trapping, and small mammal hunting. The most widespread of these use areas included traplines, usually set along streams or sloughs to trap furbearing animals.

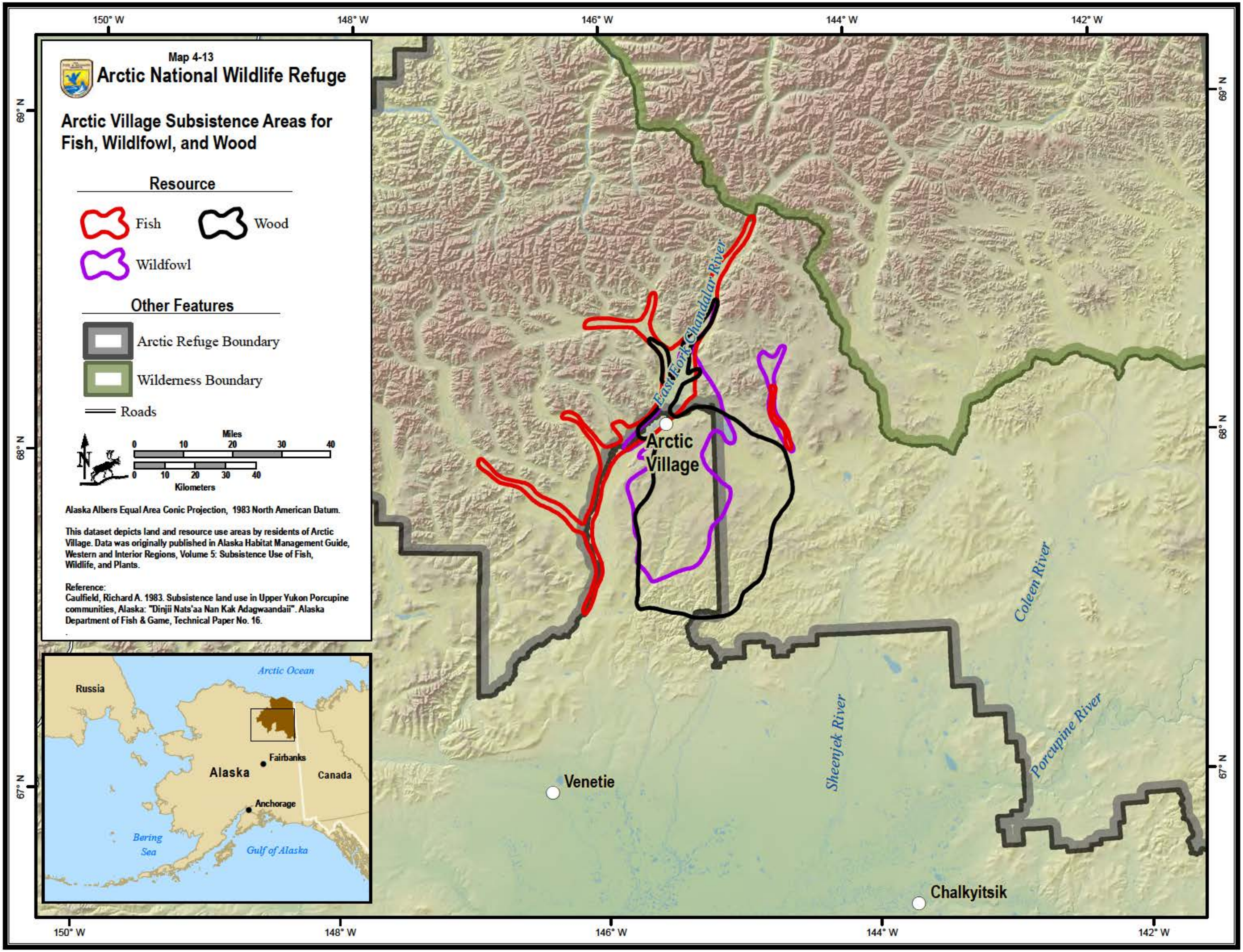
Chalkyitsik

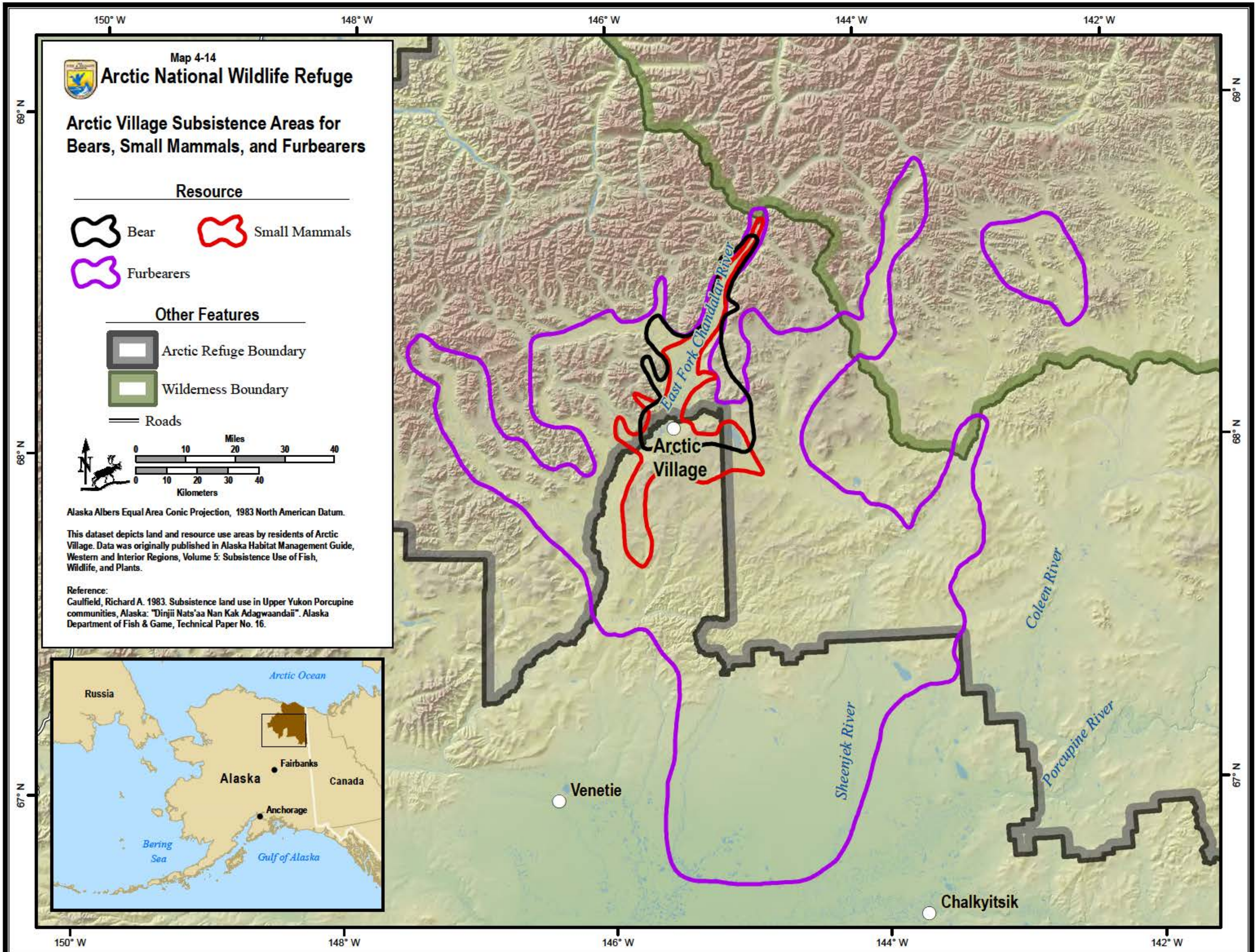
Chalkyitsik means "fish hooking place," and the village has traditionally been an important seasonal fishing site for the Gwich'in (Caulfield 1983). Chalkyitsik is located on the Black River about 21 miles from the Refuge's boundary and 50 miles east of Fort Yukon. Village elders remember a highly nomadic way of life, living at the headwaters of the Black River from autumn to spring, and then floating downriver to fish in summer. Archdeacon MacDonald encountered them on the Black and Porcupine rivers, as well as trading and socializing in Fort Yukon and Rampart, on a number of occasions from 1863 to 1868 (Caulfield 1983). The community's location near the interface of the Yukon Flats and upland areas to the east allows access to a variety of wild plant and animal resources (Alaska Department of Commerce, Community and Economic Development, Alaska Community Database).

Currently, most subsistence harvests occur outside of Arctic Refuge boundaries. However, some residents continue to use Arctic Refuge for hunting and trapping in the fall and winter (Table 4-22, Caulfield 1983). In the fall, some Chalkyitsik residents hunt moose or caribou, usually along the Porcupine River. In November, trapping begins for marten, mink, lynx, beaver, wolf, and fox. Commonly used traplines extend north to the Porcupine and Coleen rivers. Trapping continues until about mid-March. Moose hunting sometimes occurs in conjunction with trapping. Caribou are occasionally harvested during spring and are valued as a source of variety in local diets.



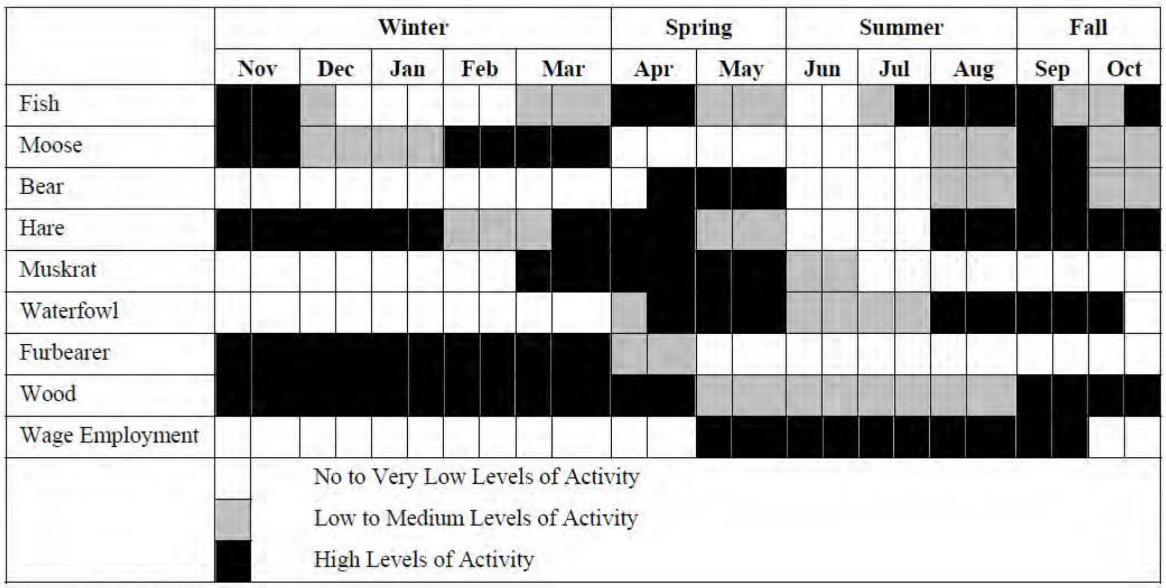
Map 4-12
Arctic National Wildlife Refuge
Arctic Village Subsistence Areas for Moose, Caribou, and Dall Sheep
Resource
Caribou
Sheep
Moose
Other Features
Arctic Refuge Boundary
Wilderness Boundary
Roads
Miles
0 10 20 30 40
0 10 20 30 40
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
This dataset depicts land and resource use areas by residents of Arctic Village. Data was originally published in Alaska Habitat Management Guide, Western and Interior Regions, Volume 5: Subsistence Use of Fish, Wildlife, and Plants.
Reference:
Caulfield, Richard A. 1983. Subsistence land use in Upper Yukon Porcupine communities, Alaska: "Dinjii Nats'aa Nan Kak Adagwaandaii". Alaska Department of Fish & Game, Technical Paper No. 16.
Russia
Arctic Ocean
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska
150° W
148° W
146° W
144° W
142° W
69° N
68° N
67° N
East Fork Chandalar River
Arctic Village
Coleen River
Venetie
Sheenjek River
Porcupine River
Chalkyitsik


Map 4-13
Arctic National Wildlife Refuge
Arctic Village Subsistence Areas for Fish, Wildlfowl, and Wood
Resource
Fish
Wood
Wildfowl
Other Features
Arctic Refuge Boundary
Wilderness Boundary
Roads
Miles
0 10 20 30 40
0 10 20 30 40
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
This dataset depicts land and resource use areas by residents of Arctic Village. Data was originally published in Alaska Habitat Management Guide, Western and Interior Regions, Volume 5: Subsistence Use of Fish, Wildlife, and Plants.
Reference:
Caulfield, Richard A. 1983. Subsistence land use in Upper Yukon Porcupine communities, Alaska: "Dinjii Nats'aa Nan Kak Adagwaandaii". Alaska Department of Fish & Game, Technical Paper No. 16.
Russia
Arctic Ocean
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska
150° W
148° W
146° W
144° W
142° W
69° N
68° N
67° N
East Fork Chandalar River
Arctic Village
Coleen River
Sheenjek River
Porcupine River
Venetie
Chalkyitsik



150° W
148° W
146° W
144° W
142° W
69° N
68° N
67° N
Map 4-14
Arctic National Wildlife Refuge
Arctic Village Subsistence Areas for Bears, Small Mammals, and Furbearers
Resource
Bear
Small Mammals
Furbearers
Other Features
Arctic Refuge Boundary
Wilderness Boundary
Roads
Miles
0 10 20 30 40
0 10 20 30 40
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
This dataset depicts land and resource use areas by residents of Arctic Village. Data was originally published in Alaska Habitat Management Guide, Western and Interior Regions, Volume 5: Subsistence Use of Fish, Wildlife, and Plants.
Reference:
Caulfield, Richard A. 1983. Subsistence land use in Upper Yukon Porcupine communities, Alaska: "Dinjii Nats'aa Nan Kak Adagwaandaii". Alaska Department of Fish & Game, Technical Paper No. 16.
Arctic Ocean
Russia
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska
East Fork Chandalar River
Arctic Village
Venetie
Sheenjek River
Coleen River
Porcupine River
Chalkyitsik

Table 4-22. Annual cycle of subsistence activities for Chalkyitsik, 1970–1982T



Source: Caulfield 1983.

Chalkyitsik Subsistence Harvests

ADFG collected subsistence harvest data by household in Chalkyitsik for 1993, 1994, 1995, 1996, and 1997. The Council of Athabascan Tribal Governments collected subsistence harvest data in 2001 and 2004 for moose, bear, and wolves (CATG 2002, CATG 2005). Busher and Hamazaki (2005) reported subsistence harvests of salmon in Chalkyitsik in 1992 to 2003, and Busher et al. (2007) reported the same data for 2005 in addition to harvest of non-salmon species. These subsistence harvest data are summarized in Appendix J of the Yukon Flats National Wildlife Refuge Environmental Impact Statement for the Proposed Land Exchange (Service 2010c). Estimated total subsistence harvest from 1993 to 1997 ranged from 1,900 to 7,700 pounds (ADFG Community Subsistence Information System). Moose constituted 73 to 85 percent of the harvest; other important species representing five percent or more of the estimated harvest during some of these years included black bear, ducks, northern pike, and chum salmon. Annual total subsistence salmon harvests ranged from 30 to 1,750 fish from 1992 to 2003 and in 2005. No per-capita harvest data are currently available for Chalkyitsik (ADFG Community Subsistence Information System). Andersen and Jennings (2001) reported a harvest of 568 total birds in Chalkyitsik for the 2000 harvest year.

Chalkyitsik Subsistence Use Areas

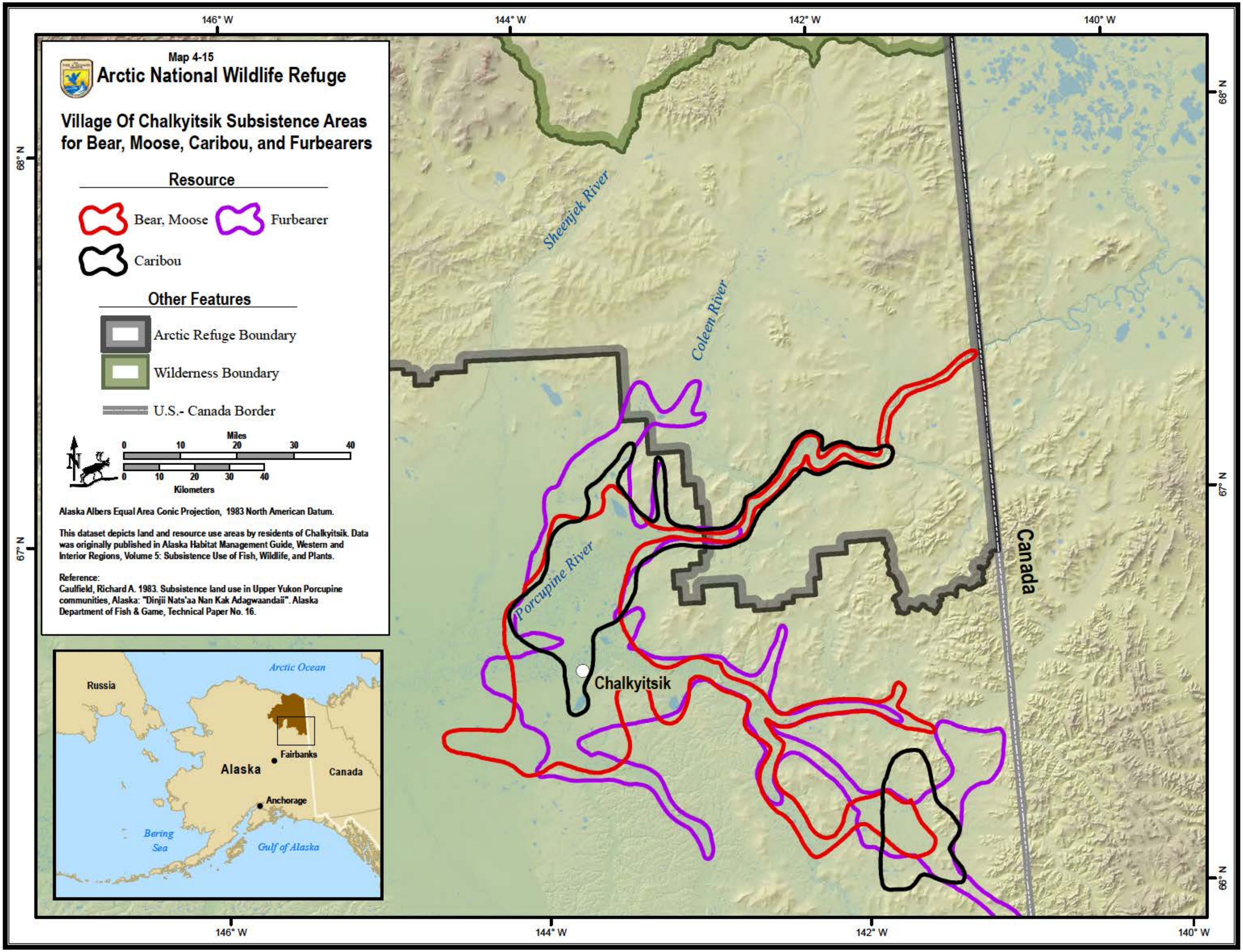
Map 4-15 represents selected Chalkyitsik "lifetime" subsistence use areas for caribou, bear, and moose hunting, and furbearer trapping. (Caulfield 1983). These data are based on 1980 interviews documenting eight respondents' lifetime subsistence use areas. This data may not represent the full range and extent of Chalkyitsik residents' contemporary use areas for resource harvesting. Harvest and use areas may have changed over time due to factors such as fluctuating populations of fish and wildlife resources, changing migration patterns, availability of resources, shifting climate and changes in habitat, and the impact of high fuel prices.

Fort Yukon

Fort Yukon is located at the confluence of the Yukon River and the Porcupine River, about 63 miles from Arctic Refuge boundary The community has historically served as a meeting place for the Gwich'in Athabascan and neighboring peoples. Its location on the Yukon River and confluence with the Porcupine River makes it an important transportation center, as well as an important area for harvesting fish resources. Fort Yukon today is the largest village of the Kutchin or Gwich'in Athabascan people and the administrative, transportation, communication, and economic center for the upper Yukon-Porcupine region. It is a large community with a blend of wage employment opportunities and subsistence components.

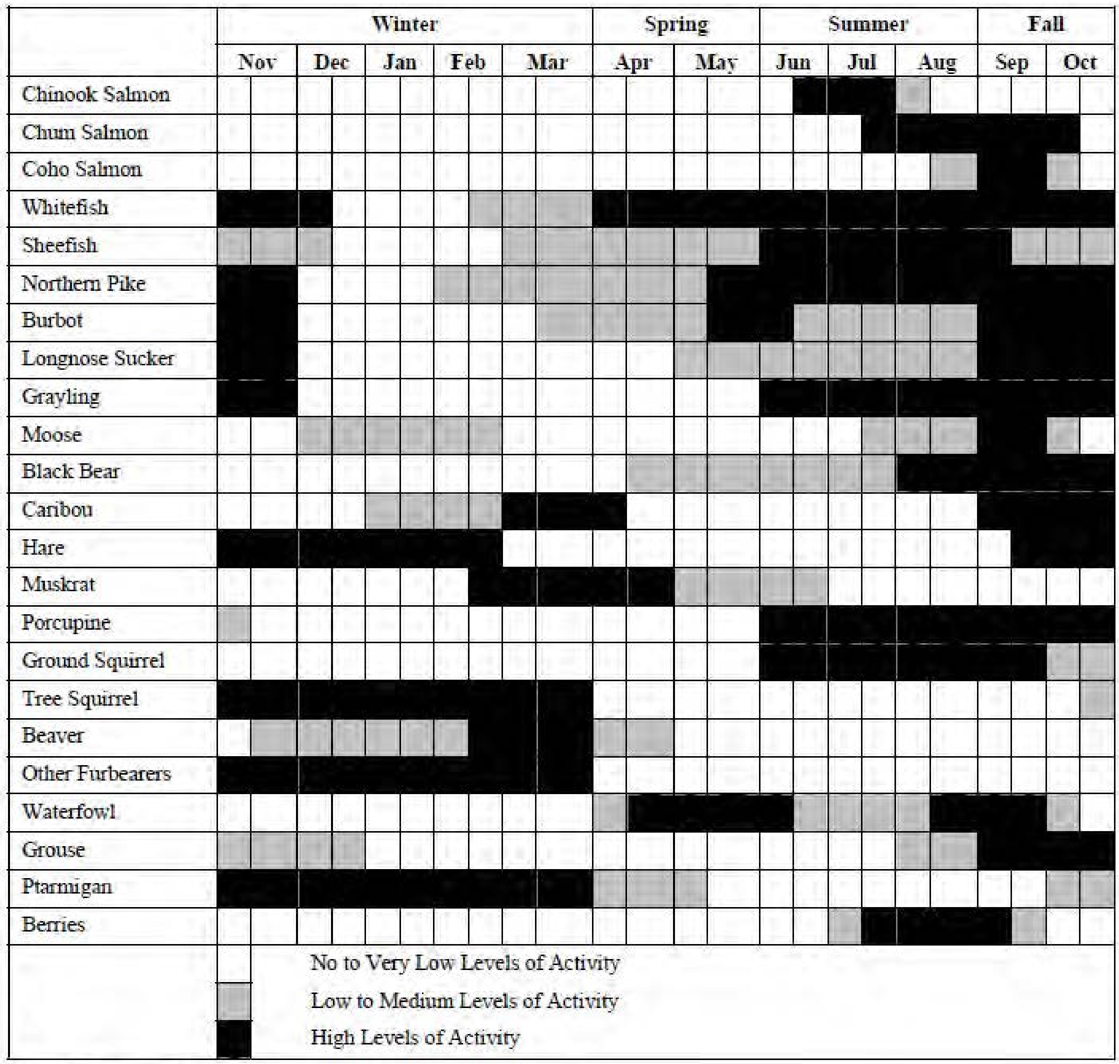
Research indicates that Fort Yukon residents reported spending less time in resource harvest activities each year than did residents of other communities in the region; however, their diversity of subsistence resources harvested was reported to be greater (Institute of Social and Economic Research 1978). Possible explanations for this may include the broad diversity of resources available due to Fort Yukon’s central location in the region with ready access to numerous major river corridors and enhanced use of access equipment made possible by income from wage employment. Most contemporary subsistence harvests occur outside of Arctic Refuge boundaries on Native lands or on Yukon Flats National Wildlife Refuge.

Currently, the Porcupine and Coleen drainages are the primary areas used by Fort Yukon residents in Arctic Refuge. Table 4-23 depicts the annual cycle of subsistence activities at Fort Yukon from 1970–1982 and 1986–1987 (Caulfield 1983, Sumida and Andersen 1990). Fort Yukon’s seasonal rounds have not changed substantially between Caulfield’s 1983 study and Sumida and Anderson’s 1990 study with the exception of accommodating new technologies in access equipment and regulatory constraints. The Porcupine River is utilized for moose, bear, waterfowl, and caribou hunting. It is also used for fishing, gathering house logs and firewood, and berry picking. In the fall, some residents travel up the Porcupine River or its tributaries, such as the Coleen River, to hunt moose; bears may also be taken in conjunction with moose hunting. Moose are sometimes harvested during the winter, usually in November and/or during February and March. Caribou hunting usually occurs in mid-September near Canyon Village or Old Rampart as animals from the Porcupine caribou herd cross the Porcupine River (Caulfield 1983). Many people in Fort Yukon today have kinship ties to residents in Arctic Village and Venetie and occasionally utilize these areas for hunting and fishing.



Map 4-15
Arctic National Wildlife Refuge
Village Of Chalkyitsik Subsistence Areas for Bear, Moose, Caribou, and Furbearers
Resource
Bear, Moose
Furbearer
Caribou
Other Features
Arctic Refuge Boundary
Wilderness Boundary
U.S.- Canada Border
Miles
0 10 20 30 40
0 10 20 30 40
Kilometers
N
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
This dataset depicts land and resource use areas by residents of Chalkyitsik. Data was originally published in Alaska Habitat Management Guide, Western and Interior Regions, Volume 5: Subsistence Use of Fish, Wildlife, and Plants.
Reference:
Caulfield, Richard A. 1983. Subsistence land use in Upper Yukon Porcupine communities, Alaska: "Dinjii Nats'aa Nan Kak Adagwaandaii". Alaska Department of Fish & Game, Technical Paper No. 16.
Russia
Arctic Ocean
Fairbanks
Alaska
Canada
Anchorage
Bering Sea
Gulf of Alaska
146° W
144° W
142° W
140° W
68° N
67° N
Sheenjek River
Coleen River
Porcupine River
Chalkyitsik
Canada

Table 4-23. Annual cycle of subsistence activities for Fort Yukon, 1970–1982, 1986–1987



Source: Sumida and Andersen 1990.

Fort Yukon Subsistence Harvests

ADFG collected subsistence harvest data for the community of Fort Yukon in 1987, 1993, 1994, 1995, 1996, 1997, and 1998. The Council of Athabascan Tribal Governments collected information on subsistence harvests in Fort Yukon for moose, bear, and wolves in 2001, 2003, and 2004. Busher and Hamazaki (2005) provided information on Fort Yukon subsistence salmon harvests from 1992 to 2003, and Busher et al. (2007) provided the same data for 2005. These subsistence harvest data are summarized by year and by species in Appendix J of the Yukon Flats National Wildlife Refuge Environmental Impact Statement for the Proposed Land Exchange (Service 2010c).

Based on data collected by ADFG, household participation rates were high during the 1987 study year. No participation data are available for the 1993 to 1998 study years. Estimates of total subsistence harvest ranged from 3,100 to 625,700 pounds (ADFG Community Subsistence Information System). Moose represented 16 to 48 percent of the harvest annually by weight during study years from 1987 to 1998. Chinook and chum salmon were very important components of the annual harvest, ranging from 40 to 65 percent of the harvest. Geese and whitefish were the only other species groups that constituted more than five percent of the annual harvest. Other species harvested included snowshoe hare, black bear, beaver, lynx, ducks, geese, grouse, and ptarmigan. Andersen and Jennings (2001) reported 3,615 birds harvested by Fort Yukon respondents in the 2000 harvest year. Based on data provided in Busher and Hamazaki (2005) and Busher et al. (2007), Fort Yukon residents harvested large quantities of chum and Chinook salmon and lesser quantities of Coho salmon from 1992 to 2003 and in 2005.

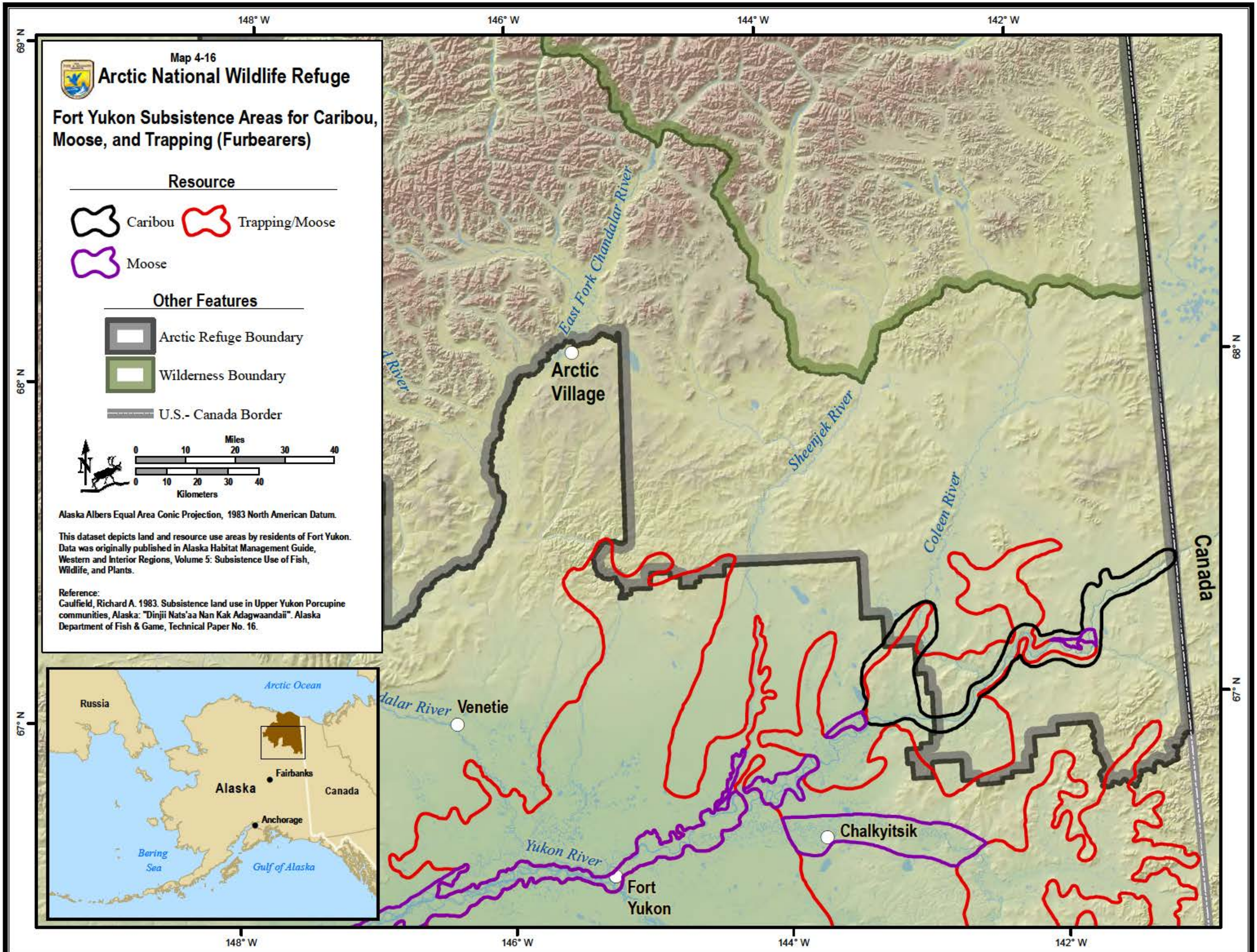
Fort Yukon Subsistence Use Areas

Map 4-16 represents selected Fort Yukon "lifetime" (circa 1925–1987) subsistence use areas (Caulfield 1983, Sumida and Andersen 1990) extending onto Arctic Refuge. These data are based on 1981 (10) and 1988 (26) interviews documenting respondents' lifetime subsistence use areas and may not represent the full range and extent of Fort Yukon residents' contemporary use areas for resource harvesting. Harvest and use areas may have changed over time due to factors such as fluctuating populations of fish and wildlife resources, changing migration patterns, availability of resources, shifting climate and changes in habitat, and the impact of high fuel prices.

Kaktovik

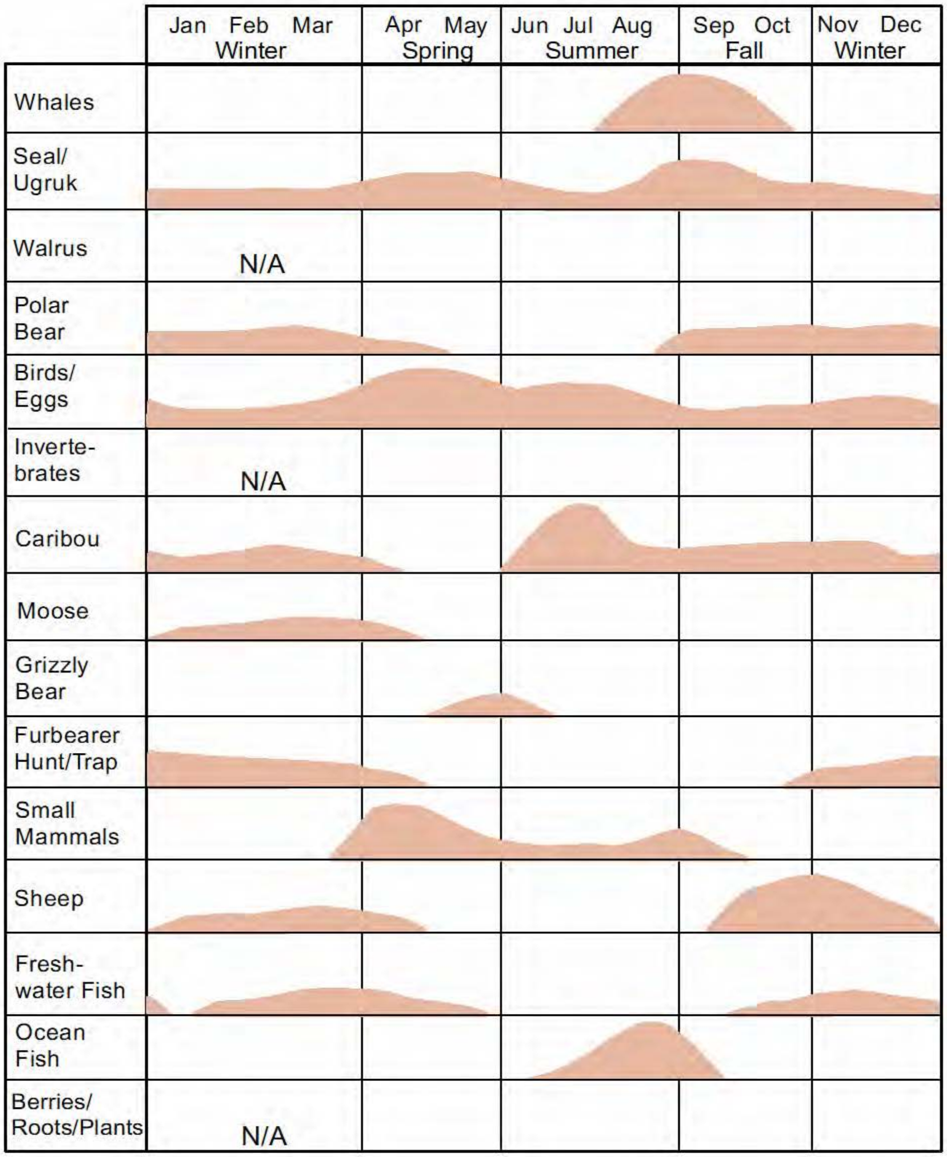
Kaktovik is an Iñupiat community located on Barter Island on the shore of the Beaufort Sea. Until the late 19th century, the island was a major trade center for the Iñupiat and was especially important as a bartering place for Iñupiat from northeastern Alaska and Inuit from Canada. As in the past, the Kaktovikmiut's way of life is heavily dependent on the subsistence harvest of marine and terrestrial animals and fish. Approximately 93 percent of Iñupiat households in Kaktovik participate in the subsistence economy, and 80 percent of non-Iñupiat households use subsistence resources (Shepro et al. 2003). The annual subsistence cycle for Kaktovik is described in Table 4-24. This may not perfectly represent current use patterns but is based on the best available published information. The community's harvest of subsistence resources can fluctuate widely from year to year because of variable migration patterns of game and because harvesting techniques are extremely dependent on snow and ice conditions and weather.

Caribou hunting occurs throughout most of the year, with a peak in the summer when open water allows hunters to use boats to access coastal areas and river drainages for caribou. Bowhead whaling occurs between late August and early October, with the exact timing depending on ice and weather conditions (Minerals Management Service 2003). The whaling season can range anywhere from longer than one month to less than two weeks, depending on these conditions. Other marine mammal hunting (mainly seals) can take place year-round, as does hunting for birds. However, most birds are taken during the spring and fall migrations. Furbearers and sheep are taken in the winter, when surface travel by snowmachine is possible. Fresh water fish are harvested mainly in the winter under the ice, while ocean fish are taken during the open water season. Moose are not a preferred species in Kaktovik, primarily due to their low population levels and limited hunting seasons where harvest numbers have been restricted in recent years.



Map 4-16
Arctic National Wildlife Refuge
Fort Yukon Subsistence Areas for Caribou, Moose, and Trapping (Furbearers)
Resource
Caribou
Trapping/Moose
Moose
Other Features
Arctic Refuge Boundary
Wilderness Boundary
U.S.- Canada Border
Miles
0 10 20 30 40
0 10 20 30 40
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
This dataset depicts land and resource use areas by residents of Fort Yukon. Data was originally published in Alaska Habitat Management Guide, Western and Interior Regions, Volume 5: Subsistence Use of Fish, Wildlife, and Plants.
Reference:
Caulfield, Richard A. 1983. Subsistence land use in Upper Yukon Porcupine communities, Alaska: "Dinjii Nats'aa Nan Kak Adagwaandaii". Alaska Department of Fish & Game, Technical Paper No. 16.
Arctic Ocean
Russia
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska
148° W
146° W
144° W
142° W
69° N
68° N
67° N
East Fork Chandalar River
Arctic Village
Sheenjek River
Coleen River
Canada
Venetie
Chalkyitsik
Yukon River
Fort Yukon

Table 4-24. Annual subsistence cycle for Kaktovik (qualitative presentation)



Source: Galginaitis et al. 2001, based on Wentworth 1979

Note: Patterns indicate desired periods for pursuit of each species based on the relationships of abundance, hunter access, seasonal needs, and desirability. Heights of graphs indicate level of effort.

Kaktovik Subsistence Resources

Marine Mammals—Whaling resumed in Kaktovik in 1964. In years when Kaktovik residents harvest and land a whale, marine resources have composed 59 to 68 percent of their total subsistence harvest. Bowhead whaling occurs between late August and early October, with the exact timing depending on ice and weather conditions (Minerals Management Service 2003). There are at least 10 whaling crews in Kaktovik, and the community has a quota of three strikes (whether the animals are landed or not). Kaktovik has what is essentially an intercommunity agreement with Anaktuvuk Pass under which muktuk, whale meat, and other marine mammal products (especially seal oil) are sent to Anaktuvuk Pass, and caribou and other land mammal products are sent from Anaktuvuk Pass to Kaktovik. Caribou is a much more variable resource for Kaktovik than for Anaktuvuk Pass, and Anaktuvuk Pass does not have access to bowhead whales or other marine mammals. Other marine mammal hunting (mainly seals) can take place year-round. Kaktovik residents also harvest a large number of bearded and smaller seals, and the occasional beluga whale or polar bear.

Terrestrial Mammals—Land mammals are the next largest category of harvest, ranging from 17–30 percent in those same years. The primary land mammal resource is caribou, but Kaktovik residents also harvest a considerable number of Dall's sheep. Of lesser abundance and availability are muskox, moose, and grizzly bears. While Kaktovik hunters have taken moose and muskox, harvest opportunities are restricted due to their low population numbers. Kaktovik's annual caribou harvest fluctuates widely because of the unpredictable movements of the herds, weather-dependent hunting technology, and ice conditions. Caribou hunting occurs throughout most of the year, with a peak in the summer when open water allows hunters to use boats to access coastal and river areas for caribou.

Fishery Resources—Fish comprise 8–13 percent of the total subsistence harvests. Fish may be somewhat less subject to these variable conditions but still exhibit large year-to-year variations. In some winter months, fish may provide the only source of fresh subsistence foods. Kaktovik's harvest effort seems to be split between Dolly Varden and whitefish, with the summer fishery at sites near Kaktovik being more productive than winter fishing on the lower reaches of the Hulahula River.

Bird Resources—Birds and eggs making up 2–3 percent of the total harvest. Since the mid-1960s, subsistence use of waterfowl and coastal birds has been growing, at least in seasonal importance. Most birds are taken during the spring and fall migrations. Important subsistence species are black brant, long-tailed duck, eider, snow goose, Canada goose, and pintail duck. Waterfowl hunting occurs mostly in the spring from May to early July (Minerals Management Service 2003). Ptarmigan are also a seasonally important bird.

Furbearer Resources —Trapping of furbearers in the Kaktovik area has decreased with time. Furbearers are taken in the winter when surface travel by snowmachine is possible. Hunters pursue wolf and wolverine by searching and harvesting them with rifles, primarily between March and April or in conjunction with winter sheep hunting. Some hunters may go out in the fall or early winter, but usually weather and snow conditions are poor at that time, and people are more concerned with meat than with fur.

Kaktovik Subsistence Harvests

Community subsistence harvest data for Kaktovik is somewhat dated in terms of the in-depth subsistence community use surveys, which were conducted in 1985, 1986, 1992 (ADFG 1985, ADFG 1986, ADFG 1992). In 1995, the North Slope Borough began to systematically collect subsistence harvest data for the eight villages in the borough. However, the borough was only able to collect subsistence harvest data for the village of Kaktovik in 1994–1995 and in 2002–2003 (Table 4-25).

Subsistence harvest studies for Kaktovik in 1995 indicated that 61 percent of the subsistence harvest (in edible pounds of food) were from marine mammals, consisting of bowhead whales, bearded seals, ringed seals, spotted seals, polar bears, and beluga whales. Terrestrial mammals comprised another 26 percent of the estimated edible pounds harvested, consisting

Table 4-25. Kaktovik community subsistence harvest surveys, major resource categories

Kaktovik Community Subsistence Harvest Surveys												
	1985			1986			1992			1995		
	Number	Pounds	% of Total Pounds	Number	Pounds	% of Total Pounds	Number	Pounds	% of Total Pounds	Number	Pounds	% of Total Pounds
All Resources	9,585	61,664	100	6,484	84,060	100	21,035	170,940	100	5,180		
Fish	6,866	11,403	18	4,416	6,951	8	18,464	22,952	13	4,426		11
Salmon	0	0	0	0	0	0	50	105	0	1		
Whitefish	3,546	2,482	4	2,402	1,682	2	8,823	6,051	4	2,358		
Other	3,320	8,921	14	2,014	5,269	6	9,591	16,796	10	2,067		
Land Mammals	714	35,491	58	382	24,946	30	425	28,867	17	178		26
Caribou	235	27,941	45	178	21,188	25	158	19,136	11	78		
Moose	4	1,893	3	1	596	1	4	2,011	1	1		
Dall Sheep	47	4,622	7	17	1,710	2	44	4,379	3	30		
Muskox	1	748	1	2	1,413	2	5	3,179	2	9		
Other	427	287	0	184	39	0	214	162	0	60		
Marine Mammals	174	10,762	17	67	49,723	59	123	115,645	68	46		61
Bearded Seal	21	3,776	6	17	2,936	3	24	4,246	2	21		
Other Seal	152	6,360	10	45	1,901	2	46	1,858	1	19		
Walrus	0	0	0	0	0	0	0	52	0	0		
Beluga	0	0	0	0	0	0	0	0	0	1		
Bowhead Whale	0	0	0	3	43,704	52	3	108,160	63	3		
Polar Bear	1	626	1	2	1,182	1	3	1,330	1	2		
Birds & Eggs	1,831	3,995	6	1,561	2,382	3	1,796	3,249	2	530		2
Vegetation	NA	13	0	58	58	0	227	227	0	NA		

Notes:
Source: ADF&G Community Information System (http://www.subsistence.adfg.state.ak.us/CSIS/) and Brower et al. 2000.
1985, 1986, and 1992 were ADF&G surveys. 1995 was a NSB survey and did not provide harvest in terms of pounds, but did provide the percentages shown for the 1995 subcategories of resources. "Pounds" for 1995 could not be calculated as for Nuiqsut, since only aggregated category percentages were provided in the published document.

of caribou, Dall's sheep, muskox, moose, and brown bear. The primary land mammal resource is caribou (Table 4-26), but Kaktovik residents also harvest a large number of Dall's sheep. Fishery resources accounted for 11 percent of the estimated total edible pounds of harvest. Seven species of fish accounted for the 4,426 fish harvested, of which Arctic Cisco and Dolly Varden represented 4,233 of the fish caught. The harvest of birds accounted for the remaining two percent of edible pounds of subsistence harvest, with 530 birds reported harvested (Brower et al. 2000).

In the 1995 study, 31 different species were reported harvested, with key species being caribou and Dall's sheep for terrestrial mammals; bowhead whales, and ringed and bearded seals for marine mammals; brant and ptarmigan for birds; Arctic cisco and Dolly Varden char for fish; and wolf and ground squirrels for furbearers.

Table 4-26. Estimated caribou harvest by year for Kaktovik

Documented Annual Caribou Harvest Kaktovik	
Year	**Estimated Harvest Kaktovik**
1981	43
1982	160
1983	107
1985	235
1986	201
1987	189
1990	113
1991	181
1992	158
1995	78[a]
2003	112

Sources: ADFG Community Information System (http:www.subsistence.adfg.state.ak.us/(CSIS), Brower et al. 2000, Brower and Hepa 1998, Harper 2007, Bacon et al. 2009 (for 2002–2003)

[a] Number reported as harvested; total estimated harvest not available.

In addition to the Beaufort Sea, Kaktovik residents have access to a number of rivers and lakes that support subsistence fish resources. Pedersen and Linn (2005) conducted surveys of the Kaktovik subsistence fishery in 2000–2001 and 2001–2002, with estimated community harvests of fish at 5,970 pounds and 9,748 pounds, respectively. Dolly Varden, lake trout, and Arctic cisco were the only fishery resources reported harvested by Kaktovik households in this study (Table 4-27). Dolly Varden was the most commonly harvested fish in terms of numbers harvested and estimated harvest weight, with Arctic cisco and lake trout ranking second and third (Pedersen and Linn 2005).

Table 4-27. Kaktovik estimated fish harvest, sample years 1985–2002

Kaktovik Fish Harvest, by Year							
Year	Reported Harvest (pounds)	Estimated Harvest (pounds)	Using	Attempting	Harvesting	Giving	Receiving
2002	3,056	9,748	76	55	47	32	47
2001	3,719	5,970	61	43	38	36	52
1992	17,123	22,952	94	83	81	70	70
1986	5,833	6,951	96	75	72	66	87
1985	9,036	11,403	100	86	81	45	93

Notes:
Source: Pedersen and Linn 2005, and ADF&G Community Information System (http://www.subsistence.adfg.state.ak.us/CSIS/).

Kaktovik Subsistence Use Areas

Contemporary subsistence use areas for caribou, bowhead whales, seals, and fish for Kaktovik are shown on Map 4-17, Map 4-18, and Map 4-19. Map 4-17 depicts caribou land use in total extent and primary areas of use. Map 4-18 depicts contemporary subsistence bowhead whale use areas and subsistence seal use areas. Map 4-19 depicts contemporary fishing areas and important sites. Harvest and use areas may have changed over time due to factors such as fluctuating populations of fish and wildlife resources, changing migration patterns, availability of resources, shifting climate and changes in habitat, and the impact of high fuel prices.

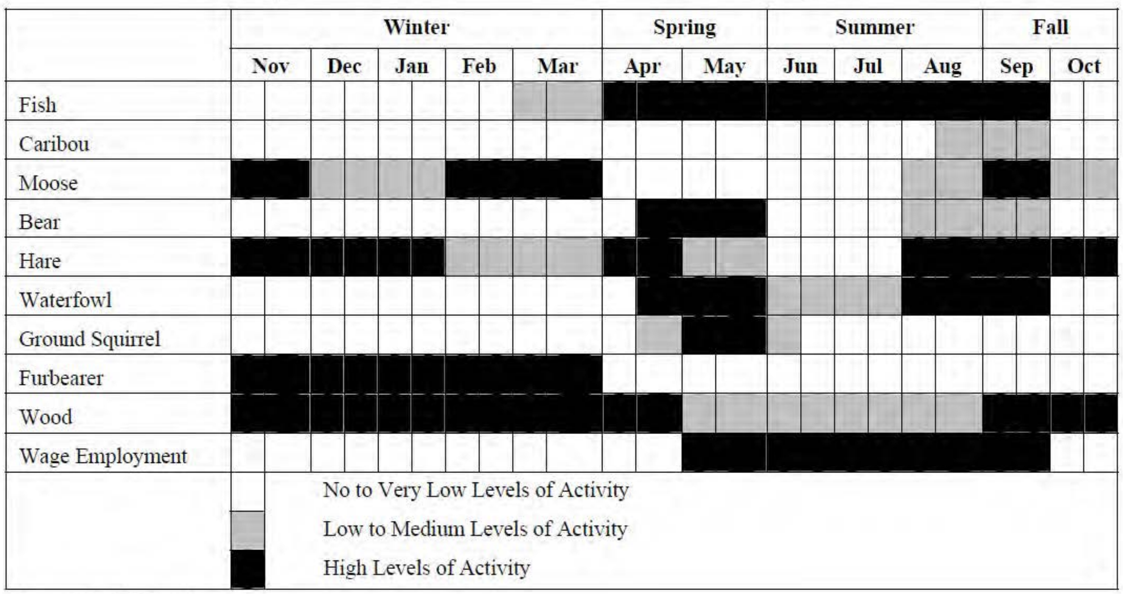
Venetie

Venetie is located on the Chandalar River, about 22 mi from Arctic Refuge and about 45 mi (70 km) northwest of Fort Yukon. The village's location in the Yukon Flats near the foothills of the Brooks Range provides access to resources of the lakes, rivers, and slough systems of the Yukon Flats, as well as to the resources of the upland regions of the Brooks Range (Caulfield 1983). The lower portions of the Chandalar River, including the East Fork of the Chandalar River drainage, are the primary area used by Venetie residents. High use areas in Arctic Refuge include the East Fork of the Chandalar River for harvesting caribou, moose, sheep, bears, fish, and furbearers.

Muskrats and ground squirrels are trapped and black bears are hunted in the spring. Waterfowl hunting usually begins in early May and continues until early June. Once the ice has melted from the rivers and small streams, gillnets are placed in the East and North Forks of the Chandalar River to harvest whitefish, pike, and suckers. Moose hunting is primarily along rivers, and gillnet fishing for salmon and whitefish are major fall activities. Black bear are also taken occasionally when encountered along rivers, as are caribou in late summer (Caulfield 1983). Trapping activities begin in November, and primary species sought are marten, mink, beaver, lynx, fox, wolf, and muskrat. In the Refuge, most trapping occurs along the East Fork of the Chandalar River (Caulfield 1983).

In November and early December, moose are occasionally taken by hunters on snowmachines. In some years, caribou travel to within hunting distance north of Venetie and are sought by snowmachine throughout the winter. A few people may hunt caribou with their relatives near Arctic Village, especially in years when caribou are not available near Venetie. In February and March, trapping focuses on beaver and muskrat (Table 4-28).

Table 4-28. Annual cycle of subsistence activities for Venetie, 1970–1982

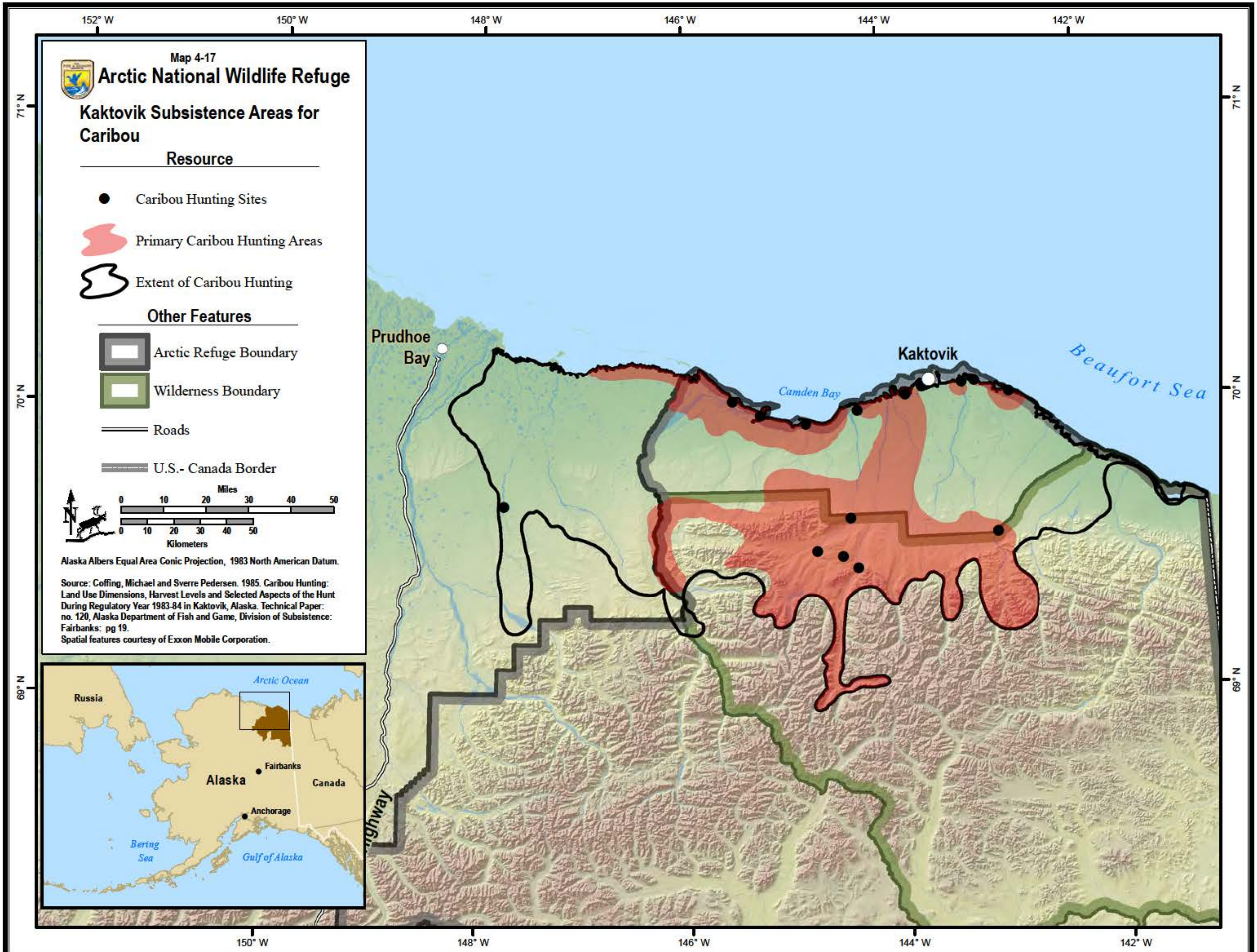


Source: Caulfield 1983.

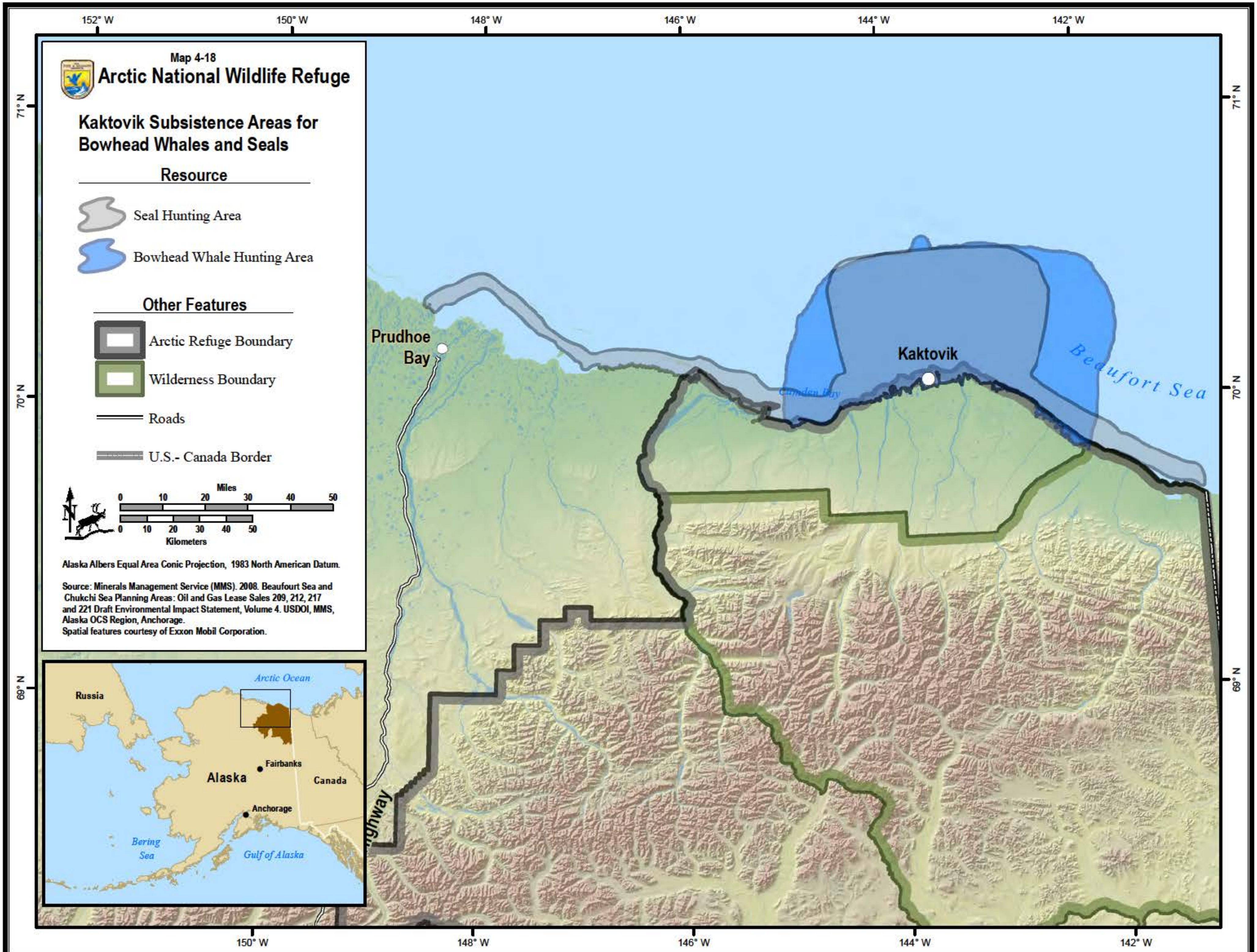
Venetie Subsistence Harvests

ADFG collected subsistence harvest data for Venetie in 1993, 1994, 1995, 1996, and 1997. The Council of Athabascan Tribal Government provided subsistence harvest information for moose, bear, and wolves for 2003 and 2004 (CATG 2002, CATG 2003, CATG 2005). Busher and Hamazaki (2005) reported subsistence harvests of salmon by Venetie residents for the years 1992 to 2003, and Busher et al. (2007) provided the same data for 2005. No per-capita or household participation rate data are available for Venetie (ADFG Community Subsistence Information System). These subsistence data are summarized by year and by species in Appendix J of the Yukon Flats National Wildlife Refuge Environmental Impact Statement for the Proposed Land Exchange (Service 2010c). Because much of the data are from years of noted reduced availability, none of the study years are considered by ADFG to be "most representative" (ADFG 2005). Estimated total annual subsistence harvests ranged from 11,000 to 24,000 pounds (ADFG Community Subsistence Information System). Estimated moose harvest from 1993 to 1997 ranged from 26 to 94 percent of the total harvest.

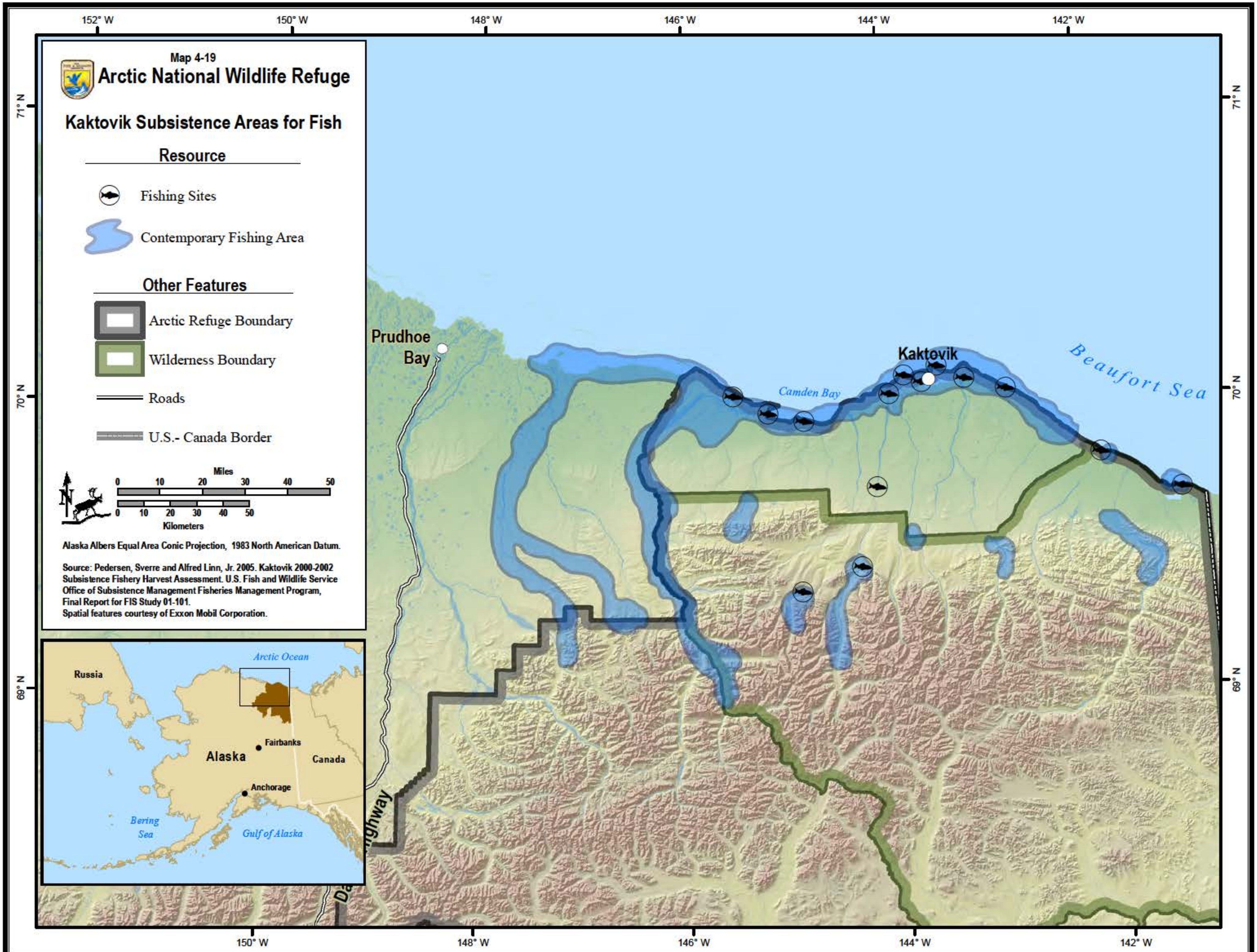
Caribou were very important components of the harvest during some years (as much as 71 percent of harvest) but not others—when no caribou harvest was reported. Fish, primarily chum salmon and whitefish, were important harvest components during some years but not others—ranging from 0.1 to 40 percent of the harvest. Busher and Hamazaki (2005) reported that the salmon harvest ranged for 233 to 8,010 fish from 1992 to 2003, and Busher et al. (2007)



Map 4-17
Arctic National Wildlife Refuge
Kaktovik Subsistence Areas for Caribou
Resource
Caribou Hunting Sites
Primary Caribou Hunting Areas
Extent of Caribou Hunting
Other Features
Arctic Refuge Boundary
Wilderness Boundary
Roads
U.S.- Canada Border
Miles
0 10 20 30 40 50
0 10 20 30 40 50
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
Source: Coffing, Michael and Sverre Pedersen. 1985. Caribou Hunting: Land Use Dimensions, Harvest Levels and Selected Aspects of the Hunt During Regulatory Year 1983-84 in Kaktovik, Alaska. Technical Paper: no. 120, Alaska Department of Fish and Game, Division of Subsistence: Fairbanks: pg 19.
Spatial features courtesy of Exxon Mobile Corporation.
Russia
Arctic Ocean
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska
Prudhoe Bay
Kaktovik
Camden Bay
Beaufort Sea
152° W
150° W
148° W
146° W
144° W
142° W
71° N
70° N
69° N



152° W
150° W
148° W
146° W
144° W
142° W
71° N
70° N
69° N
Map 4-18
Arctic National Wildlife Refuge
Kaktovik Subsistence Areas for Bowhead Whales and Seals
Resource
Seal Hunting Area
Bowhead Whale Hunting Area
Other Features
Arctic Refuge Boundary
Wilderness Boundary
Roads
U.S.- Canada Border
Miles
0 10 20 30 40 50
0 10 20 30 40 50
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
Source: Minerals Management Service (MMS). 2008. Beaufourt Sea and Chukchi Sea Planning Areas: Oil and Gas Lease Sales 209, 212, 217 and 221 Draft Environmental Impact Statement, Volume 4. USDOI, MMS, Alaska OCS Region, Anchorage.
Spatial features courtesy of Exxon Mobil Corporation.
Russia
Arctic Ocean
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska
Prudhoe Bay
Kaktovik
Beaufort Sea
ghway



Map 4-19
Arctic National Wildlife Refuge
Kaktovik Subsistence Areas for Fish
Resource
Fishing Sites
Contemporary Fishing Area
Other Features
Arctic Refuge Boundary
Wilderness Boundary
Roads
U.S.- Canada Border
Miles
0 10 20 30 40 50
0 10 20 30 40 50
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
Source: Pedersen, Sverre and Alfred Linn, Jr. 2005. Kaktovik 2000-2002 Subsistence Fishery Harvest Assessment. U.S. Fish and Wildlife Service Office of Subsistence Management Fisheries Management Program, Final Report for FIS Study 01-101.
Spatial features courtesy of Exxon Mobil Corporation.
Prudhoe Bay
Kaktovik
Camden Bay
Beaufort Sea
Arctic Ocean
Russia
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska
152° W
150° W
148° W
146° W
144° W
142° W
71° N
70° N
69° N

reported a harvest of 1,860 fish in 2005. Andersen and Jennings (2001) reported that Venetie respondents harvested 2,078 migratory birds in 2000.

Venetie Subsistence Use Areas

Subsistence use areas for Venetie are shown on Map 4-20, Map 4-21, and Map 4-22. These maps represent selected Venetie "lifetime" subsistence use areas identified by (Caulfield 1983). These data are based on 1980 interviews documenting nine respondents' lifetime subsistence use areas. This data may not represent the full range and extent of Venetie residents' contemporary use areas for resource harvesting. Harvest and use areas may have changed over time due to factors such as fluctuating populations of fish and wildlife resources, changing migration patterns, availability of resources, shifting climate and changes in habitat, and the impact of high fuel prices.

Map 4-20 depicts lifetime subsistence use areas for brown and black bear hunting, caribou hunting, and moose hunting. Map 4-21 depicts lifetime subsistence use areas for furbearer hunting and trapping, small mammal hunting, and wildfowl hunting. Map 4-22 depicts lifetime subsistence use areas for fishing, use of plants and berries, and the harvest of wood fuel and/or structural materials.

Wiseman

Wiseman is located on the middle fork of the Koyukuk River at the junction of Wiseman Creek in the Brooks Range approximately 56 miles from the Refuge boundary. Wiseman is located a short distance from the Dalton Highway about 260 miles northwest of Fairbanks. Wiseman residents who have lived in the area since the early 1970s indicate that their total area of renewable resource use has not changed over time; however, the intensity of subsistence use in specific regions of the area has changed considerably. This occurred primarily in response to changing modes of access and restrictions on their use, construction of the pipeline and haul road, and changing land management policies and hunting regulations. Construction of the Dalton Highway and oil pipeline, along with the establishment of the Gates of the Arctic National Park, greatly altered Wiseman's spatial use patterns, shifting use away from what is now the pipeline corridor and away from Gates of the Arctic National Park areas to the west (Scott 1993).

Changing land management policies and regulations, such as hunting closures and restrictions in the Dalton Road corridor, along with the increased sport hunting (particularly guided hunting) to the east of the corridor after the State's individually managed (exclusive) guide areas were abolished (Owsichek v. State, Guide Licensing, 1988,763 P.2d 488) resulted in substantially increased competition for resources between local and general hunters. With increasing numbers of sport hunters in the corridor and to the east, many of Wiseman subsistence hunters shifted their use areas more intensively back to the west (Scott 1993).

Wiseman subsistence use areas south of the Brooks Range, where aircraft access is allowed, extended eastwardly up to the edge of Arctic Refuge (J. Reakoff, Chair of the Western Interior Federal Subsistence Regional Advisory Council, pers. comm.). On the north side of the Brooks Range, Wiseman residents have a long history of utilizing the Atigun Gorge and Galbraith Lake area, and the Sagavanirktok, Ribdon, and Ivishak River drainages to hunt and fish. Caribou would be hunted in the summer and fall, as would sheep in late winter (J. Reakoff, Chair of the Western Interior Federal Subsistence Regional Advisory Council, pers.

comm.). Wiseman residents are known to travel down the Atigun Gorge, traveling outside of the Dalton Road corridor to hunt. Federal Subsistence Regulations list Wiseman as having customary and traditional use of Dall's sheep and caribou in Game Management Unit 26B (Map 4-24), which includes Refuge lands north of the Brooks Range.

In addition to changing land management policies and regulations affecting local use area and increased competition for resource by non-local users, Wiseman's subsistence harvest and use areas may have changed over time due to factors such as fluctuating populations of fish and wildlife resources, changing migration patterns, availability of resources, shifting climate and changes in habitat, and the impact of high fuel prices.

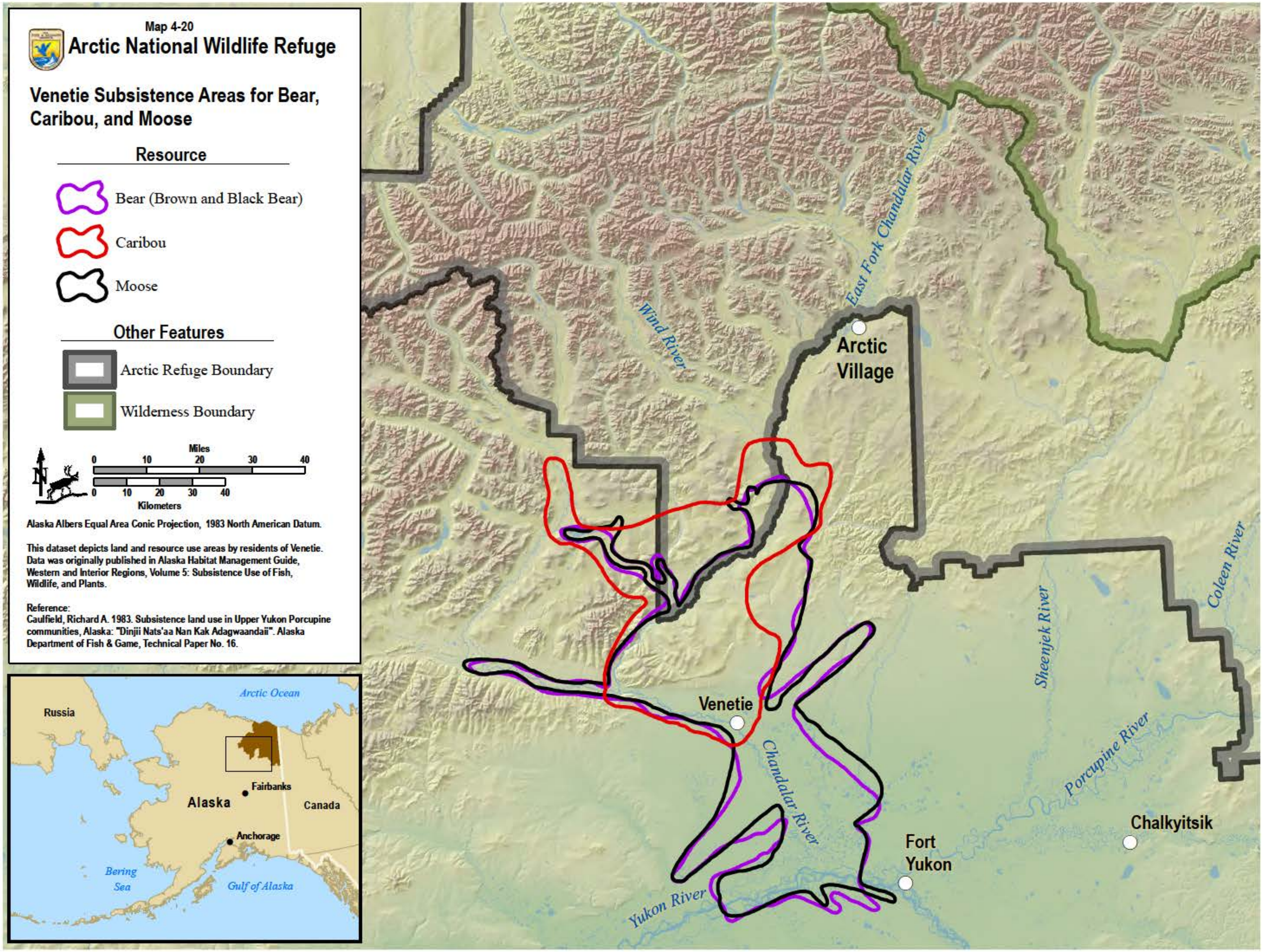
Map 4-23 depicts the land use areas by Wiseman residents from Scott's 1993 study regarding land and renewable resource use over time. The Primary Use Area illustrates the land area Wiseman residents consider to be of critical importance in conducting their resource harvest activities. The Extent of Use Area on the map illustrates the land area that residents consider extremely important in conducting their resource harvest activities.

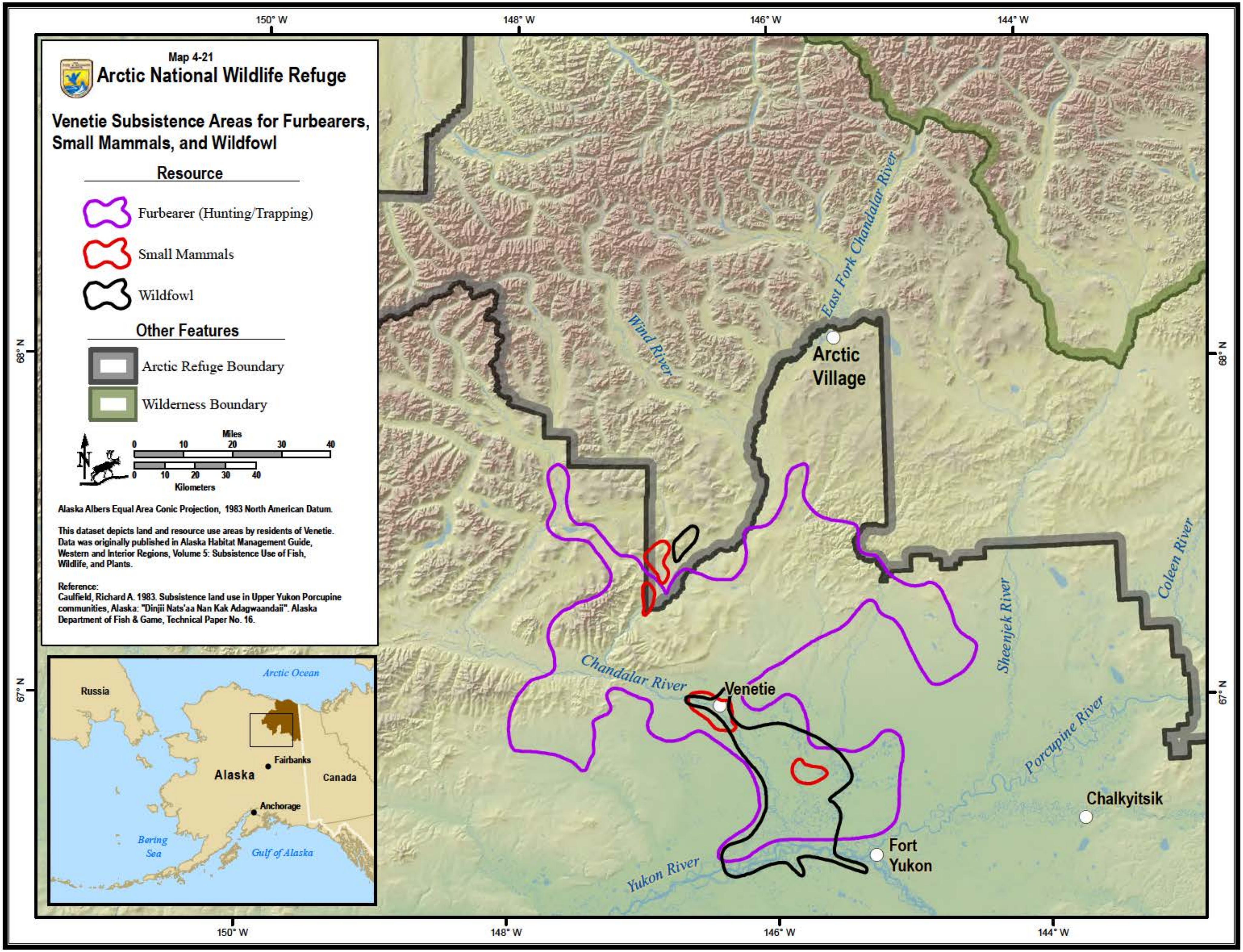
4.4.4.3 Trapping

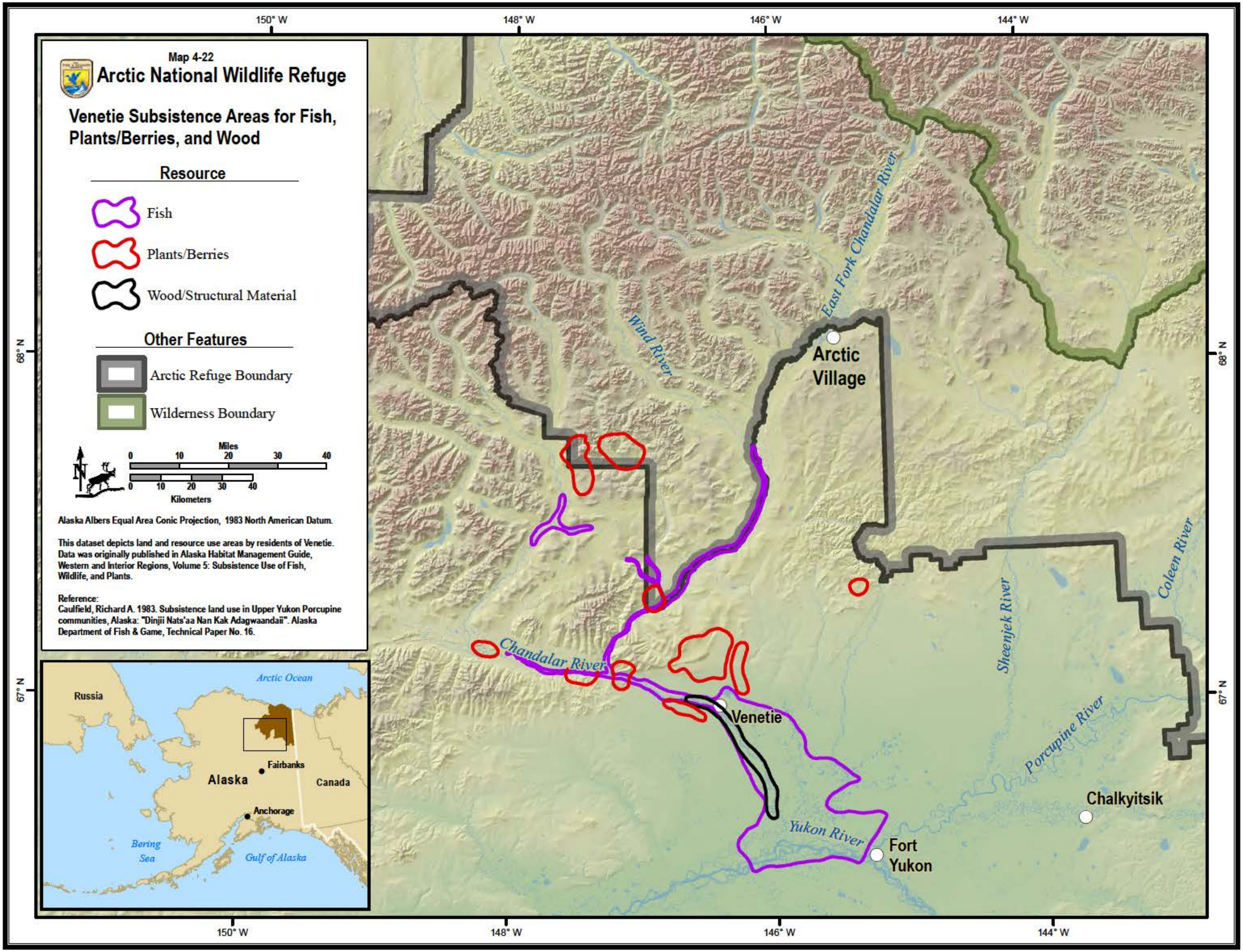
Early subsistence trapping harvest information is poorly documented, but the use of fur has long been an important resource for making clothing items, such as hats, gloves, parkas, moccasins, or mukluks, or using as material for bedding and rugs. Historically, the sale of fur for cash income by residents of communities near the Refuge has been an important component of the local economy. While incomes from trapping have been low in recent years, trapping still represents one of the few cash-earning options for residents during the winter months and remains an integral part of the mixed subsistence-cash economy of the study area communities (Andersen 1993). Some residents also use fur to make Alaska Native handicrafts for personal use and for sale. Meat from furbearers such as beaver, muskrat, and lynx is prized for its nutritional value (Caulfield 1983).

Trapping does not involve a large number of people, but it does require use of large geographic areas to locate and harvest various furbearer species. Trapping remains a highly labor-intensive activity, demanding long hours and hard work for relatively small and often uncertain returns. Most village subsistence economies are characterized by few full-time jobs and limited opportunities to earn cash. Over the years, local residents have returned to trapping after short periods of wage labor provided by seasonal road construction, firefighting, commercial fishing, oil industry jobs, military service, and other limited wage earning opportunities.

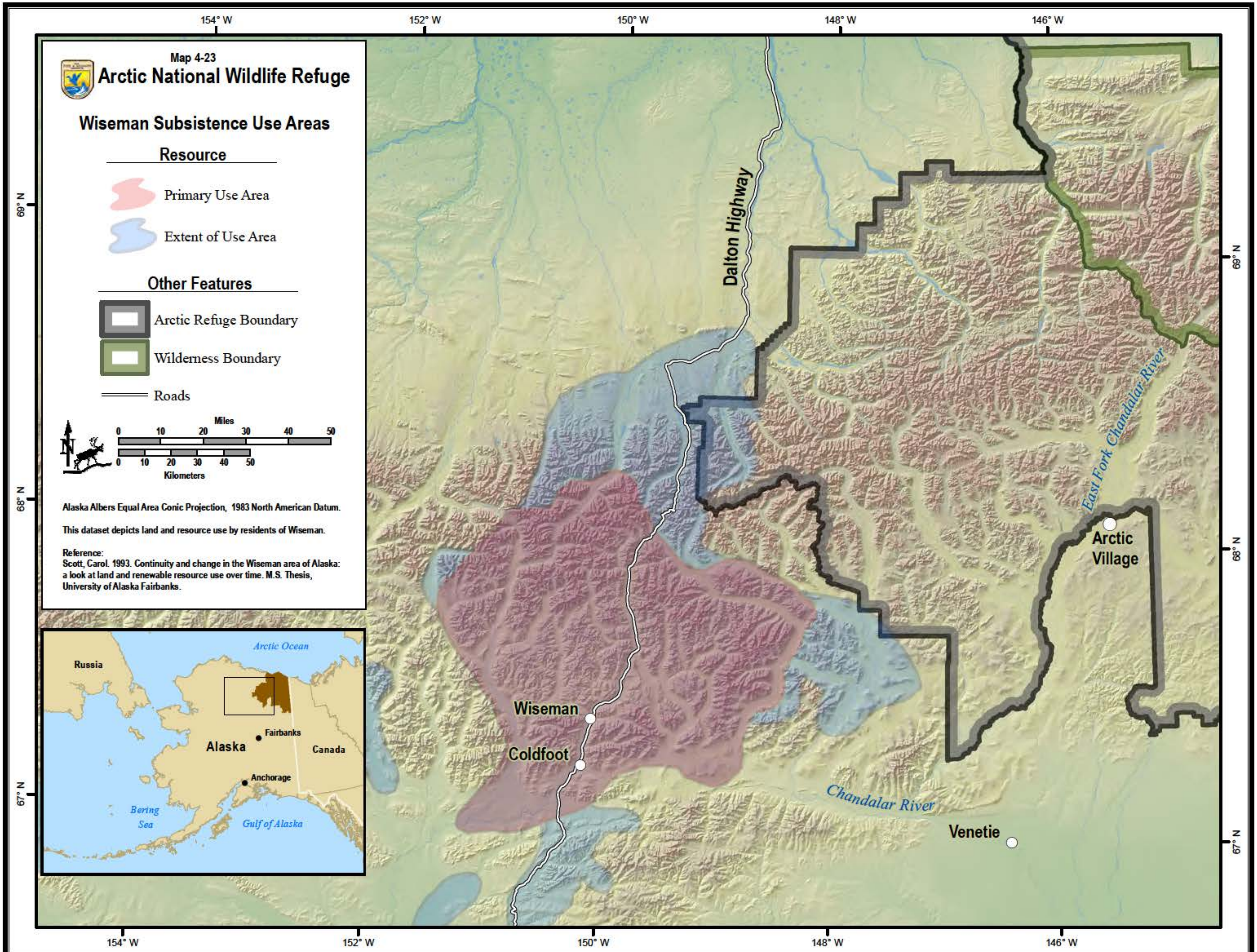
On the South Slope, trapping continues to be an important activity for residents of the upper Yukon region. Several mammal species are trapped for fur, including marten, lynx, red fox, beaver, muskrat, wolf, wolverine, mink, and river otter. Residents of Arctic Village, Venetie, Chalkyitsik, and Fort Yukon trap these species on the Refuge during winter. Established traplines may be trapped for several years then left fallow for other years depending on abundance and distribution of furbearers. Historically, beaver have been an important furbearing animal in the Yukon region. Muskrats also have been important, exceeding the value of beaver in some years. The key to profits has often been the abundance of beaver and muskrat (the amount of species harvested), not necessarily the per unit price of the pelts. Based on current fur prices and resource abundance, marten is probably the most important


Map 4-20
Arctic National Wildlife Refuge
Venetie Subsistence Areas for Bear, Caribou, and Moose
Resource
Bear (Brown and Black Bear)
Caribou
Moose
Other Features
Arctic Refuge Boundary
Wilderness Boundary
Miles
0 10 20 30 40
0 10 20 30 40
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
This dataset depicts land and resource use areas by residents of Venetie. Data was originally published in Alaska Habitat Management Guide, Western and Interior Regions, Volume 5: Subsistence Use of Fish, Wildlife, and Plants.
Reference:
Caulfield, Richard A. 1983. Subsistence land use in Upper Yukon Porcupine communities, Alaska: "Dinjii Nats'aa Nan Kak Adagwaandaii". Alaska Department of Fish & Game, Technical Paper No. 16.
Russia
Arctic Ocean
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska
East Fork Chandalar River
Wind River
Arctic Village
Venetie
Chandalar River
Sheenjek River
Coleen River
Porcupine River
Fort Yukon
Chalkyitsik
Yukon River


Map 4-21
Arctic National Wildlife Refuge
Venetie Subsistence Areas for Furbearers, Small Mammals, and Wildfowl
Resource
Furbearer (Hunting/Trapping)
Small Mammals
Wildfowl
Other Features
Arctic Refuge Boundary
Wilderness Boundary
Miles
0 10 20 30 40
0 10 20 30 40
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
This dataset depicts land and resource use areas by residents of Venetie. Data was originally published in Alaska Habitat Management Guide, Western and Interior Regions, Volume 5: Subsistence Use of Fish, Wildlife, and Plants.
Reference:
Caulfield, Richard A. 1983. Subsistence land use in Upper Yukon Porcupine communities, Alaska: "Dinjii Nats'aa Nan Kak Adagwaandaii". Alaska Department of Fish & Game, Technical Paper No. 16.
Russia
Arctic Ocean
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska
150° W
148° W
146° W
144° W
68° N
67° N
East Fork Chandalar River
Wind River
Arctic Village
Chandalar River
Venetie
Sheenjek River
Coleen River
Porcupine River
Chalkyitsik
Fort Yukon
Yukon River



Map 4-22
Arctic National Wildlife Refuge
Venetie Subsistence Areas for Fish, Plants/Berries, and Wood
Resource
Fish
Plants/Berries
Wood/Structural Material
Other Features
Arctic Refuge Boundary
Wilderness Boundary
Miles
0 10 20 30 40
0 10 20 30 40
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
This dataset depicts land and resource use areas by residents of Venetie. Data was originally published in Alaska Habitat Management Guide, Western and Interior Regions, Volume 5: Subsistence Use of Fish, Wildlife, and Plants.
Reference:
Caulfield, Richard A. 1983. Subsistence land use in Upper Yukon Porcupine communities, Alaska: "Dinjii Nats'aa Nan Kak Adagwaandaii". Alaska Department of Fish & Game, Technical Paper No. 16.
150° W
148° W
146° W
144° W
68° N
67° N
East Fork Chandalar River
Wind River
Arctic Village
Chandalar River
Venetie
Sheenjek River
Coleen River
Porcupine River
Yukon River
Fort Yukon
Chalkyitsik
Arctic Ocean
Russia
Alaska
Fairbanks
Anchorage
Canada
Bering Sea
Gulf of Alaska



Map 4-23
Arctic National Wildlife Refuge
Wiseman Subsistence Use Areas
Resource
Primary Use Area
Extent of Use Area
Other Features
Arctic Refuge Boundary
Wilderness Boundary
Roads
Miles
0 10 20 30 40 50
0 10 20 30 40 50
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
This dataset depicts land and resource use by residents of Wiseman.
Reference:
Scott, Carol. 1993. Continuity and change in the Wiseman area of Alaska: a look at land and renewable resource use over time. M.S. Thesis, University of Alaska Fairbanks.
Russia
Arctic Ocean
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska
Dalton Highway
Wiseman
Coldfoot
Arctic Village
Venetie
East Fork Chandalar River
Chandalar River
154° W
152° W
150° W
148° W
146° W
69° N
68° N
67° N

fur animal sought by trappers south of the Brooks Range. Fur trapping provides the only notable export item for the South Slope communities, although revenues can vary greatly from year to year depending on harvest levels and fur prices (Andersen 1993).

On the North Slope, residents of Kaktovik trap red fox in inland areas and arctic foxes in coastal areas. Wolf and wolverine are also valued for their fur, but on the North Slope are usually taken by hunting rather than trapping. Because of decreased demand and dropping fur prices, as well as the considerable time investment in setting and checking a trapline, trapping activity has decreased with time for Kaktovik residents. ADFG's estimated harvest for wolf and wolverine from Refuge lands in the mid-1980s is still a good indicator of harvest effort and take. On the North Slope, 11 wolves were harvested in 1983–1984, 5 wolves in 1984–1985, and 1 wolf in 1985–1986.

Wolverines are also highly valued for their fur, especially for making parka ruffs. Kaktovik residents harvest wolverines most often in the foothills and northern mountainous areas of the Sadlerochit, Hulahula, and Okpilak rivers. ADFG records indicate that an average of about one wolverine per year is harvested; this may be an underestimate because of incomplete reporting (Clough et al. 1987). During the winter of 1980–1981, seven wolverines were taken by Kaktovik residents (Jacobson and Wentworth 1982).

4.4.5 Visitor Use and Recreation

4.4.5.1 Overview

We define visitor use as any use of the Refuge by recreational visitors or general hunting and fishing visitors, not including federally qualified subsistence users or other local residents (Appendix M). Subsistence use and harvest on Refuge lands are not discussed in this section; we only discuss general hunting and trapping harvest data available from records compiled by the State of Alaska.

People from around the State, the nation, and the world visit Arctic Refuge. Visitors to Arctic Refuge may experience wilderness qualities and opportunities that are unique relative to most protected areas in North America. While visiting, people may travel and explore Refuge lands for days or weeks without seeing another person. Arctic Refuge is a place where people may experience and appreciate remarkable scenery, diverse wildlife resources, and remoteness (Christensen and Christensen 2009).

Visitors to Arctic Refuge participate in a variety of activities, such as river floating, hiking, backpacking, camping, long-distance expeditions, mountaineering, dog sledding, berry picking, wildlife observation, and photography. Hunting is also a popular activity at the Refuge. Most recreational hunters (referred to as general hunters) visit the Refuge to hunt Dall's sheep, caribou, moose, and/or brown bears.

Recreational fishing (referred to as general fishing) may be a secondary activity for some visitors, but managers do not consider general fishing to be a primary reason for visiting Arctic Refuge. General fishing is not discussed in this section because it is not a prominent recreational activity, and managers do not have data on general fishing.

4.4.5.2 Early Records of Visitor Use

There was little recreational use in 1960 when the original Arctic National Wildlife Range (Range) was established. A small number of hikers, backpackers, and general hunters occasionally visited the Range in the early 1960s. According to Arctic Refuge Draft River Management Plan and Environmental Assessment (1993), few people were canoeing in the Range in the 1960s. Commercial hunting guides most likely began working in the Range as early as the late 1960s, but observations and data on visitor use from that time is substantially limited because the Range was not staffed until fall 1969. Complete and accurate data recording early use are not available, and we report best estimates of visitor numbers for the Range.

By the early 1970s, Arctic Alaska and the Brooks Range were receiving considerable national and international attention due to proposals to create public lands and discovery of oil at Prudhoe Bay in 1968. Use of the Range by visitors was less than 1,000 use days per year (a use day is defined as one person spending one 24 hour period in Arctic Refuge) but was most likely increasing at relatively slow rates (Arctic Refuge 1993). A bush pilot named Walt Audi began flying from Kaktovik in 1968, offering commercial fight services in 1972. People were known to hike between Barter Island and Arctic Village or explore parts of the Refuge for extended periods of recreation (Arctic Refuge 1976). Other early visitors were mountain climbing, fishing, trapping, photographing, canoeing, boating, camping, and berry picking. Hunting for Dall's sheep was especially popular. Hunting guide Joe Want began taking horses from Circle to the upper Sheenjek River in the early 1970s, and Marlin Grasser was operating on the Hulahula River during this time.

A visitor use study estimated that 281 persons visited the original Range in 1975. More than half of these visitors were general hunters. The study reported the greatest number of use days for backpackers, many of whom reportedly hiked and camped in the upper Hulahula and Okpilak river valleys. Another study estimated that 248 general hunters and 186 recreational visitors visited in 1977. General hunters accounted for 51 percent of the use days (Arctic Refuge 1993). In addition to this early visitation data, a descriptive study of activities, attitudes, and management preferences of recreationists was conducted on the Arctic National Wildlife Range and published in 1980 (Warren 1980).

Eight to ten general hunting guides were thought to be operating commercially in the area in 1974 (Arctic Refuge 1993). One recreation guide was issued a commercial permit in 1975, increasing to five permits in 1977 (Arctic Refuge 1977). A similar level of commercial activity related to general hunting continued annually through 1979 (Arctic Refuge 1979, Arctic Refuge 1980).

A new era of visitor use activity began with the expansion of the Range to the Arctic National Wildlife Refuge in 1980. Guided and private recreation continued to increase, especially near the end of the 1980s. Several factors contributed to this increase, including changes brought about by the Alaska National Interest Lands Conservation Act of 1980 and the State of Alaska's efforts to promote tourism. Talk of possible oil and gas development at Arctic Refuge most likely heightened public awareness of the Refuge (Arctic Refuge 1987).

In the early 1980s, backpacking and camping were the most popular summer activities, followed by river floating. General hunting for big game was the most popular fall recreational activity on the Refuge in the 1980s. River floating became the most popular activity at the Refuge by the end of the decade (Arctic Refuge 1990). Wildlife observation and photography also were integral parts of most recreational visits. Fishing occasionally occurred as a secondary or incidental activity on recreational trips (Arctic Refuge 1993).

In the early 1980s, the Dalton Highway was not yet open to the public, but some data on travel by vehicles servicing facilities were collected. In 1983, an average of 103 vehicles per day was estimated to pass the Yukon River Bridge. In 1984, averages of 150 vehicles per day were estimated to pass the bridge (State Department of Transportation Planning, pers. comm.).

The Refuge first required permits for commercial air operators in 1987. These operators were required to record details about their clients' trips, which provided the best and most trusted source of data on numbers of visitors to the Refuge. During 1980 and 1981, the Refuge estimated 3,450 use days by recreational visitors and general hunters, who were guided and transported by commercial air operators (non-guided). This only represents a portion of the total use for those years because the number of unreported charters and private aircraft that flew into the Refuge is unknown.

Data provided by Audi Air, Inc., a primary air operator service at that time based on the North Slope of the Refuge, show some evidence of an increase in visitor use beginning around 1983. Audi Air flew 109 people in 1983, 147 in 1984, and 165 in 1985 (Arctic Refuge 1984, Arctic Refuge 1985, Arctic Refuge 1986). Data from 1986 continues this trend, and shows Audi Air provided the majority of the charter air service north of the Brooks Range in the Refuge and reported flying in 568 hunters, backpackers, floaters, fishermen, and other charters during that year. This dramatic increase might be attributed to improvements in record-keeping by Audi Air, but it also includes charters originating from Prudhoe Bay (which may or may not have landed in the Refuge), in addition to those originating from Barter Island, in the Refuge. Since there were also an undetermined additional number of visitors who were flown in by other charter services and by privately-owned aircraft, the approximate estimate provided by Audi Air in 1986 serves as a reasonable indicator of increasing, but not necessarily dramatically increasing use during this time (Arctic Refuge 1987).

Substantial increases in visitor use at the Refuge occurred in 1988 and 1989, especially in two main river valleys. In the three-year period between 1987–1989, commercial river use was reported to have increased by 395 percent on the Kongakut River and 518 percent on the Hulahula River (Arctic Refuge 1988, Arctic Refuge 1989, Arctic Refuge 1990). The number of permits issued by the Refuge to commercial service providers had increased from seven in 1980 to 20 in 1989. The 20 guides provided 56 float or river-based backpacking trips to groups that ranged from 3 to 28 people. The increase in visitor use recorded in the 1980s prompted interest and support for the development of the Arctic Refuge Draft River Management Plan and Environmental Assessment which was drafted but never formally adopted or implemented (Arctic Refuge 1993).

In 1992, after soliciting public comments on a draft policy, the Service established a Regional Policy and formal process in which big-game guides were competitively selected to operate on Refuge lands. An environmental assessment was completed with the original guide allocation and a compatibility determination done which found guided hunting to be compatible with Refuge purposes. This competitive permit system was later codified in 50 CFR 36.41. The draft regulations were published in the "Federal Register" on November 1, 1996 for a 60-day public review period. Public meetings were held in Anchorage and Fairbanks, Alaska, during the period of public review of the draft regulations. The competitive application process used to select big-game hunting guides on Arctic Refuge continues to this day, and is what defines the available number of guided hunting opportunities, which is not increasing.

Managers at Arctic Refuge have limited unguided hunting and recreational visitor information for the period between 1992 and 1997. Collection methods for the data that exist are unconfirmed.

4.4.5.3 Contemporary Records of Visitor Use

Arctic Refuge is vast, geographically remote, and primarily managed to provide visitors with a wilderness experience (Service 1988a). There are no maintained facilities on the Refuge, and visitors may come and go from the Refuge without campsite assignments or registration requirements. The Refuge has no formal registration system to comprehensively track visitor use and recreation trends, and managers currently use no formal methods to document visitors who access the Refuge on their own without the commercial services of a guide or commercial air operator. An unknown number of visitors enter the Refuge each year by private planes and boats or by hiking.

The Refuge staff requires permits for all commercial uses. The number of hunt guide permits issued is limited, and hunt guide permits are issued for multiple years under a competitive program, whereas other service providers apply annually for an unlimited number of permits. Big-game guide permits are valid for five years, and guides can opt for a one-time, five-year permit extension based on good performance, after which guides must again compete for the opportunity to obtain new permits. Because guided hunting permits are competitively awarded, hunting guides are the most regulated, restricted, and monitored user group on Arctic Refuge. On Arctic Refuge, permitted hunting guides have exclusive commercial use of a guide use area but they do not have exclusive hunting use. In other words, all guide use areas are open to unguided hunting by the general public.

The State of Alaska hunting regulations require, under most circumstances, non-residents to hunt with a guide if they're pursuing brown bear, Dall's sheep or mountain goat. By allowing commercial hunting guides on national wildlife refuges in Alaska, the Service is providing hunting opportunities to all visitors, not just Alaska residents.

Since 1980, the Refuge has issued an increasing number of annual permits to commercial recreation operators and commercial air operators (includes air-taxis and air transporters) for the purpose of bringing visitors to the Refuge (Figure 4-12).

This increase in number of annual permits issued is particularly notable among visitors guided in Atigun Gorge, which is accessible from the Dalton Highway. The number of service providers operating in the Atigun Gorge has increased from one to five businesses since 2001 (Arctic Refuge Commercial Permit Database, Service, unpublished data). Preliminary data also suggests a recent notable increase in the number of unguided general hunters served by permitted, State-licensed, air transporters (Appendix M) (Arctic Refuge Commercial Permit Database, Service, unpublished data).

Guides and air operators are required to submit client use reports as a condition of their permits. Beginning in 2001, managers clarified and enforced the instructions given to commercial operators for reporting numbers of clients and other data to ensure consistency. Managers have created a database of numbers of visitors and other information provided in the client use reports. Managers use this database as a consistent source of data for estimating how many people use commercial services to access the Refuge each year. Client use reports also provide insights about group size and distribution of visitors.

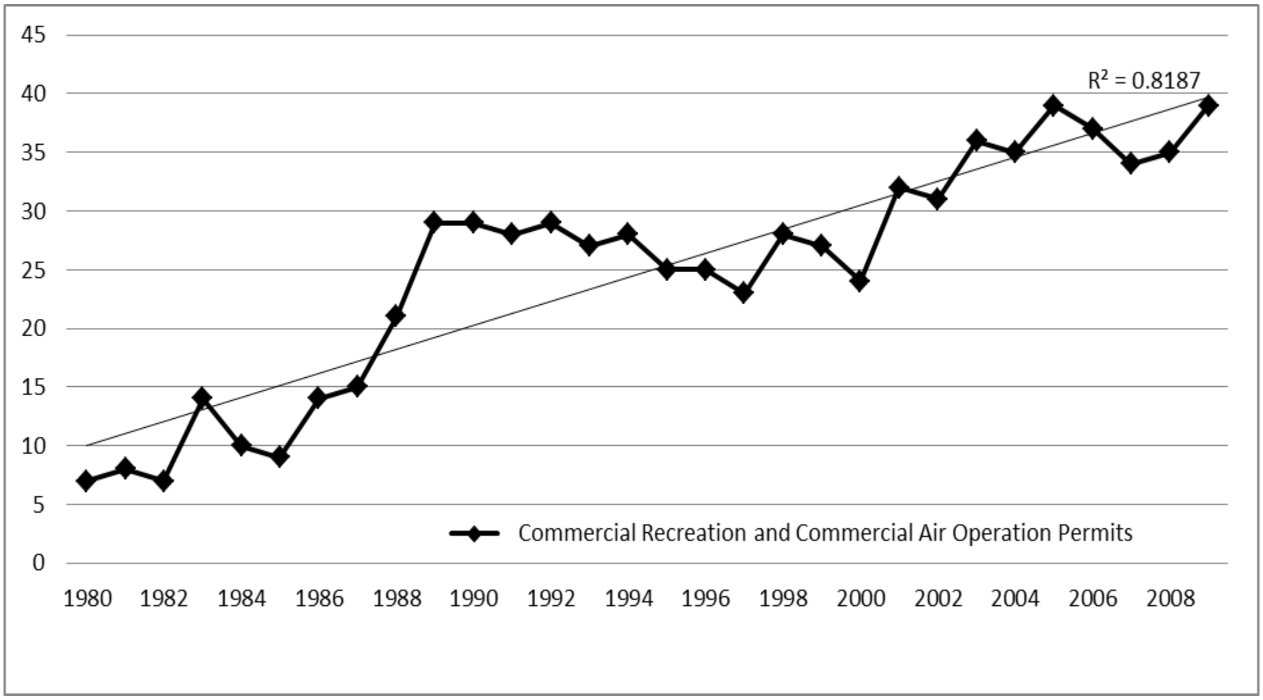


Figure 4-12. Numbers of commercial permits issues by Arctic Refuge, 1980–2009 (excludes hunt guide permits).

The numbers of visitors who were flown in or guided by a commercial operator during 2001–2009 ranged from a low of 852 visitors in 2009 to a high of 1,128 visitors in 2005 (Figure 4-13). In most years from 2001 to 2009, about one-half of commercially-supported visitors were accompanied by a permitted guide. Numbers of guided visitors decreased after 2005, while numbers of non-guided visitors remained relatively stable (Figure 4-14). A reduced group size or number of trips taken by each guide business may account for this decrease coincident with an overall increase in permitted operators.

Managers at Arctic Refuge suspect a substantial amount of visitors originate from lands outside or adjacent to the Refuge boundary, such as the Dalton Highway and airports served by commercial airlines near the Refuge boundary. On an annual basis, managers collect voluntary reports of independent visitor use from people who drive the Dalton Highway and visit the Arctic Interagency Visitor Center in Coldfoot. The Refuge collects similar information about residents of the University of Alaska-Fairbanks Institute of Arctic Biology Toolik Field Station north of Galbraith Lake from Station managers. Arctic Refuge occasionally participates in recreation research surveys to learn about visitor use.

In 2009, the Refuge estimated that the total number of documented visitors was approximately 1,000 people (Figure 4-13). About 12 percent of these visitors voluntarily reported traveling to the Refuge from the Dalton Highway. Of this smaller group, eight percent were people working at Toolik Field Station and four percent were visitors who voluntarily reported their travels in or near the Refuge at the visitor center in Coldfoot. The number of visitors who do not use commercial services to access the Refuge is most likely higher than what is reflected by the voluntary reports collected at these locations.

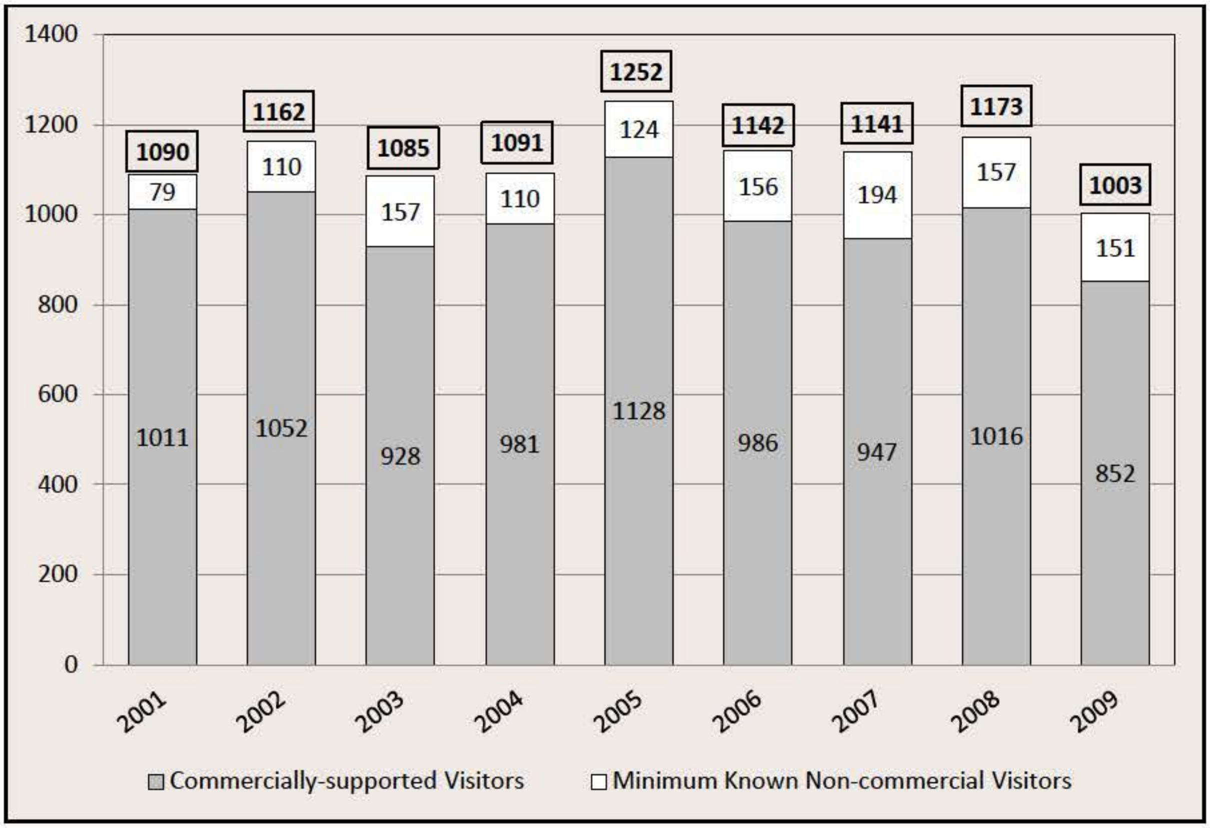


Figure 4-13. Total number of documented visitors. Visitors at Arctic Refuge based on client use reports and voluntary reports from Toolik Lake and Coldfoot Visitor Center, 2001–2009.

People who visit the Refuge on their own without using the services of a commercial operator may concentrate in the Atigun Gorge area (Reed and St. Martin 2009). Since the Dalton Highway was opened to the public in 1994, the number of people driving it and visiting the surrounding area has increased. The highway provides an access corridor to Arctic Refuge for hikers, hunters, mushers, and skiers (Christensen and Christensen 2009). The scenic Atigun Gorge and adjacent drainages are easily accessible from this road, while most other Refuge lands are more difficult to reach because of the absence of roads.

Alaska residents travelling the Dalton Highway reported accessing lands between Atigun Pass and Toolik and in the Galbraith Lake area (Stegmann et al. 2008). The Alaska Residents Statistics Program reported 11 percent of residents of interior Alaska who responded to this survey had visited areas accessible from the Dalton Highway, including Arctic Refuge (Fix 2009).

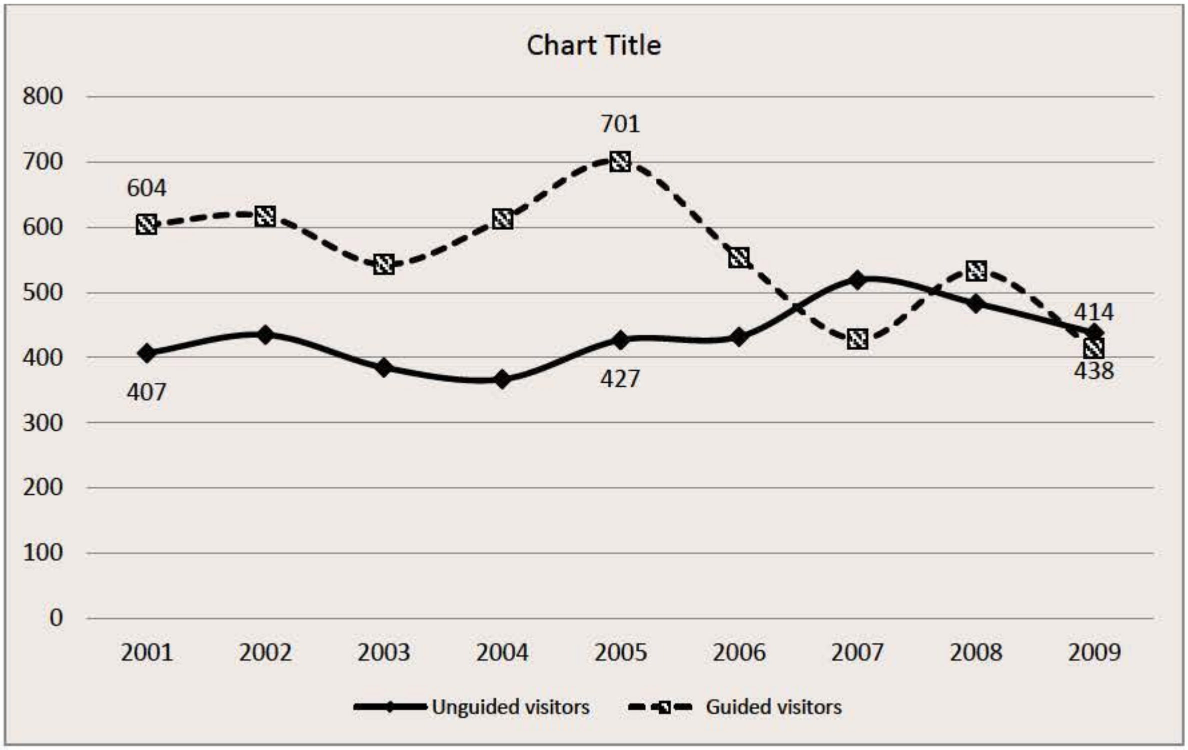


Figure 4-14. Comparison of guided and non-guided commercially-supported visitors to Arctic Refuge, 2001–2009.

4.4.5.4 Recreational Activities

Recreational activities by commercially-supported visitors occur in five primary categories: general hunting, hiking and/or backpacking, river floating, base-camping, and other recreation (Appendix M). General hunters usually hike, camp, and float rivers while hunting. Recreational visitors, including some hunters, may also engage in wildlife observation, including polar bear viewing, bird watching, photography, mountaineering, dog sledding, sea kayaking, and fishing. A more detailed summary of commercially-supported recreational visitor activity by year can be viewed on the Arctic Refuge website (Arctic Refuge 2011).

Floating rivers is the most frequently reported activity for commercially-supported visitors to Arctic Refuge, but hunting and hiking and/or backpacking are also popular (Figure 4-15). These data include the number of clients and guides for river floating and hiking but do not include the number of guides for hunting. Recent research that surveyed over 300 Refuge visitors corroborates these popular activities: 49 percent of respondents were river floating, 40 percent were backpacking and/or hiking, and 21 percent were hunting (Christensen and Christensen 2009).

Because the air space of Arctic Refuge is regulated by the Federal Aviation Administration—not the Refuge—commercial flightseeing trips are not currently subject to regulation, nor are they monitored or quantified unless the pilot lands on the Refuge. If commercial flightseeing trips were to land on the Refuge, they would require a special use permit, and the visit(s) would be reported in client use reports submitted by these commercial air operators.

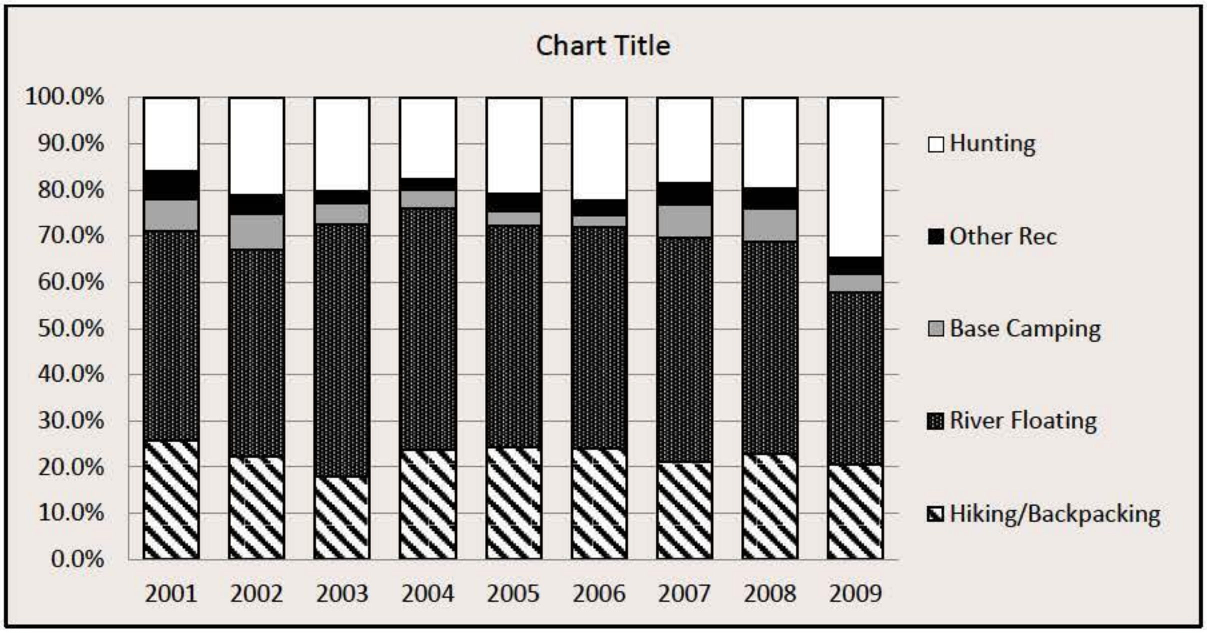


Figure 4-15. Comparison of guided and non-guided commercially-supported visitors to Arctic Refuge, 2001–2009.

4.4.5.5 Visitor Access, Distribution, and Group Size

Managers have documented that most people visit Arctic Refuge during the summer and fall seasons during June, July, August, and September. Managers suspect that most undocumented visitors also prefer this time of year, but some most likely visit the Refuge in spring and winter. The main recreational season is short due to weather and river conditions, with a total of six to eight weeks when water levels in most rivers are adequate for floating and the weather is ideal for backpacking. With long periods of summer daylight, rivers may be floated in three to five days, but most groups tend to spend considerable time relaxing and hiking, extending their trips to more than five days (Arctic Refuge 2011, Christensen and Christensen 2009).

The primary means of access for all visitors in and out of Arctic Refuge is by aircraft. Pilots can only land where ground topography or lake size are appropriate, limiting the number of useable access sites. Wheeled aircraft are predominantly used, particularly on the North Slope, though float planes are occasionally used in the Refuge. Motorboat use by visitors, which is generally not common, occurs almost exclusively on the south side for general hunting. Motorboats are occasionally used for polar bear viewing along the Arctic coast near Barter Island and on rivers accessible from the Dalton Highway. Inflatable rafts and other types of non-motorized craft are commonly used when and where water depth is adequate. Recreational floaters tend to use rafts, although packrafts, kayaks, and canoes are sometimes used.

Rivers in the northern parts of the Refuge often have open and treeless riparian areas, allowing recreational visitors to observe the presence of other groups of visitors over long distances. Hikers and floaters tend to make use of the same primary aircraft access sites, mostly along rivers. Hikers tend to wander away from riparian areas to traverse side valleys, ridge tops, and mountainsides, encountering floaters only intermittently while crossing rivers or camping in riparian areas. Concentration and overlap of visitors around primary access sites can occur, but there is little competition for camping areas, and few encounters occur between hikers and river floaters away from access and egress sites. The exact locations of hiking routes and distributions of hikers in river corridors are difficult to determine. Managers track where visitors enter the Refuge but have less data on their travel routes.

On average, 77 percent of commercially-supported visitor use occurs north of the Brooks Range, while about 23 percent occurs on the south side, and nearly 24 percent of commercially-supported visitors to the Refuge visit the Kongakut River drainage (Arctic Refuge 2011). Other popular North Slope rivers include the Hulahula River (10 percent), Marsh Fork-Canning River (nine percent), Jago River (six percent), and main stem of the Canning River (five percent). Similar to the data from client use reports, a recent visitor survey found that the most common entry places reported by respondents were the Kongakut (27 percent), Canning (Marsh Fork and main stem combined) (18 percent), and Hulahula (13 percent) drainages (Christensen and Christensen 2009). South of the Brooks Range, the Sheenjek River (10 percent) is most commonly visited. The Coleen River also has notable amounts of visitor use (four percent) (Arctic Refuge 2011).

Group size and length of stay may affect resource conditions and people's wilderness experience. In 2001, commercial groups were restricted to no more than 10 individuals on rivers and 7 when travelling on land. Managers continue to require these group sizes for commercial operators and recommend them to non-guided visitors, though reports of non-guided Dalton Highway-based hiking visitors exceeding group size recommendations are common (Arctic Refuge 2008a). In summer and fall of 2008, researchers found that average group size was six visitors, and groups spent an average of 11 days and camped at an average of six locations during their trips to Arctic Refuge (Christensen and Christensen 2009). Over 80 percent of respondents in this study said that they support limits on group size, preferring on average a maximum of nine people for float trips and base camping (Christensen and Christensen 2009). In 2009, client use reports showed that

visitors spent about nine days in the Refuge in groups that averaged five people. The calculation of this weighted average excludes guided hunters because hunting guides are not required to report group size (Arctic Refuge 2011).

Commercially-supported visitor use data shows that groups on the Kongakut River tend to be slightly larger than groups visiting other river drainages. The Sheenjek River is generally visited by much smaller groups than other rivers in the Refuge, and floaters on the Sheenjek River tend to stay one day longer than the overall average. For the four most popular rivers in Arctic Refuge, numbers of visitors are down in recent years, while visitor numbers for the Canning River, particularly the Marsh Fork, have slightly increased since 2001 (Arctic Refuge 2011).

4.4.5.6 Recreational Floating of the Kongakut River

Approximately 240 Refuge visitors travel to the Kongakut River within a six to eight week period each year. Most people visit the Kongakut River corridor during two peak times: two weeks in mid- to late June to witness the mass caribou migration on the lower portions of the river and two weeks in mid-August to hunt Dall's sheep in the mountainous headwaters (Figure 4-16).

In a recent visitor study, survey respondents reported that they encountered an average of two other groups during their trip on the Kongakut River; they also observed four airplanes and saw an average of one site with evidence of previous visitors (Christensen and Christensen 2009). Managers suspect that encounters between groups of floaters on the Kongakut River are higher than at other areas of the Refuge. During limited monitoring efforts from the air and on the ground, Refuge staff have observed large numbers of individuals (i.e., as many as five groups totaling at least 39 visitors at one time) at primary access points along the Kongakut River (Bartlett 2007). Visitor impact monitoring, which has documented 27 impacted sites and at least 10 impaired sites (Appendix M) along the river, is limited, occurring approximately every six years (Arctic Refuge 2010). Typically, only one or two officers will float the river one time during June to check permits of air operators and recreational guides; private users are contacted incidentally during these efforts. During the Dall's sheep hunting season, an officer occasionally flies over the Kongakut River and contacts floaters and/or hunters where it is safe to land.

A number of concerns about issues related to recreation on the Kongakut River have been identified by managers, permittees, visitors, and residents of the village of Kaktovik. Refuge managers consider the potential effects of current conditions on visitor experiences. With a primary responsibility to preserve Wilderness character, clear objectives—and an understanding of how those objectives will be attained to achieve desired conditions (Appendix M)—is needed for the Kongakut River and other places on the Refuge (Cole 2004, Landres 2004).

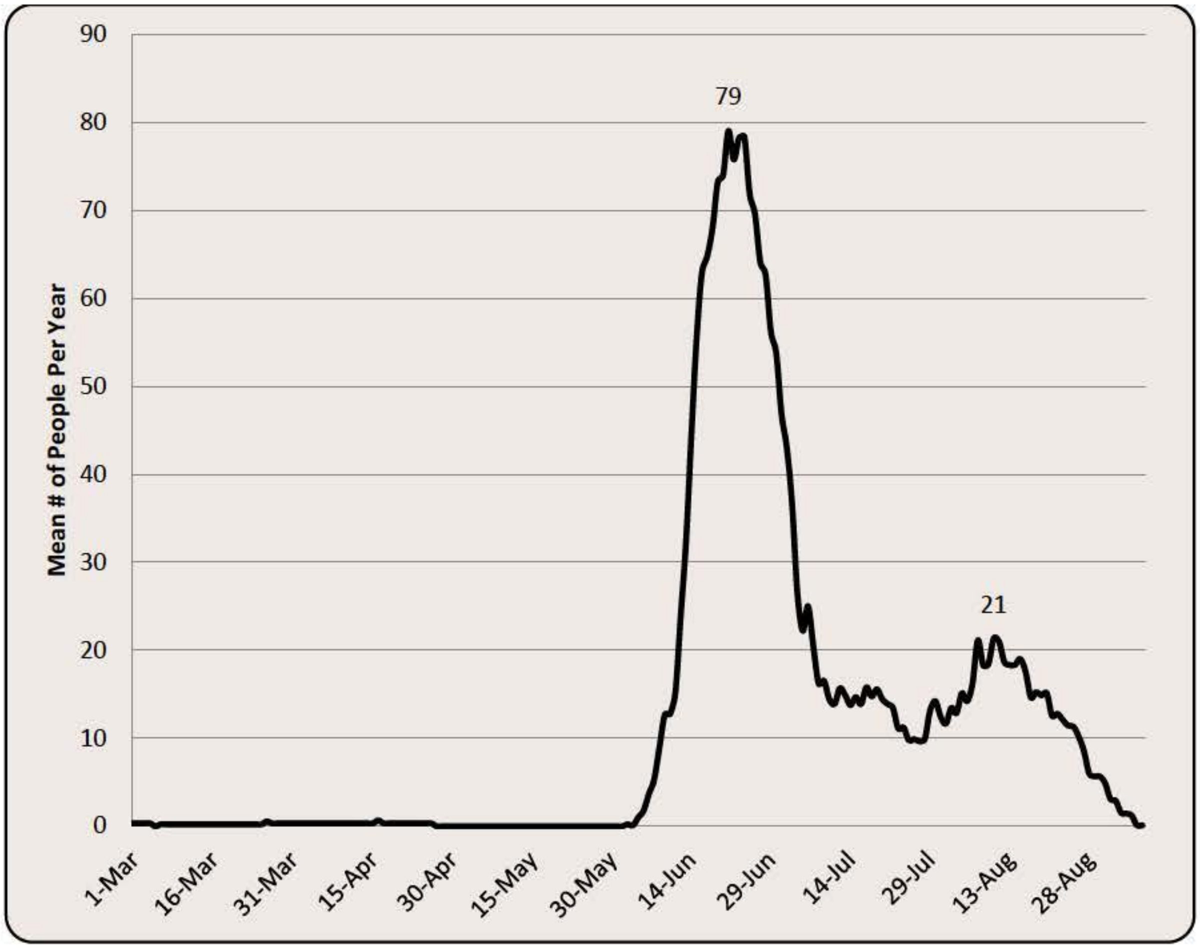


Figure 4-16. Mean daily distribution of commercially-supported visitors on the Kongakut River in Arctic Refuge, 2001–2009.

4.4.5.7 State Harvest Records for General Hunting and Trapping

General hunting and trapping are considered recreational activities at Arctic Refuge and records do not include subsistence harvests by federally qualified rural residents of the area.

ADFG is the agency responsible for regulating and monitoring general hunting and trapping throughout Alaska. This section summarizes the species and numbers of animals harvested—not the number of hunters and trappers on the Refuge. The number of hunters and trappers physically present on the Refuge is substantially lower than the total number of reports.

The State of Alaska is divided into 26 GMUs (Map 4-24). These units are divided into subunits identified by letters. Arctic Refuge is primarily located in GMU 25A, 26B, and 26C. Units 25A and 26B include lands outside Refuge boundaries. Harvest data collected by the State for units 25A, 26B, and 26C encompass the majority of Arctic Refuge and depict general trends in harvest for the Refuge. GMU 26B includes the Dalton Highway Management Corridor Area, which is a popular and road-accessible caribou hunting destination that accounts for most of the caribou hunting in this unit. Caribou harvested in unit 26B are most likely members of the Central Arctic herd.

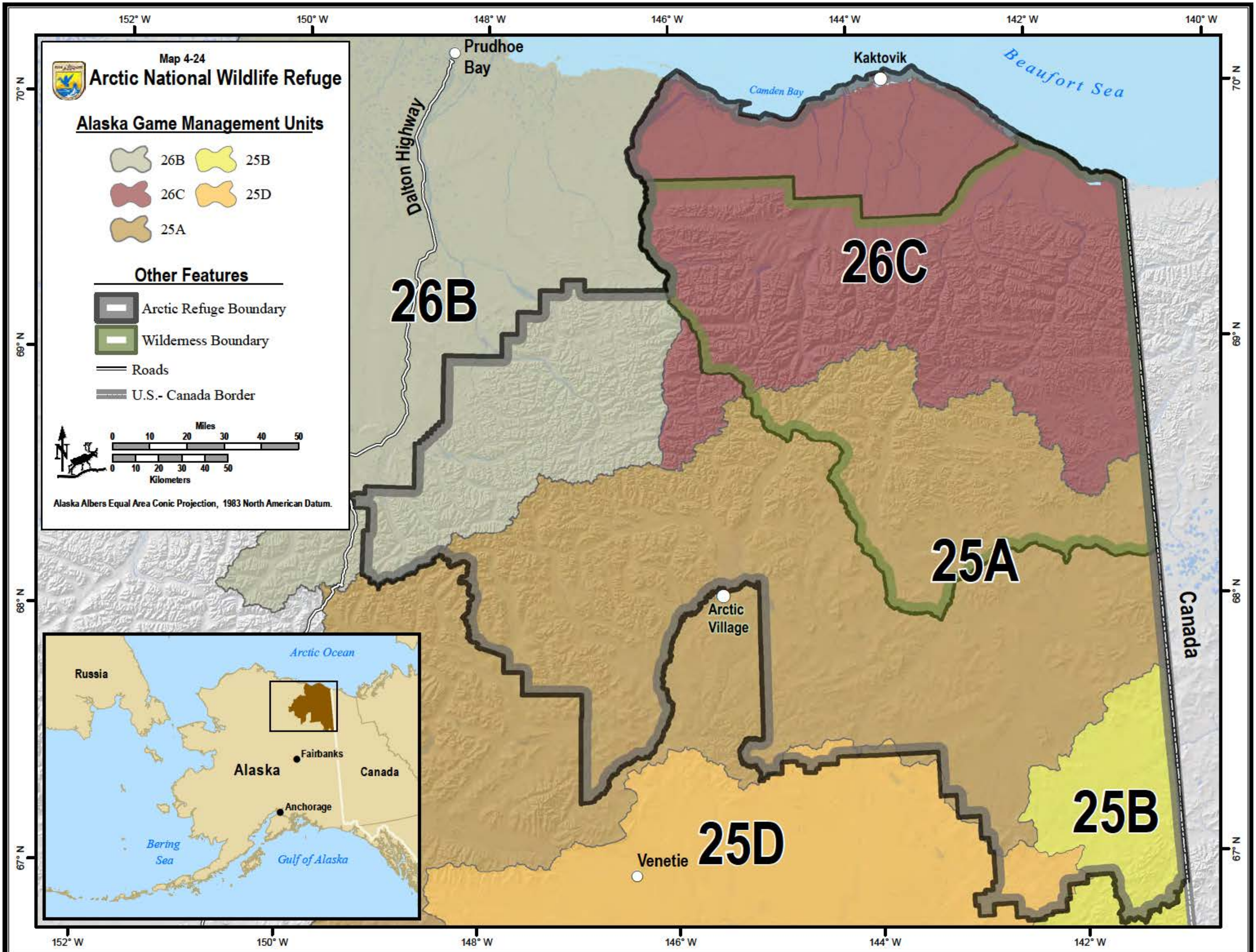
The harvest records for general hunting and trapping that are summarized in this section were accessed from the ADFG Wildlife Information Network (WinfoNet) at http://winfonet.alaska.gov. WinfoNet is an online database that stores all general hunting and trapping reports, harvest records, and fur sealing information for Alaska. The WinfoNet database contains records for hunters who properly obtain, complete, and return harvest tickets, and for trappers who have their furs sealed. Hunters are required to return a harvest ticket to ADFG whether they harvest an animal or not. Harvest tickets are used to collect data such as hunters' names, hunting locations (not land ownership), number of animals harvested, dates hunted, and dates of harvest. Harvests by hunters and trappers who do not comply with the harvest ticket or fur sealing regulations are not recorded in this database.

The State uses sealing certificates to record the number and location of animals harvested by trapping. Sealing certificates do not provide data on trapping effort in the Refuge (i.e., total number of trappers). Trappers in the Refuge are required to seal river otter, lynx, wolf, or wolverine. Trappers in the Refuge do not need to seal other species that they harvest. Trapping data discussed in this section reflects the number of times a trapper sealed furs and the species. Trappers often seal furs multiple times throughout the trapping season. A new sealing certificate is issued each time a trapper seals a fur or multiple furs of the same species. For example, if a trapper has a wolverine and three wolves to be sealed, one certificate would be issued for the wolverine, and a separate certificate would be issued for the wolves and would specify that three wolves were sealed. The same trapper could return later in the season to have more furs sealed, at which time more sealing certificates would be issued.

For the years 2001 through 2009, general hunters (guided and non-guided) comprised, on average, 28 percent of the total number of commercially-supported visitors to the Refuge. Of these, guided hunters made up 25 percent of the total, while non-guided hunters made up 75 percent. This was the case, in part, because guides are limited to a certain number of clients, which varies by guide use area. Each guide use area has a different amount and quality of habitat used by big-game species and a different number of feasible access and egress points. When deciding how many guided hunting clients to allow in each guide use area, managers consider the number of clients proposed during the competitive application process and the number of clients the area can support.

When reviewing the information for Arctic Refuge in the following graphs, please note:

1. Approximately one-third of lands in GMU 25A and approximately two-thirds of lands in GMU 26B are outside the Refuge. State lands in GMU 25A receive substantial sheep hunting pressure. GMU 26B includes the Dalton Highway Management Corridor Area, which is a popular and road-accessible caribou hunting destination and accounts for most of the caribou hunting efforts in GMU 26B. Caribou in this unit are most likely associated with the Central Arctic caribou herd.
2. Trapping activity is believed to be higher than what these numbers represent because harvest by people who did not have their furs sealed is not represented in this data set. Trappers, whether rural or non-rural residents, are required to have their furs sealed, yet many rural residents do not.
3. The trapping data reflect the number of sealing certificates and the number of animals harvested. They do not include the number of trappers or trapping effort. Numbers for black bear, brown bear, and trapping records indicate the number of animals harvested but do not indicate the number of hunters or trappers. The State does not


Map 4-24
Arctic National Wildlife Refuge
Alaska Game Management Units
26B
25B
26C
25D
25A
Other Features
Arctic Refuge Boundary
Wilderness Boundary
Roads
U.S.- Canada Border
Miles
0 10 20 30 40 50
0 10 20 30 40 50
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
152° W
150° W
148° W
146° W
144° W
142° W
140° W
70° N
69° N
68° N
67° N
Prudhoe Bay
Dalton Highway
Kaktovik
Camden Bay
Beaufort Sea
26B
26C
25A
25B
25D
Arctic Village
Venetie
Canada
Russia
Arctic Ocean
Alaska
Fairbanks
Anchorage
Canada
Bering Sea
Gulf of Alaska

require a report for unsuccessful bear hunting or trapping efforts; it only requires post-harvest sealing, which is done by ADFG or a designated representative.

4. Many of the hunters on Arctic Refuge hunt various species during the same hunt. It is common for a hunter to have sheep, caribou, and/or grizzly tags for a north side hunt or moose, sheep, caribou, and/or grizzly tags for a south side hunt. Therefore, the number of hunters physically present on the Refuge is much lower than the total of all of the hunting reports.
5. A hunter can have multiple harvest tickets for caribou. The hunting information does not reflect the number of hunters; it reflects the number of submitted harvest tickets. Therefore, the number of hunters present on the Refuge is lower than the numbers reported.
6. The Wildlife Information Network provides data; it does not provide inferences to trends. Many variables affect hunting and trapping efforts, which makes it difficult to determine trends.
7. The graphs here provide a visual representation of hunting and trapping efforts on Arctic Refuge. The first two graphs provide an overview of all hunting and trapping efforts on Arctic Refuge, and the remaining graphs depict hunting and trapping efforts by GMU and species. This information is meant to provide a general understanding of the documented harvests occurring on Arctic Refuge.

Harvest Information

Figure 4-17 depicts harvest data for GMUs 25A, 26B, and 26C. Caribou harvest (Figure 4-18) is shown separately because: 1) caribou data were only available for 10 years, and 2) more caribou are harvested than any other species each year. Displaying caribou data along with data for other species would make it difficult to discern annual variations for the other species. Most of the increase in caribou harvest has occurred along the Dalton Highway in GMU 26B, which is off the Refuge.

Trapping records for Arctic Refuge are shown in Figure 4-19. Trapping records reflect a substantial trapping effort by a limited number of trappers. In other words, a relatively low number of trappers are responsible for the recorded harvest. The total trapping harvest is likely underestimated because there are no designated fur sealers in many communities, and the fur from animals is often used locally and never sealed (Stephenson 2006).

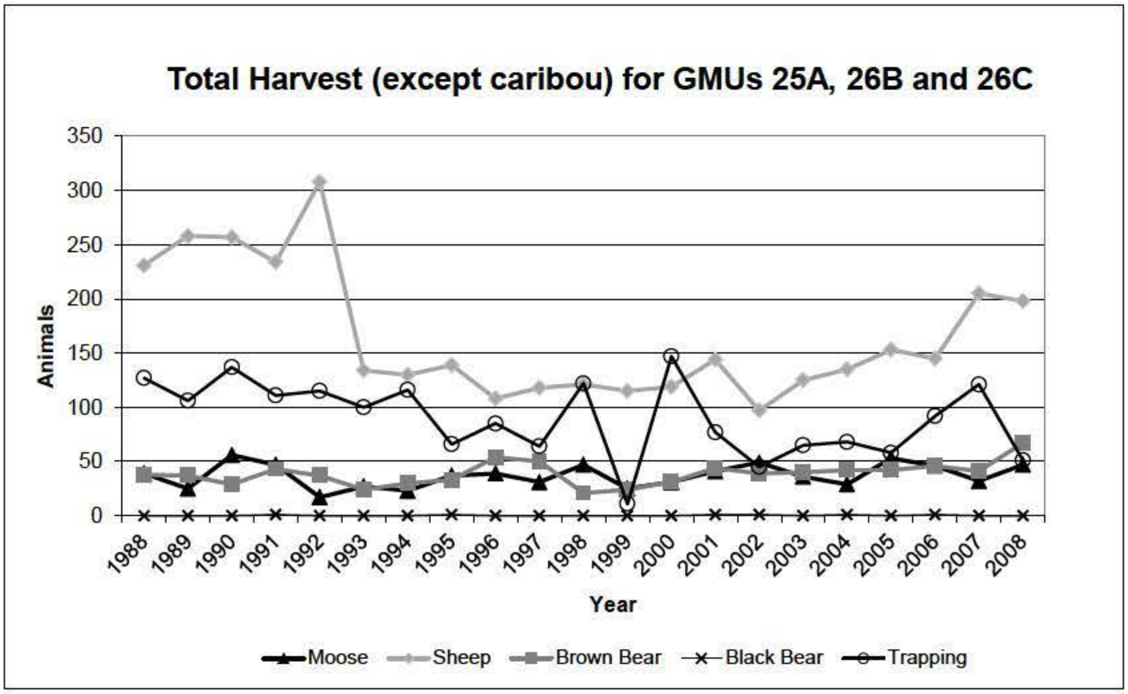


Figure 4-17. Harvest information (except caribou) from Game Management Units of Arctic Refuge over the 20-year period 1988–2008. Trapping harvest includes lynx, wolf, wolverine, and otter.

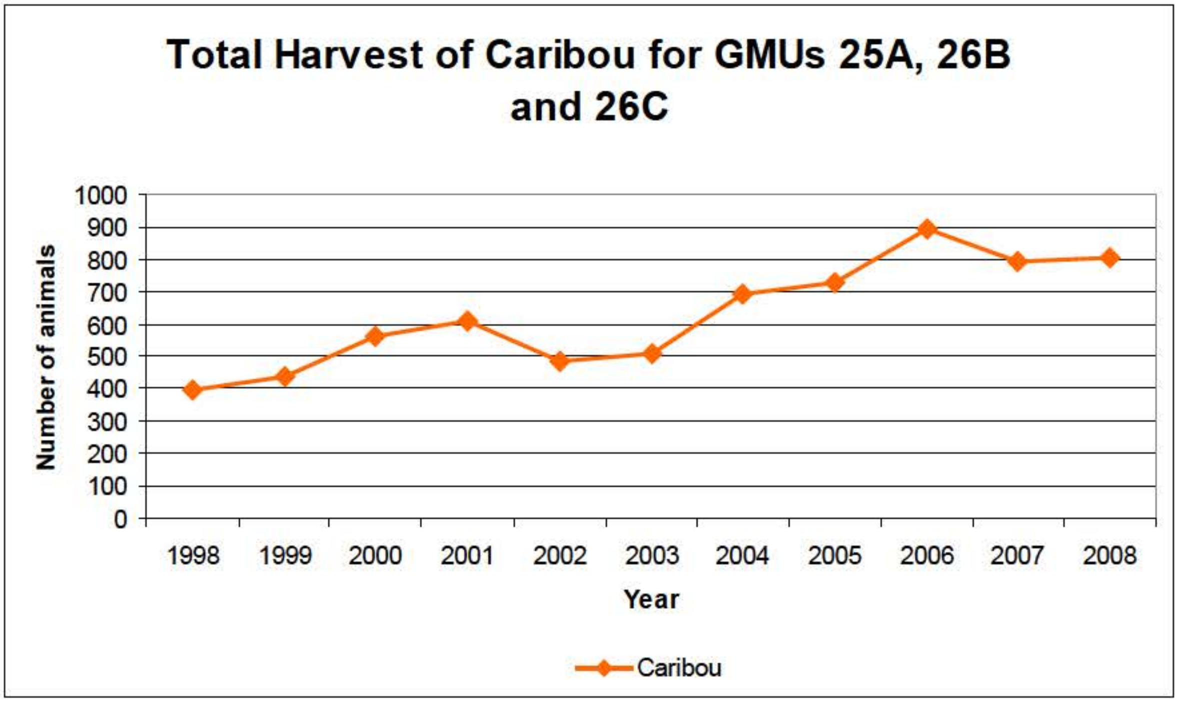


Figure 4-18. Caribou harvests from Game Management Units of Arctic Refuge during the 20-year period 1998–2008 (includes harvest on State-owned lands).

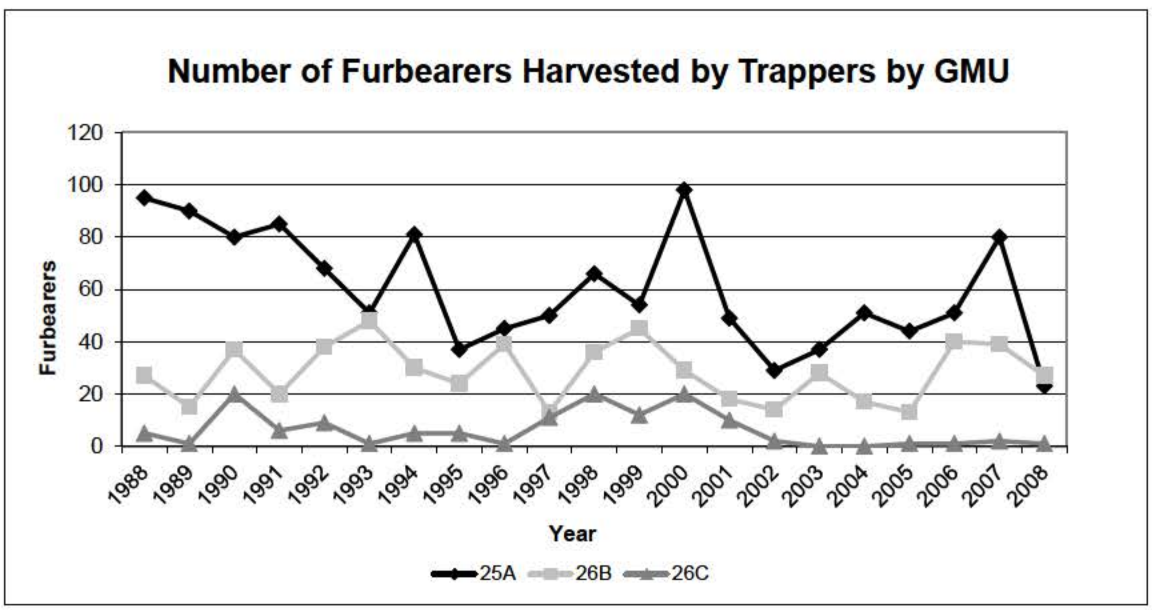


Figure 4-19. Trapping records of furbearers (lynx, wolf, wolverine, and otter) harvested in GMUs 25A, 26B, and 26C during the 20-year period 1988–2008.

GMU 25A

About two-thirds of GMU 25A falls in Arctic Refuge; therefore, some harvest occurs off the Refuge. However, most of the viable sheep hunting habitat is in the Refuge. Harvest records for GMU 25A are shown in Figure 4-20.

GMU 26B

Only one-third of GMU 26B is in Arctic Refuge, and the percent of the harvest of big game outside the Refuge, shown in Figure 4-21, is unknown. However, most of the GMU's sheep habitat lies in the Refuge portion of the Unit, so most sheep harvests occur on Arctic Refuge. By contrast, most of the caribou harvest in GMU 26B occurs off the Refuge. The increase in caribou harvest in GMU 26B in recent years is attributed to increased hunting pressure along the Dalton Highway, which was opened to the public in 1994. However, the western portion of the Refuge may also be experiencing increased caribou hunting pressure due to 1) more commercial air operators offering services along the Dalton Highway; 2) the Refuge's proximity to the Dalton Highway; and 3) the dramatic increase in the Central Arctic Caribou herd population.

Moose hunting was prohibited in GMU 26B from 1996-2005 because of declining moose populations. In recent years, a limited hunt for moose has been permitted by the State of Alaska in GMU 26B.

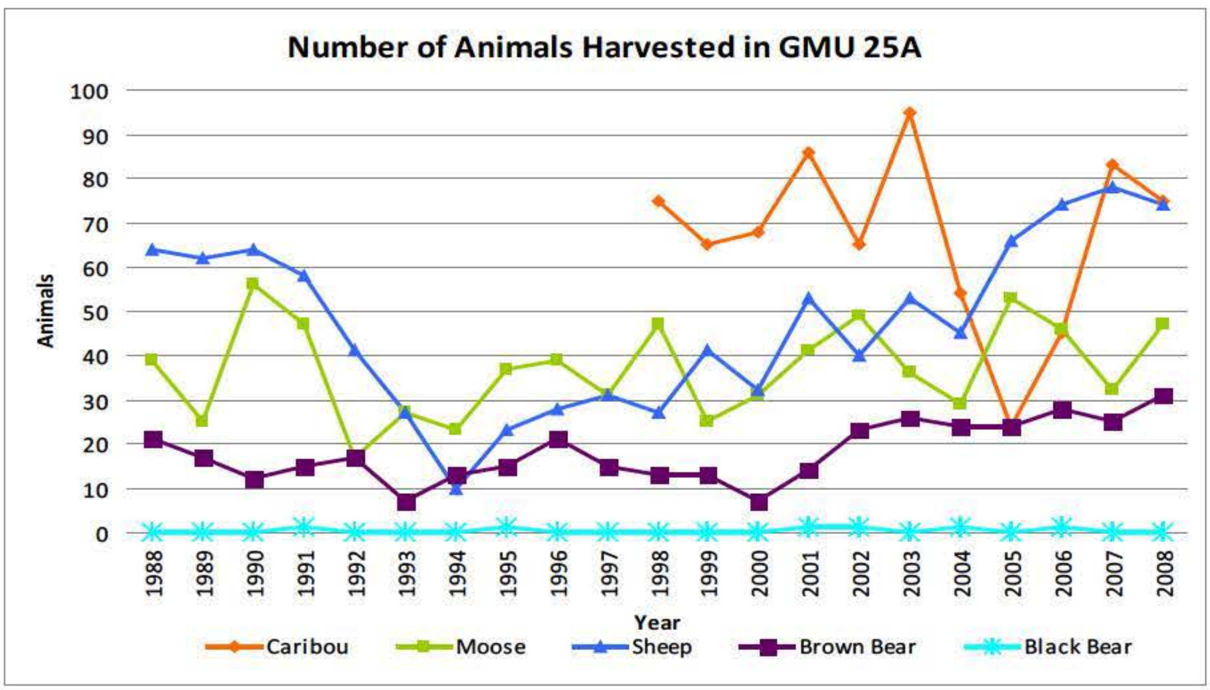


Figure 4-20. Hunting records from Game Management Unit 25A for harvest of each big-game species over the 20-year period 1988–2008.

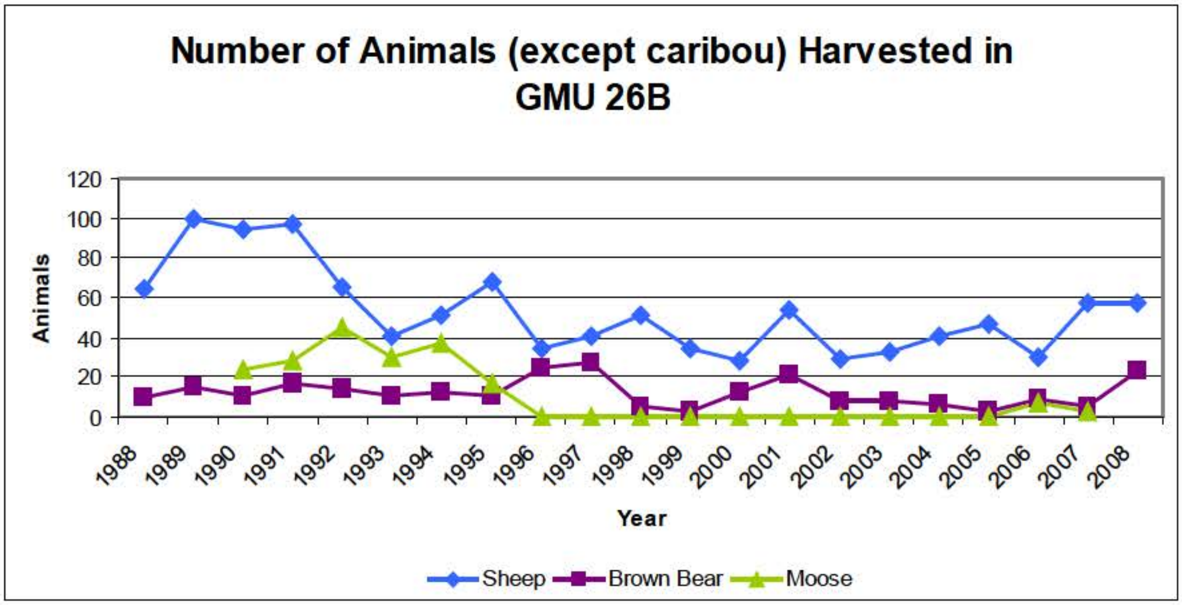


Figure 4-21. Harvest records (excluding caribou) from Game Management Unit 26B over the 20-year period 1998-2008.

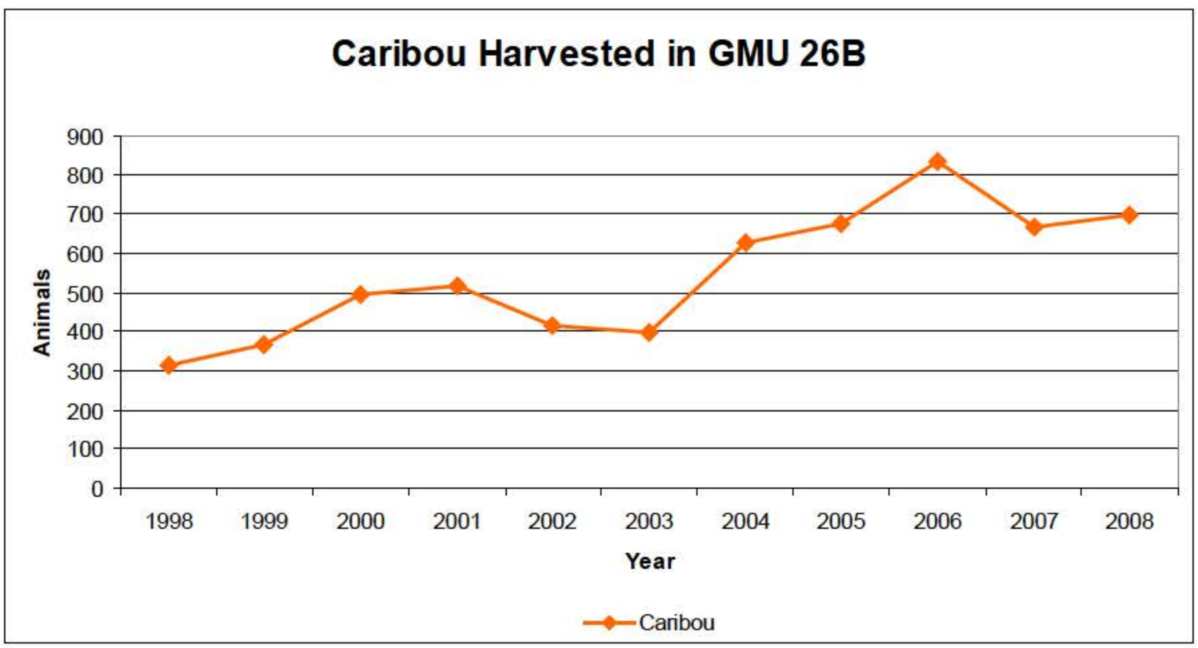


Figure 4-22. Caribou harvest records from Game Management Unit 26B for Arctic Refuge, 1998–2008 (includes harvest on State-owned lands).

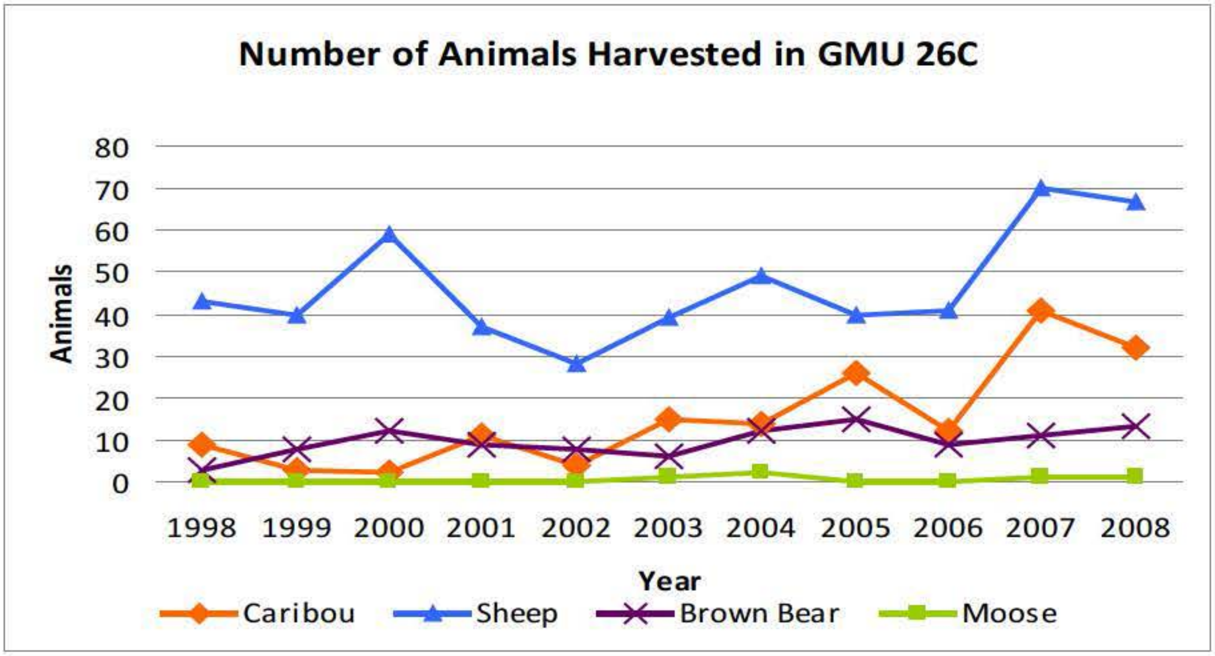


Figure 4-23. Harvest records for each big-game species from GMU 26C during the 10-year period 1998–2008.

GMU 26C

GMU 26C lies completely in Arctic Refuge; therefore, all of the animals were harvested from Refuge lands. Big-game harvest records are depicted in Figure 4-23.

4.4.5.8 Perceived Crowding, Conflict, and Resource Impacts

At times, hunting and other recreation groups find themselves in the company of other groups that may or may not be engaged in the same activity or behaviors. Encounters of this nature often are due to weather, high demand, or simply the nature of access at the Refuge (e.g., limited aircraft landing sites). This can lead to impacts to visitor experience and resource conditions such as crowding, social conflicts, accumulation of human waste, or site-hardening (Appendix M). Conflicts reported between groups have tended to be between groups of similar activity types (e.g., hunters complaining about other hunters). Recently, managers have begun to hear complaints from recreational floaters about hunting floaters or vice versa.

In recent years, the number of air transporters applying for commercial permits has increased (Arctic Refuge Commercial Permit Database, Service, unpublished data). Because hunting guide permits are awarded competitively and restricted to certain areas, and air transporter permits are non-competitive and not restricted to certain areas, the potential for competition and conflict may be increasing. For example, the clients of guides, air-taxis, and transporters, and non-commercially-supported hunters often overlap and concentrate at access points in places where people want to hunt Dall's sheep, which increases the potential for competition for places to hunt. Managers have observed growing tensions between hunting guides and transporters, particularly in the northwest portions of the Refuge. The amount and distribution of Refuge use by general hunting private pilots remains unknown.

At Arctic Refuge, managers currently do not identify different use zones, or recreational units, with varying goals for visitor use management; visitors are asked to disperse activities throughout the Refuge, while focusing their traffic on the most durable natural surfaces that will show fewer signs of their passing (Arctic Refuge 2008b, Marion 2009). Popular areas are showing site-hardening where repeated use is compromising the wilderness characteristics of naturalness, and signs of previous users are obvious. In order to balance quality of recreational opportunities in a wilderness setting with high demand for these opportunities, managers may eventually choose to identify different zones with different management goals. In moderate to high use zones, such as camping areas immediately adjacent to popular landing areas, infrastructure (e.g., Hardened campsites meant to accommodate intensive recreation traffic while minimizing impacts (Marion 2009)) may be designed to blend in with surroundings to optimize natural wilderness characteristics while accommodating higher use levels. In low use zones, managers frequently implement "dispersal" strategies designed to prevent the occurrence of visitor impacts (Hammitt and Cole 1998, Leung and Marion 1999) and stress visitor practices that reduce signs of previous visitor use.

To preserve desired conditions (Appendix M) managers decide the specific conditions and visitor experiences that will be available to the public, and develop condition goals, standards, indicators, measures, and threshold that trigger management actions, to insure management condition goals are maintained.

Managing visitor-caused impacts and maintaining visitor experience opportunities requires long-term monitoring of visitor experience opportunities and resource conditions. Efforts are ongoing through visitor surveys, recreation impacts monitoring, and by observation on the Refuge's most-visited rivers and along the western boundary of the Refuge, but managers currently have no detailed plans for addressing impacts once they are identified. Aplanned management program with actions that violate standards, and budget and personnel/resources dedicated to implementing management actions are needed to preserve desired conditions.

4.4.5.9 Dalton Highway Visitors and Resource Impacts

In addition to the previously noted increase in commercial guided day hiking and overnight trips to Refuge areas along the Dalton Highway, managers believe that non-guided visitation to areas adjacent to this area has increased considerably over the past decade (Reed and St. Martin 2009). The Dalton Highway, which was open to the public in 1994, allows relatively easy and inexpensive access to western portions of the Refuge, particularly the Atigun Gorge area, which is recognized for exceptional scenery, wildlife values, and wilderness qualities. The Dalton Highway Corridor Management Area extends five miles on either side of the Dalton Highway from the Yukon River to the Arctic Ocean. The ADFG currently uses the area five miles on either side of the highway to regulate hunting limiting it to certified bow hunters only. Hunting regulations in this area are intended to prevent overharvest of wildlife by limiting the number of hunters who use the area. Licensed highway vehicles are allowed only on designated public roadways. To protect fragile tundra and wetland vegetation, recreational use of off-road vehicles or snowmachines is prohibited by State law within the five-mile corridor. However, people may access the area at any time by boat, airplane, foot, ski, or dog team, depending on the season. Federal Subsistence Management regulations do authorize the use of snowmachines for subsistence hunting and trapping by residents living within the Dalton Highway Corridor Management Area. However, any user can start outside the five-mile corridor on a snowmachine and then cross the highway corridor to access other hunting areas or villages.

The Dalton Highway was designated a scenic byway by the State of Alaska, which continues to expand road infrastructure to facilitate tourism in northern Alaska. Managers predict that the western portion of the Refuge will become a more popular destination for visitors as awareness and use of the Dalton Highway increase. Continued improvements to the highway will most likely increase visitors to the area, particularly when rental car companies authorize their customers to drive this increasingly-paved and straightened road. Beyond the Arctic Interagency Visitor Center in Coldfoot, there are no developed facilities or formally constructed trails in areas such as Atigun Gorge, but greater numbers of visitors to this area could substantially increase day hiking activity and, most likely, the proliferation of informal (visitor-created) trail networks in tundra habitat currently managed for dispersal. (Monz et al. 2009).

Land managers frequently experience substantial challenges successfully implementing dispersal strategies for several reasons, including 1) inadequate educational programs that fail to communicate when activities should be dispersed, what durable surfaces are, and a compelling rationale for practicing dispersal; 2) visitation levels that are too high to support effective dispersal; 3) lack of sufficiently durable surfaces; and 4) topography or vegetation that constricts traffic to a common route (J. L. Marion, Unit Leader of Virginia Tech Field Station, Patuxent Wildlife Research Center, USGS, pers. comm.). These challenges apply to areas of the Refuge along the Dalton Highway—particularly in Atigun Gorge.

To balance quality of recreational opportunities in the Atigun Gorge with high demand for these opportunities, and as Refuge objectives for desired conditions are defined, the creation of some informal trails may be determined to be acceptable, provided they are associated with acceptable types of visitor activity and at access points of interest that allow travel through constricted topography. However, recent research cautions that visitors choose less sustainable trail alignments and can create unnecessarily duplicative networks of trails that entail a substantial amount of avoidable impact as compared to planned hardened sites and trails designed to accommodate common visitor use patterns, such as where visitors commonly travel, stop to rest, or gather to view scenery and wildlife (Leung et al. 2011, Wimpey and Marion 2010). The Refuge has not developed visitor use management strategies for the Atigun Gorge.

A recreation research study of the Atigun Gorge area is in progress to develop and implement monitoring protocols for measuring the number, distribution, and condition of emerging informal trails in and adjacent to the Atigun Gorge (Monz et al. 2009). Managers at Arctic Refuge must provide messages to visitors before their arrival that are clear and easy to understand but complex enough to clarify preferred visitor behavior in transition areas or where impacts are emerging (J. L. Marion, Unit Leader of Virginia Tech Field Station, Patuxent Wildlife Research Center, USGS, pers. comm.). Managers continue to consider increasing the efficacy of their outreach messages about minimum impact techniques such as Leave No Trace and to better understand ways to manage impacts to fragile tundra resources and visitor experiences in Arctic Refuge areas adjacent to the Dalton Highway.

4.4.5.10 Polar Bear Viewing

In the previous eight years, there has been increasing polar bear viewing activity on Refuge lands and non-Refuge lands within the external boundary of Arctic Refuge (Miller 2010). Managers suspect that polar bear viewing has become more popular in recent years for a number of reasons. Beginning in 2002, a large number of polar bears were observed aggregating near the Alaska Native community of Kaktovik, around Barter Island. This area is known to host the highest density of polar bears along the north coast of Alaska and western Canada. The number of polar bears on shore seems to be closely correlated to the distance of ice from shore and the high density in the area of ringed seals, a preferred food; the presence of carcasses of subsistence-harvested whales also attract bears (Kaktovik Polar Bear Committee et al. 2010). This phenomenon most likely spurred an increase in commercial interests and enterprises focused on providing opportunities to members of the public who want to see polar bears in the wild. Increased infrastructure was developed in Kaktovik to house visitors, and local airlines began accommodating charter requests and actively promoting bear viewing tours. In May of 2008, the Service listed the polar bear as threatened under the Endangered Species Act. This Federal action was surrounded by increased media reports featuring global climate change, disappearance of sea ice, and the plight of the polar bear in the Arctic, which attracted public attention to the species.

The opportunity to view polar bears outside of captivity offers a valuable tool for delivering conservation messages to the public. To minimize potential disturbance to polar bears caused by bear viewing activities, the Service has intensified public education and outreach about polar bear safety and about its cooperative management program with the community of Kaktovik, which is designed to achieve conservation goals for the species, reduce human-bear conflicts, and educate the community and visitors about human-bear safety. After conducting broad efforts to increase partnerships, training opportunities, and education, the Refuge implemented a special use permit requirement for commercial guided polar bear viewing and received applications from eight local operators for the activity on Refuge lands and waters surrounding Kaktovik.

Managers at Arctic Refuge share concerns about future developments for polar bear viewing, including the potential use of tour ships, helicopters, and other methods commonly used in other parts of the circumpolar north where polar bear viewing occurs.

4.4.5.11 Packrafting

Commercially manufactured packrafts are lightweight, inflatable rafts that can be packed into an area using backpacks or similar gear. This new type of watercraft is making rivers and streams that were once un-floatable, due to low water or lack of access, more available to recreational visitors. Managers believe that this technology has some potential to change patterns of recreational activity at Arctic Refuge. Having a packraft may encourage more people to explore or pioneer routes into areas of the Refuge that have not previously had much, if any, use by visitors. With the proliferation of packraft use, visitors may spend more time at the Refuge pursuing a combination of backpacking and river floating in one adventure. Increasing use of packrafts may provide more opportunities for floating rivers and streams, dispersing these visitors across a broader swath of the Refuge.

4.4.5.12 Winter Camping

Managers at the Refuge have begun to observe more unrestricted use by non-motorized visitors along the western Refuge boundary and visitors who embark with snowmobiles from villages or other areas near Refuge boundaries. Snowmachine use on Refuge lands is generally legal except during periods of inadequate snow cover, except for certain size and weight classes of machine, and except where prohibited by State law. Potential management concerns include illegal use of snowmachines along the Dalton Highway corridor, especially during periods of inadequate snow cover, and increased use of snowmachines in sensitive habitat used by wintering wildlife or during sensitive times, such as the spring when polar bears are in maternal dens.

4.4.6 Interpretation and Environmental Education

At Arctic Refuge, outreach and education programs are tailored toward three distinct audience types with information designed to meet their interests.

One audience consists of people who come to visit the Refuge, including those from outside the area and local residents. Outreach specialists at the Refuge provide this group with specific information that will help them enjoy safe and rewarding experiences while minimizing impacts. Information includes how to plan their trip, what to bring, what minimum impact techniques are appropriate for a wilderness setting, what regulations they must follow, and how to identify and respect private lands. Refuge staff does not direct visitors to specific locations or destinations. Outreach messages do include information that will help visitors avoid conflicts with bears and avoid disturbing other wildlife. Visitors are told about wildlife conservation and stewardship of Refuge lands and natural resources. They are provided information about invasive plants and reducing their footprint, especially in popular places where visitors tend to congregate.

Another main audience consists of those who live in communities and/or visit the visitors center in interior and northeast Alaska. These people are interested in interpretive and environmental education programs about plants and wildlife, Wilderness, and management activities at Arctic Refuge. The Refuge serves this audience at a variety of venues, including community gatherings, visitor centers, and other facilities located outside the Refuge. Refuge staff creates and presents materials and activities for kindergarten through college-aged students at schools in Fairbanks, Kaktovik, Arctic Village, Venetie, and other locations in interior and northeast Alaska. These educational efforts include in-classroom programs and summer camps. The Refuge staff also produces posters to display at kiosks throughout the region.

The third group is a distant audience. These are members of the public who live far from the Refuge. They are widely dispersed throughout Alaska, the remainder of the US, and internationally. This group tends to be interested in Arctic Refuge and its management issues, but most of its members may never have the opportunity or desire to visit. They are interested in information about an extensive range of topics including the biological sciences, Wilderness, conservation, public uses of the Refuge, management of Refuge lands, arctic and boreal environments and wildlife, climate change, and energy development. Outreach methods include personal communications, oral presentations, brochures, and other printed materials. Outreach is primarily conducted via the Internet, email, and telephone.

4.4.6.1 Web-based Information

Arctic Refuge staff created a website (http://arctic.fws.gov) in 1995 and has expanded it each year since. This website is the Refuge’s primary outreach tool and is especially important for reaching distant audiences. The site contains nearly all the outreach materials and products produced at the Refuge, and it has become the Refuge’s most effective communication tool.

The number of page visits to the Arctic Refuge website reached a peak in 2005, after almost a decade of intense political and media interest in the Refuge. That year, the public visited the Refuge's web pages an average of 1,850 times per day. In fiscal year 2010 (October 1, 2009-September 30, 2010), a period during which there was relatively limited political and media interest in the Refuge, the website received an average of 761 page visits per day (Figure 4-24). Twice as many pages were visited during the school months (an average of 880 per day from November to May) as during the summer months (an average of 453 per day for July and August). These data suggest that the majority of Arctic Refuge web visitors are students or educators making use of the Refuge's web content for academic purposes.

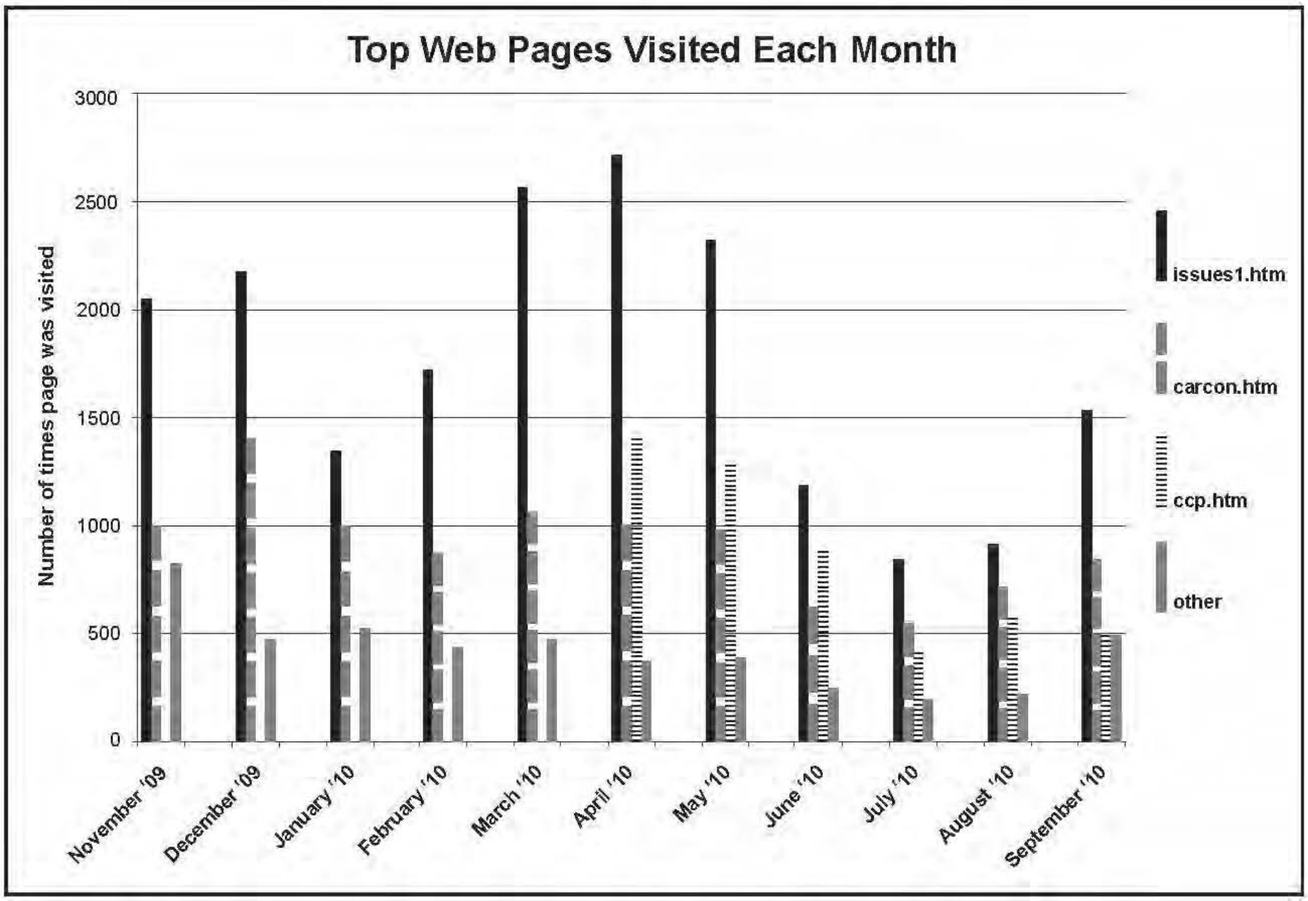


Figure 4-24. Number of visits per month to the most popular Arctic Refuge web pages, fiscal year 2010.

Notes: issues1.htm = "Potential Impacts of Proposed Oil and Gas Development on Arctic Refuge's Coastal Plain." carcon.htm = "Frequently Asked Questions about Caribou." ccp.htm = the Comprehensive Conservation Plan.

The two most popular Refuge web pages in fiscal year 2010 were "Potential Impacts of Proposed Oil and Gas Development on Arctic Refuge's Coastal Plain: Historical Overview and Issues of Concern" and "Frequently Asked Questions about Caribou." In most instances, pages that focus on wildlife ranked third each month. In April 2010, during the period of public scoping for this Plan, the Refuge's Comprehensive Conservation Plan web page ranked second in number of visits.

4.4.6.2 Arctic Interagency Visitor Center

Since 1989, the BLM, the NPS, and the Service have cooperated to provide information to travelers along the Dalton Highway. Staff from these agencies help visitors prepare for, enjoy, and participate safely in a variety of recreational activities on Federal lands in the region. Through personal contacts, interpretative programs, exhibits, and publications, visitors can gain a better understanding of the arctic and its unique resources.

In 2003, a new Arctic Interagency Visitor Center opened in Coldfoot, Alaska. This visitor center operates from late May to mid-September each year and provides Federal agencies with a major point of contact for people traveling the Dalton Highway. The facility includes a 60-seat theatre for delivering education programs and special events, a trip planning room for hikers, dioramas and displays about the arctic and boreal forest, and a sales area where Alaska Geographic (formerly the Alaska Natural History Association) sells educational and interpretative items. The visitor center provides the public with information about the Refuge System and Arctic, Kanuti, and Yukon Flats refuges.

4.4.6.3 Arctic Village Visitor Contact Station

Arctic Village serves as an important access hub community for visitors to Arctic Refuge due to its location next to the Refuge's southern boundary and the community's airport, which has regularly scheduled commercial flights. The Refuge operates a small visitor contact station that provides brochures, maps, and other information and an opportunity to view a video about the Refuge. This facility is frequently used by local residents traveling on regularly scheduled commuter planes. The contact station is used by visitors as a place to stage trips to and from locations inside the Refuge with commercial air operators. An informational kiosk is located on the airport ramp area, and a second kiosk is located in town.

The Arctic Interagency Visitor Center in Coldfoot, Alaska

4.5 Refuge Infrastructure and Administration

4.5.1 Administrative Facilities

Administrative facilities described in this section include offices, bunkhouses, maintenance shops, vehicles storage, aircraft hangar, airport leases or tie-down space, storage sites for fuel and other hazardous materials, and remote administrative sites.

4.5.1.1 Fairbanks

The primary administrative facilities for the Refuge are located in Fairbanks, approximately 170 air miles south of the Refuge's southernmost boundary. The Refuge headquarters is co-located with those of the Kanuti and Yukon Flats refuges and the Fairbanks Fish and Wildlife Field Office in the Fairbanks Federal building. A 2-acre parcel located immediately west of the Federal building off of Noble Street is used for boat, vehicle, and material storage. A maintenance shop is located adjacent to the Federal building and is shared with the other Service offices located on the premises. The Service maintains a hangar at the Fairbanks International Airport east ramp where Arctic Refuge stores three aircraft. The hangar facility is also utilized by other Service offices. An aircraft tie-down slip is rented for securing a float plane at the Fairbanks International float pond.

4.5.1.2 Kaktovik

The Refuge owns and maintains a 3,100-square-foot field station in the city of Kaktovik located on Barter Island. The facility can house up to 16 people and includes four bedrooms, two bathrooms, a garage with a storage loft and workshop, two storage sheds, and an above ground 560-gallon heating fuel storage tank. The bunkhouse was constructed in 1987, replacing a smaller bunkhouse that was donated to the Native Village of Kaktovik in the late 1990s. The bunkhouse receives a majority of its use from June through September during the field season, providing temporary housing and/or staging for field crews. The bunkhouse is also used by non-government, State, and other Federal partners performing resource related field work near Kaktovik. The bunkhouse lot is leased from the City of Kaktovik. In collaboration with the Kaktovik community, the Refuge maintains two informational kiosks—one located at the airport ramp area and the second along the community access road near the harvested whale processing area.

In addition to the bunkhouse facilities in Kaktovik, the Refuge owns and maintains two 4,000-gallon fuel storage tanks and accompanying refueling pump sheds. One contains aviation fuel and is located adjacent to the former Department of Defense aircraft hangar located next to the Barter Island Airport. The other tank contains jet fuel for helicopters and is located adjacent to the helicopter pad west of the airport. Fuel tank lots are leased from the Department of Defense, U.S. Air Force.

Barter Island Bunkhouse and Field Station in Kaktovik

The Barter Island airport is located on a gravel bar spit extending from the northeast corner of Barter Island. The runway is exposed to the Beaufort Sea and the Kaktovik Lagoon on three sides and is periodically submerged by floods from sea storms surges. The North Slope Borough operates and maintains the existing runway through a lease from the Department of Defense. The North Slope Borough, in cooperation with the Federal Aviation Administration, proposed to resolve the recurrent flooding at Barter Island Airport by relocating the airport to higher ground on the island approximately one mile southwest of the community. The existing airport would be decommissioned and abandoned for all aviation use.

The new location of the airport would be on land owned by KIC. Upon completion of the new airport, the Refuge would negotiate a lease or the purchase of a lot on which to relocate the aviation fuel and jet fuel storage tanks and accompanying refueling pump sheds. The lot would be of sufficient size to accommodate future aviation support needs such as aircraft tie-down space or an aircraft hangar.

Storage Shed, Visitor Contact Station, and Aviation Fuel Tank at Arctic Village Airport Runway

4.5.1.3 Arctic Village

In Arctic Village, near the airport ramp area, the Refuge has a 305-square-foot visitor contact station, which includes a small office space used primarily by the local Refuge information technician. This building is rented from the Arctic Village Council.

Other facilities at this site include an informational kiosk, an outhouse, and a 2,500-gallon aviation fuel tank and storage shed. The storage shed was constructed in 2008, and is used to store field gear, tools, a four-wheeler, and other equipment. The storage shed also houses an alternative energy solar system that was installed in 2010 and provides electricity to the shed and the aviation fuel tank. The fuel tank and storage shed lots are leased from the Native Village of Venetie Tribal Government.

Administrative Cabin and Storage Shed at Big Ram Lake

4.5.1.4 Big Ram Lake

The Big Ram Lake Field Station is located near the Wind River in the southwest corner of the Refuge. The facility consists of three structures: the bunkhouse (288 square feet), a cookhouse (240 square feet), and an outhouse. The original buildings were constructed in the 1970s by private individuals who used them for prospecting and hunting. The Refuge acquired the facilities in the late 1980s. Several of the original buildings were removed, while the remaining buildings were renovated to accommodate administrative uses. The site currently receives use for wildlife surveys and law enforcement patrols amounting to an average of five days per year. The site is accessed via float plane in the summer or ski plane in the winter.

4.5.1.5 Galbraith Lake

The Galbraith Lake Field Station is situated on BLM land at the Galbraith Lake Airport located on the north side of the Brooks Range and at mile 275 of the Dalton Highway. The original cabin (384 square feet) was built in 2001 and consisted of one large room with a kitchenette. In 2006, it was expanded (600 square feet) to include two bunkrooms, a small living area, a full kitchen, and a screened-in porch for storage or sleeping. The site also contains an above ground 300-gallon heating fuel storage tank and a 2,500-gallon aviationAvgas fuel tank. The facilities operate off an alternative energy wind and solar power

Refuge Field Station at Galbraith Lake

system that was added in 2006 and updated in 2009. The facility receives the majority of its use from May to September during the field season. It has provided long-term and short-term housing to Refuge staff for various field projects. It is also used by a variety of non-government, State, and other Federal partners working in the area. The site is accessed via the Dalton Highway or by fixed-wing aircraft.

4.5.1.6 Lake Peters

The G. William Holmes Research Station, also known as Lake Peters facility, consists of four structures located on the east side of Lake Peters, a part of the Neruokpuk Lakes PUNA in the Franklin Mountains. The facility was originally constructed in the late 1950s by the USGS to serve as a research facility. Soon thereafter, the Department of the Navy, Naval Arctic Research Laboratory in Barrow took over the facility as one of several field sites on the North Slope of Alaska. After Naval Arctic Research Laboratory was closed down, the Refuge acquired the facility and improved it. The Lake Peters facility and vicinity was included in the Wilderness area established by ANILCA in 1980. In 1999, the Service altered and reduced the footprint from the original facility; it now includes a bunkhouse (448 square feet), a cookhouse (360 square feet) with a full kitchen, a warehouse (320 square feet) to store tools and equipment, and a newly renovated outhouse.

Over the years, the facility has been used as a base camp; technician training location; and study site for sheep, caribou, bear, small mammals, lake productivity, and fish investigations. It remains a good site for such work, as well as for studies on tundra vegetation, alpine birds, Alaska marmots, limnology, and climate change. The facility also provides shelter for scientists working in the region and for field visits by agency leaders and others. The site is used at irregular intervals throughout the year, can be unoccupied for long periods, and is costly to maintain. The facility is accessed via ski plane in the winter and float plane during the summer.

4.5.1.7 Recreation Facilities

There are no public recreation facilities in the Refuge. There are no developed trails, signage (other than private property signs), or public use cabins. To preserve the wild, unaltered character of the Refuge, there are no plans to develop any of these facilities in the future.

4.5.1.8 Refuge Staffing

Arctic Refuge staff presently consists of 22 permanent full-time positions, one permanent part-time position, one full-time term position, and four temporary intermittent positions. There are six positions in Arctic, Kanuti, and Yukon Flats refuges that are shared (duty station indicated in the following text), two of which are full-time employees assigned to Arctic Refuge and are included in the Refuge's total count of permanent full-time staff.

G. William Holmes Research Station on the Eastern Shore of Lake Peters

Biology

- Supervisory Ecologist
- Ecologist
- Botanist (Permanent Part-time)
- Wildlife Biologist – Ungulates
- Fish and Wildlife Biologist
- Wildlife Biologist – Avian
- Aquatic Ecologist

Facilities Management

- Maintenance Mechanic

Fire Management

- Fire Management Officer (Shared; Kanuti National Wildlife Refuge)
- Assistant Fire Management Officer (Shared; Kanuti)

Law Enforcement

- Park Ranger – Law Enforcement/Refuge Officer and Airplane Pilot

Outreach

- Wildlife Interpretive Specialist
- Park Ranger – Visitor Services
- Park Ranger – Village Liaison
- Visitor Services Specialist (Full-time Term)
- Visitor Services Technician (Temporary Intermittent)
- Refuge Information Technician (2 Temporary Intermittent)

Refuge Management

- Refuge Manager
- Deputy Refuge Manager
- Assistant Manager – Law Enforcement/Airplane Pilot
- Wilderness Specialist – Airplane Pilot
- Wildlife Refuge Specialist

Support Staff

- Airplane Pilot
- Supervisor Information Technology Specialist (Shared; Arctic)
- Information Technology Specialist (Shared; Arctic)
- Information Technology Specialist (Temporary Intermittent)
- Contracting Officer (Shared; Kanuti)
- Administrative Officer
- Administrative Support Technician

Subsistence Management

- Refuge Subsistence Coordinator (Shared; Yukon Flats National Wildlife Refuge)

Generally, three to five temporary, seasonal employees are hired each year to support summer biological field work. Depending on experience, they are hired as GS-4 to GS-7 biological science technicians. Many of these employees are hired through seasonal employment registers generated from positions advertised on the USA Jobs website. Others are hired through other authorities, e.g., Student Temporary Experience Program, Student Career Experience Program, Alaska Native Science and Engineering Program, Student Conservation Association, or other internships. The number of seasonal employees varies depending on the number and complexity of the planned projects and available funding. Appointments for seasonal employees usually run from mid-May to early September, although some have been extended on a part-time basis to assist with additional work. An additional four to six volunteers per year are recruited for various field or office projects.

High school students in remote communities near Arctic Refuge are hired for summer Youth Conservation Corps projects in their villages. Between 5 and 11 high school students have been hired each year to support various projects taking place either in Arctic Village or elsewhere on the Refuge. Appointments usually run from four to eight weeks in length from early June until mid-August.

4.6 Poker Flat Research Range

4.6.1 Overview

Since the late 1960s, the National Aeronautics and Space Administration (NASA), other government agencies, and various educational institutions have carried out scientific research using suborbital rockets launched from the Poker Flat Research Range (Poker Flat), a University of Alaska-Fairbanks-owned facility located on the Steese Highway between 155-185 miles (mi) (250-300 kilometers (km)) south of Arctic Refuge.

Poker Flat is the only high-latitude rocket launching facility in the United States where a sounding rocket can readily study not only the aurora borealis but also the interaction between the sun and earth's upper atmosphere. Much of the research conducted at Poker Flat focuses on the understanding of geospace—a vast region in the earth's ionosphere/magnetosphere stretching from the earth's atmosphere to thousands of miles beyond. The processes that occur in this region have been found to have far-reaching implications for life on earth and therefore must be better understood. Poker Flat's location and range characteristics (e.g., northerly trajectories, downrange observation sites) provide a unique opportunity to study these processes at a relatively low cost via sounding rockets.

4.6.2 Types of Research Conducted

A majority of the science enabled by Poker Flat can be considered fundamental science (or pure science), the goal of which is to understand the most basic characteristics of nature. The knowledge gained by the research at Poker Flat can then be applied practically by scientists and engineers in atmospheric and space physics, as well as disciplines such as communications and electrical distribution.

The data collected at Poker Flat also benefits climate change research, though mainly indirectly. For example, data collected by sounding rockets (e.g., ionospheric density, neutral density and temperature, electric fields, etc.) in upper atmospheric regions can be utilized to develop and calibrate atmospheric models to assess change (e.g., Qian et al. 2008). Of particular note are those "whole atmosphere" models that can consistently simulate the dynamic processes of the Sun-Earth system (Liu et al. 2010). These models require data to perform realistic predictions. The only way to gather the necessary measurements in the upper atmosphere (between 20-100 mi (30-160 km) altitudes) is with probes on sounding rockets.

In addition to the majority of Poker Flat missions, which study the aurora and its associated physical processes, some missions' objectives are directly related to weather and climate change. For example, a February 2011 mission investigated a technique to measure the nighttime distribution of nitric oxide; a compound produced by aurora and thought to descend to lower altitudes during long polar nights, where it is a destroyer of ozone. If this process occurs, it is likely to impact the wind patterns of the stratosphere, which would then affect the Earth's climate.

4.6.3 Launch Site Operations

Since its first launch in March 1969, Poker Flat has supported approximately 219 NASA rockets and an additional 116 for other agencies and organizations. Since 1995, all launches have been NASA-funded missions. Over the past 10 years, launch frequency has averaged approximately four rockets flights per year, with all launches occurring during the winter months when scientific conditions are optimum. This level of activity is expected to remain constant into the reasonably foreseeable future.

As the rockets launched from Poker Flat are suborbital, meaning that they do not place objects into orbit around the earth, all items onboard return to earth, most following a ballistic trajectory. Along its flight path, a sounding rocket “sheds” various components, including rocket motors once their propellant is consumed, and small doors and nosecones prior to the collection of the desired scientific information. Ultimately the scientific experiment, referred to as the payload, also returns to earth. The amount and final landing location of rocket hardware is highly mission-dependent, and varies based upon the rocket configuration and the ultimate scientific objectives. Depending on the nature of the experiment, some payloads may be recovered from their landing locations for analysis or subsequent re-use. Post-flight recovery operations are generally conducted with a combination of fixed and rotary wing aircraft.

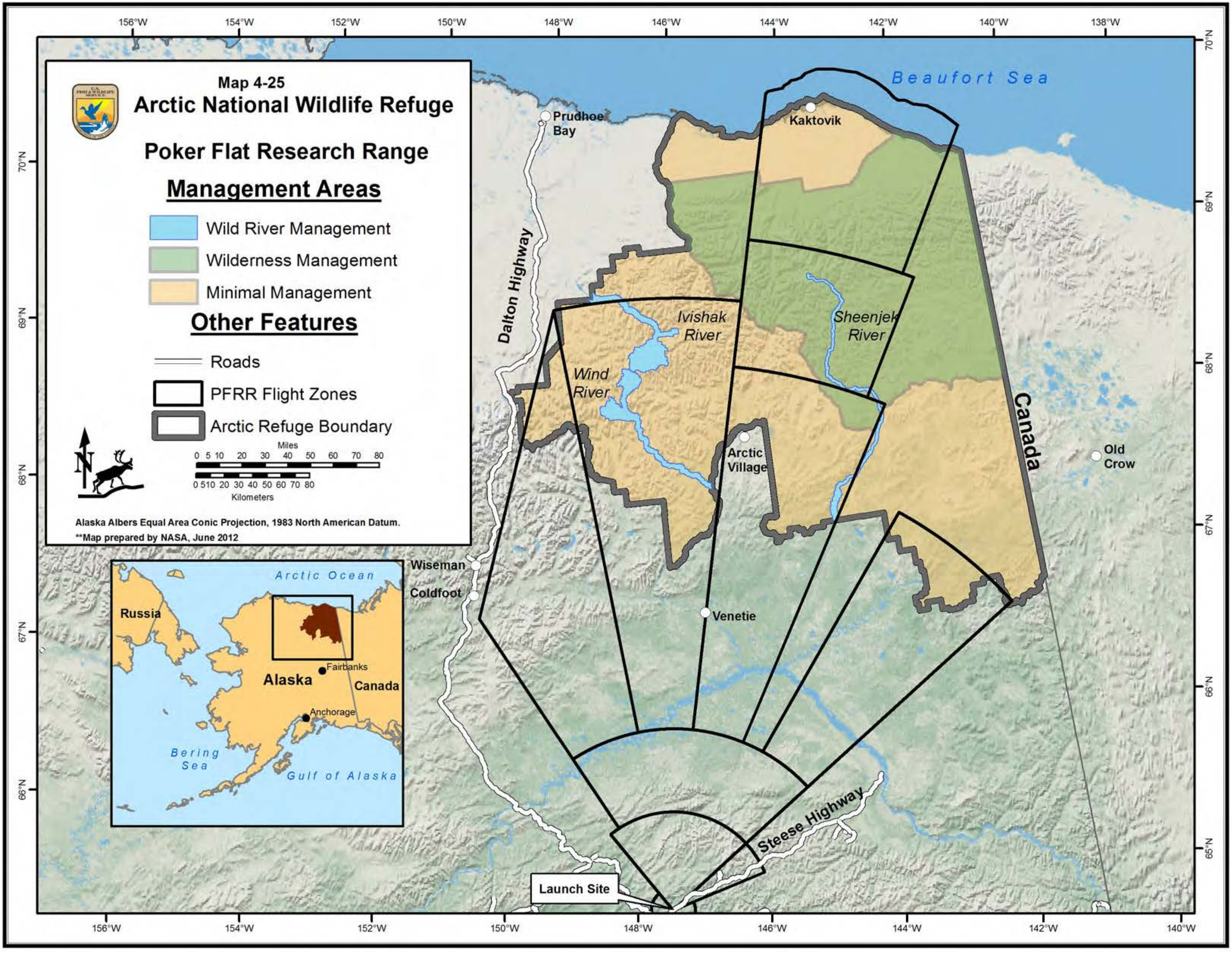
4.6.4 Relationship to Arctic Refuge

Poker Flat has been launching sounding rockets into the Brooks Range area since 1969, before ANILCA (1980) established the Refuge. The original Arctic National Wildlife Range was established in 1960. A number of past and current Poker Flat-launched sounding rockets have the potential to land within the boundaries of Arctic Refuge (Map 4-25); it is estimated that approximately 79-90 rocket motors and 45-55 payloads have landed in Arctic Refuge since the inception of Poker Flat. In the future, it is likely that a greater percentage of NASA missions would need to land in Arctic Refuge due to the trajectories of the higher performing rockets that are more frequently specified by researchers. Therefore, a special use permit is required from the Refuge for Poker Flat to conduct many of its launch and recovery operations. In support of issuing special use permits for rocket and payload impact and recovery, Arctic Refuge completed compatibility determinations in 1994 and 2004.

The University of Alaska-Fairbanks has applied to Arctic Refuge on an annual basis, and the Refuge has issued, a special use permit provided that certain conditions are met, including that Poker Flat cannot have planned landing locations in the Mollie Beattie Wilderness area; landings are prohibited on the remainder of the Refuge from 1 May through 30 September to avoid the high public use season; NASA will maintain a viable rocket component recovery program; and efforts are made to improve NASA’s technology to track and remove items from Refuge lands.

Current operations have not required planned landings in the designated Wilderness. As such, the current special use conditions do not adversely affect NASA’s ability to conduct its missions; most rocket hardware either lands well south or north of Mollie Beattie Wilderness. The Refuge plans to update the existing compatibility determination upon the signing of the record of decision for the Final EIS for the NASA Sounding Rockets Program at Poker Flat, which is expected to be completed in 2013. If future planned landings are proposed in designated Wilderness, a new compatibility determination would be required.

The Revised Plan’s Goal 6 (Chapter 2, Section 2.1.6), and its subsequent objectives, state that the effects of climate change on Refuge resources are to be evaluated through research and monitoring, and considered in management decisions. NASA missions may directly or indirectly contribute to our understanding of and capacity to predict and adapt to climate



Map 4-25
Arctic National Wildlife Refuge
Poker Flat Research Range
Management Areas
Wild River Management
Wilderness Management
Minimal Management
Other Features
Roads
PFRR Flight Zones
Arctic Refuge Boundary
Miles
0 5 10 20 30 40 50 60 70 80
0 5 10 20 30 40 50 60 70 80
Kilometers
Alaska Albers Equal Area Conic Projection, 1983 North American Datum.
**Map prepared by NASA, June 2012
Beaufort Sea
Prudhoe Bay
Kaktovik
Dalton Highway
Ivishak River
Sheenjek River
Wind River
Arctic Village
Canada
Old Crow
Wiseman
Coldfoot
Venetie
Steese Highway
Launch Site
Arctic Ocean
Russia
Alaska
Fairbanks
Canada
Anchorage
Bering Sea
Gulf of Alaska
156°W 154°W 152°W 150°W 148°W 146°W 144°W 142°W 140°W 138°W
70°N 69°N 68°N 67°N 66°N 65°N

change. Managers and scientists will maintain and enhance their involvement in broad-scale programs studying the effects of climate change in arctic and subarctic environments.

In addition to climate change, a full range of appropriate and compatible science-based activities would be considered and potentially implemented across Refuge lands and resources, including sounding rocket landings and recoveries in designated Wilderness. These missions could inform the management of lands under Minimal Management as wells as Wilderness stewardship actions taken by Refuge management. However, those missions with no direct or indirect connection to Refuge purposes, goals, objectives, policies, and guidelines would be unable to obtain authorization for landing and recovery in special land designations, and therefore could not be undertaken. Additionally, the impact of rockets and rocket parts in designated Wilderness, and the potential inability to recover them, would be contrary to the Wilderness Act's requirement to preserve Wilderness character.

Given that approximately five percent of NASA's missions launched from Poker Flat within the past 10 years have had direct climate change related research objectives, any future changes in the land management designations of Arctic Refuge (i.e., additional Wilderness) could present land use conflicts. However, the research conducted at Poker Flat has national importance. Additionally, NASA's increased commitment to locating and removing items from downrange lands, with highest priority assigned to designated Wilderness areas, would further reduce the potential effects on Wilderness character and wilderness characteristics. To that end, one way to facilitate Poker Flat's non-conforming use would be for Congress to include a special provision in any Wilderness establishing legislation that would allow the regulated use of the Wilderness area for rocket landings. The record of decision for the Revised Plan will identify whether the Service supports such a provision, should the decision select an alternative that recommends additional Wilderness areas.