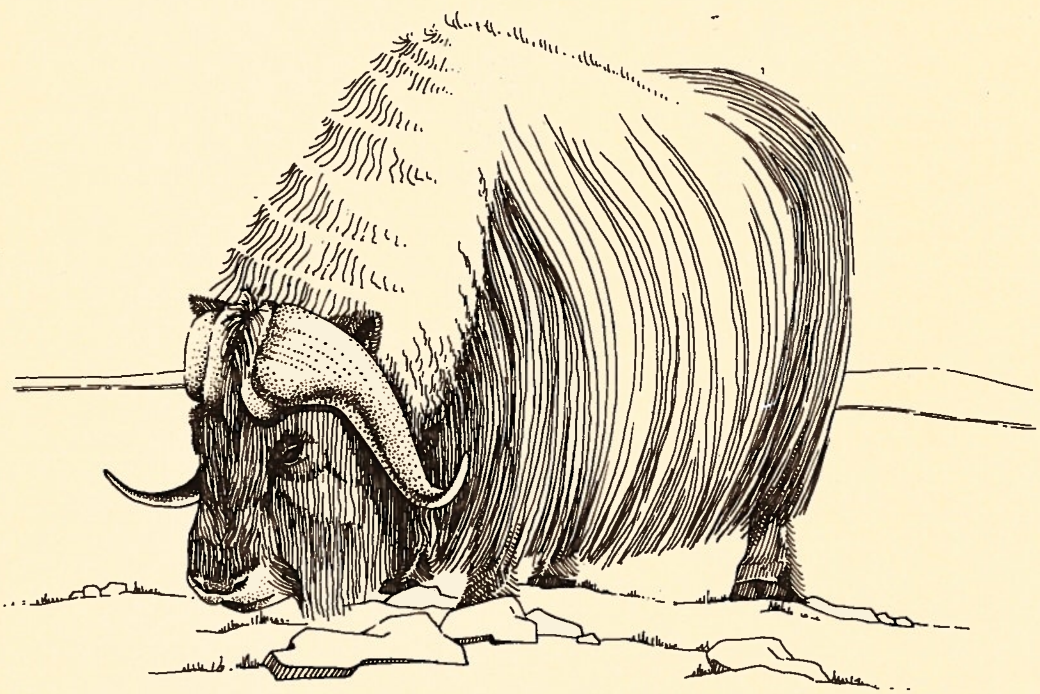
ARCTIC NATIONAL WILDLIFE REFUGE COASTAL PLAIN
RESOURCE ASSESSMENT

# FINAL REPORT BASELINE STUDY OF THE FISH, WILDLIFE, AND THEIR HABITATS

Volume II
Section 1002C
Alaska National Interest Lands Conservation Act



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U.S. Department of the Interior
U.S. Fish and Wildlife Service
Region 7
Anchorage, Alaska
December 1986

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# FINAL REPORT
# BASELINE STUDY
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Section 1002C
Alaska National Interest Lands Conservation Act

Edited by
Gerald W. Garner and Patricia E. Reynolds

U.S. Department of the Interior
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LIST OF PREPARERS

| Name | Positions | Educational background |
|---|---|---|
| Steven C. Amstrup | Wildlife Biologist<br>U.S. Fish and Wildlife Service<br>Alaska Fish and Wildlife Research Center<br>Anchorage, Alaska | B.S. Forestry, University of Washington, Seattle.<br>M.S. Wildlife Biology, University of Idaho, Moscow. |
| Alan W. Brackney | Wildlife Biologist<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | B.S. Fish and Wildlife Biology, Iowa State University, Ames.<br>M.S. Zoology, Ohio State University, Columbus. |
| David C. Douglas | Biological Technician<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | B.S. Biology, Utah State University,<br>M.S. Wildlife Biology, Washington State University, Pullman. |
| Nancy A. Felix | Botanist<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | A.B. Biology, Washington University St. Louis, Missouri.<br>M.S. Ecology, University California, Davis.<br>M.S. Range Management, University California, Davis. |
| Douglas Fruge | Assistant Refuge Manager<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | B.S. Zoology, McNeese State University, Lake Charles, Louisiana.<br>M.S. Fisheries Biology, Louisiana State University, Baton Rouge. |

| Name | Positions | Educational background |
|---|---|---|
| Gerald Garner | Wildlife Biologist<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | B.S. Wildlife Management Oklahoma State University, Stillwater.<br>M.S. Game Management, Louisiana State University, Baton Rouge.<br>Ph.D. Wildlife Ecology, Oklahoma State University, Stillwater. |
| M. Torre Jorgenson | Botanist<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | B.S. Geography and Biology, University of Minnesota, Duluth.<br>M.S. Natural Resource Management, University of Alaska, Fairbanks. |
| William Kirk | Botanist<br>U.S. Fish and Wildlife Service<br>Program Support Services<br>Anchorage, Alaska | B.S. Zoology/Biology, University of Miami, Miami, Florida.<br>M.A. Biological Instruction in Post Secondary, University of Miami, Florida.<br>Ph.D. Botany/Biology, Texas A & M University, College Station. |
| Robert Lipkin | Botanist<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | B.A. Anthropology, State University of New York, Albany.<br>M.S. Botany, University of Alaska, Fairbanks. |

| Name | Positions | Educational background |
| --- | --- | --- |
| Francis Mauer | Wildlife Biologist<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | B.S. Wildlife Biology, South Dakota State University, Brookings.<br>M.S. Zoology, University of Alaska, Fairbanks. |
| Marta McWhorter | Biological Technician<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | B.S. Wildlife Biology, Colorado State University, Fort Collins. |
| Gary Muehlenhardt | Biological Technician<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | B.S. Wildlife Biology, University of Wisconsin, Stevens Point. |
| Russel M. Oates | Wildlife Biologist<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | B.S. Zoology, North Carolina State University, Raleigh.<br>M.S. Wildlife Science, Oregon State University, Corvallis. |
| Martha K. Raynolds | Botanist<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | B.S. Geography and Environmental Sciences, Dartmouth College Hanover, New Hampshire.<br>M.S. Botany, Virginia Polytechnic Institute and State University, Blacksburg. |
| Patricia E. Reynolds | Ecologist<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | B.S. Zoology, University of Utah, Salt Lake City.<br>M.S. Zoology, University of Montana, Missoula. |
| Susan Schulmeister | Biological Technician<br>U.S. Fish and Wildlife Service<br>Northern Alaska Ecological Services<br>Fairbanks, Alaska | B.A. Wildlife Biology, Humboldt State University, Arcata, California. |

| Name | Positions | Educational background |
|---|---|---|
| Tonya M. Stevens | Biological Technician<br>U.S. Fish and Wildlife Service<br>Fish and Wildlife Enhancement<br>Fairbanks, Alaska | B.S. Fisheries,<br>University of Alaska,<br>Fairbanks. |
| Gregory J. Weiler | Wildlife Biologist<br>U.S. Fish and Wildlife Service<br>Arctic National Wildlife Refuge<br>Fairbanks, Alaska | B.S. Wildlife Management,<br>University of Alaska,<br>Fairbanks. |
| Robin L. West | Fisheries Biologist<br>U.S. Fish and Wildlife Service<br>Fish and Wildlife Enhancement<br>Fairbanks, Alaska | B.S. Wildlife Science,<br>Oregon State University,<br>Corvallis. |
| David Wiswar | Fisheries Biologist<br>U.S. Fish and Wildlife Service<br>Fish and Wildlife Enhancement<br>Fairbanks, Alaska | B.S. Biological Sciences,<br>University of Alaska,<br>Fairbanks. |

## CONVERSION TABLE

For those readers who may prefer the commonly used American units, rather than the metric (Sl), the conversion factors for the units used in this report are given below.

| Multiply Metric S(l) Units | By | To obtain American Units |
|---|---|---|
| Centimeters (cm) | 0.3937 | Inches (in) |
| Meter (m) | 1.0936 | Yards (yd) |
| Kilometers (km) | 0.6215 | Miles (mi) |
| Grams (g) | 0.0352 | Ounces (oz) |
| Kilograms (kg) | 2.2046 | Pounds (lb) |
| Liters (L) | 0.2642 | Gallons (gal) |
| Square kilometers ($km^2$) | 0.3861 | Square miles ($mi^2$) |
| Square kilometers ($km^2$) | 247.1050 | Acres |
| Hectares (ha) | 2.4711 | Acres |
| Kilograms per hectare (kg/ha) | 0.8262 | Pounds per acre (lb/acre) |
| Cubic meters per second | 35.7143 | Cubic feet per second |
| Degrees Celsius (°C) | (°Cx1.8)+32 | Degrees Fahrenheit (°F) |

Chapter 6

# FISH

This chapter presents information relevant to fishery resources on the ANWR coastal plain and adjacent areas (Fig. 1) and is divided into 5 sections: 1) a brief review of recent work done by the Fairbanks Fishery Resources office and a short summary of pertinent studies carried out by other research organizations; 2) habitat description; 3) species descriptions; 4) discussion of impacts of human activities; and 5) remaining data gaps concerning fishery resources within the ANWR study area.

## Recent Work

In the initial baseline report of 1982, the following 6 major information gaps were identified:

a. fish distribution in lakes and streams east of the Canning River.

b. locations and quality of fish overwintering areas.

c. locations and discharge of springs.

d. population sizes and life histories of arctic char in various drainages.

e. species composition and distribution in the nearshore and lagoon fisheries.

f. human fishing pressure.

To address these data gaps, USFWS investigators in 1981 and 1982 assessed habitat conditions and the general distribution and life histories of major species in drainages between the Canning and Sadlerochit Rivers. Radio telemetry was used to monitor fall and winter movements of anadromous arctic char on the Canning River (Fig.2).

Survey work continued in 1983 on the Okpilak, Jago, and Hulahula Rivers and on the smaller drainages between the Katakturuk and Aichilik Rivers. Char overwintering locations and movements, spawning grounds, and habitat requirements were examined on the Hulahula and Canning Rivers (Fig.2).

In 1984 information was collected on seasonal abundance, age, growth, and food habits of fishes in Nuvagapak Lagoon (Beaufort Lagoon) (Fig.2). The char radio-tracking project on the Hulahula River was completed; char in the Aichilik River and grayling in 3 western refuge drainages were radio-tagged and tracked to determine distribution, migration patterns, and overwintering locations.

The Beaufort Lagoon investigations were modified slightly and repeated in 1985. Researchers expanded the grayling telemetry project and conducted a fisheries survey on the Kongakut River. This river does not lie within the 1002c study area; however, any oil development within the refuge may result in an influx of sport fishermen due to the high-quality char and grayling fishing on the Kongakut.

The Division of Sport Fisheries of the Alaska Department of Fish and Game has conducted monitoring and evaluation studies of arctic waters since 1969. Most of these studies occurred in Prudhoe Bay, and the Colville and Sagavanirktok Rivers (Fig. 1). The investigations included:

1. fish distribution along the ANWR coast (Roguski and Komerek 1972),
2. fish distribution in lakes along the pipeline corridor of the north slope (Bendock 1980 and 1982, Furniss 1974),
3. tagging and recovery of arctic char from the Sagavanirktok River drainage (Yoshihara 1972 and 1973, Furniss 1974 and 1975),
4. aerial counts of arctic char in the Sagavanirktok River drainage (Yoshihara 1972 and 1973, Furniss 1974 and 1975, Bendock 1980, 1981, 1982 and 1983, Bendock and Burr 1984),
5. overwintering habitat in the Colville River (Bendock 1980, 1981),
6. overwintering locations of arctic char and burbot in the Sagavanirktok River (Bendock 1981, 1982 and 1983, Bendock and Burr 1984),
7. monitoring the subsistence fishery at Barter Island (Furniss 1974)

Also working in the same areas in the 1970's was a private research group, Aquatic Environments Limited, which undertook biological investigations for Alaska/Canada Arctic Gas along proposed routes of an Alaska-Canada pipeline. The study area extended from Prudhoe Bay to the Mackenzie River delta. An extensive collection of baseline information concerning water availability, fish distribution, and habitat condition was generated and serves as excellent reference (Craig and McCart 1974, Craig and Poulin 1974, DeBruyn and McCart 1974, Glova and McCart 1974, Ward and Craig 1974, Craig 1977a, Griffiths et al. 1977, Mann 1975, Griffiths et al. 1979).

The Beaufort Sea became the focus of many other scientists through projects directed under NOAA's Outer Continental Shelf Environmental Assessment Program (OCSEAP) beginning in 1975. Norton and Weller (1984) reviewed the history of scientific endeavor linked with development of oil at Prudhoe Bay. This review is 1 of a collection of papers written after culmination of the program (Barnes et al. 1984). This collection of papers is a comprehensive assemblage of work done on the meteorology, oceanography, geology, and biology of the Beaufort Sea.

Permits for certain oil development activities require environmental assessment and monitoring programs. Thus, in recent years, private biological consulting firms engaged in monitoring the fisheries resources for oil companies have added a considerable amount of fisheries information to the north slope data base.

Although much of the Prudhoe Bay work has been cited in this chapter, it is important to recognize key differences between the western coastal region of the Beaufort Sea (Simpson Lagoon, Prudhoe Bay) and the eastern Beaufort Sea coastal region (ANWR). The refuge has more lagoons protected by barrier islands and fewer large bays. Coastal zone habitat in ANWR is influenced by the input of mountain streams, many of which are spring-fed and provide overwintering areas for fish. In contrast, on the western coastal plain, the lotic environment is comprised of slow-flowing tundra streams and rivers where tundra lakes may play a large role as overwintering fish habitat. Fish abundance and distribution on ANWR are directly related to habitat which is described in the following section.

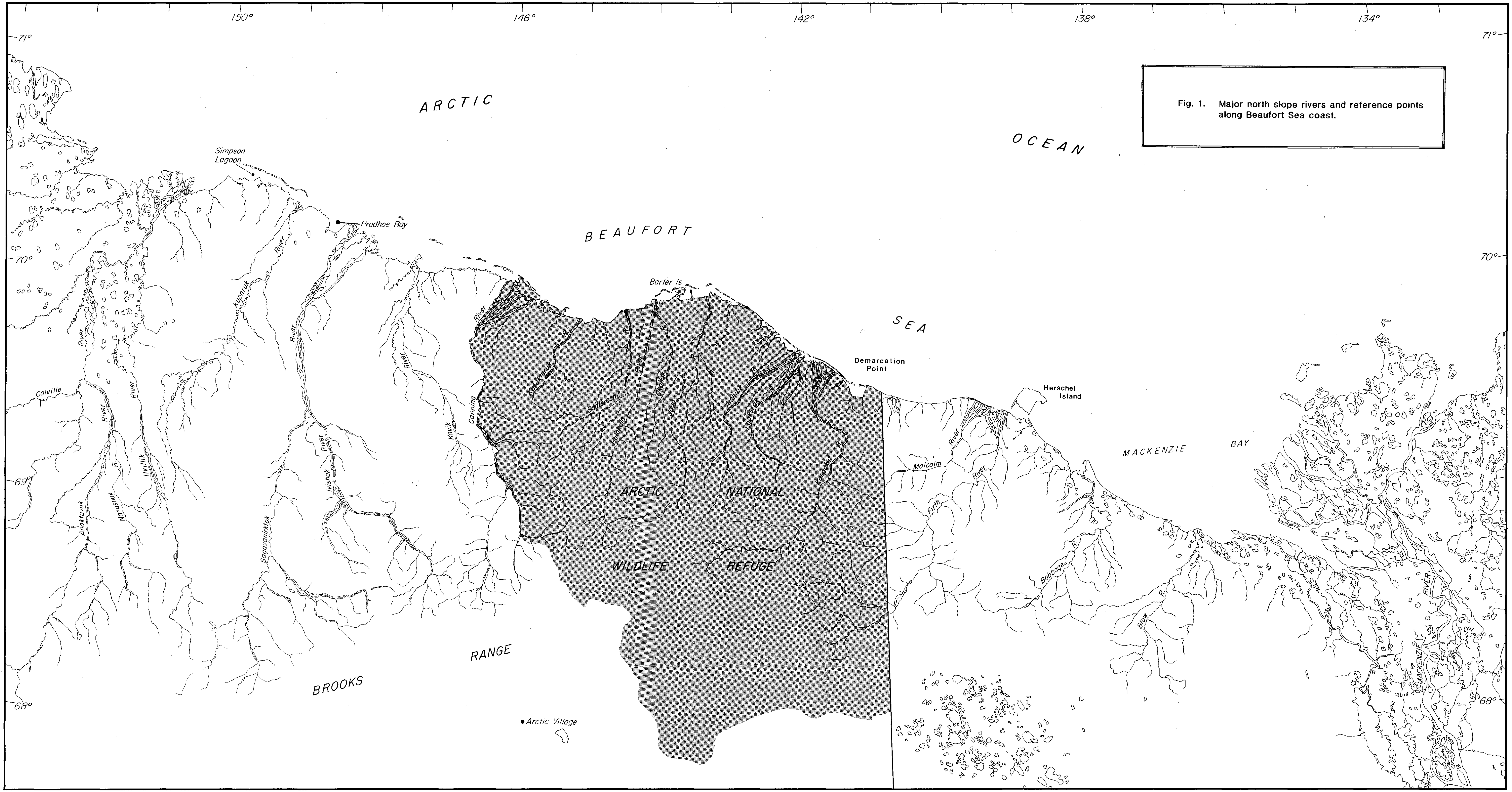


Fig. 1. Major north slope rivers and reference points along Beaufort Sea coast.

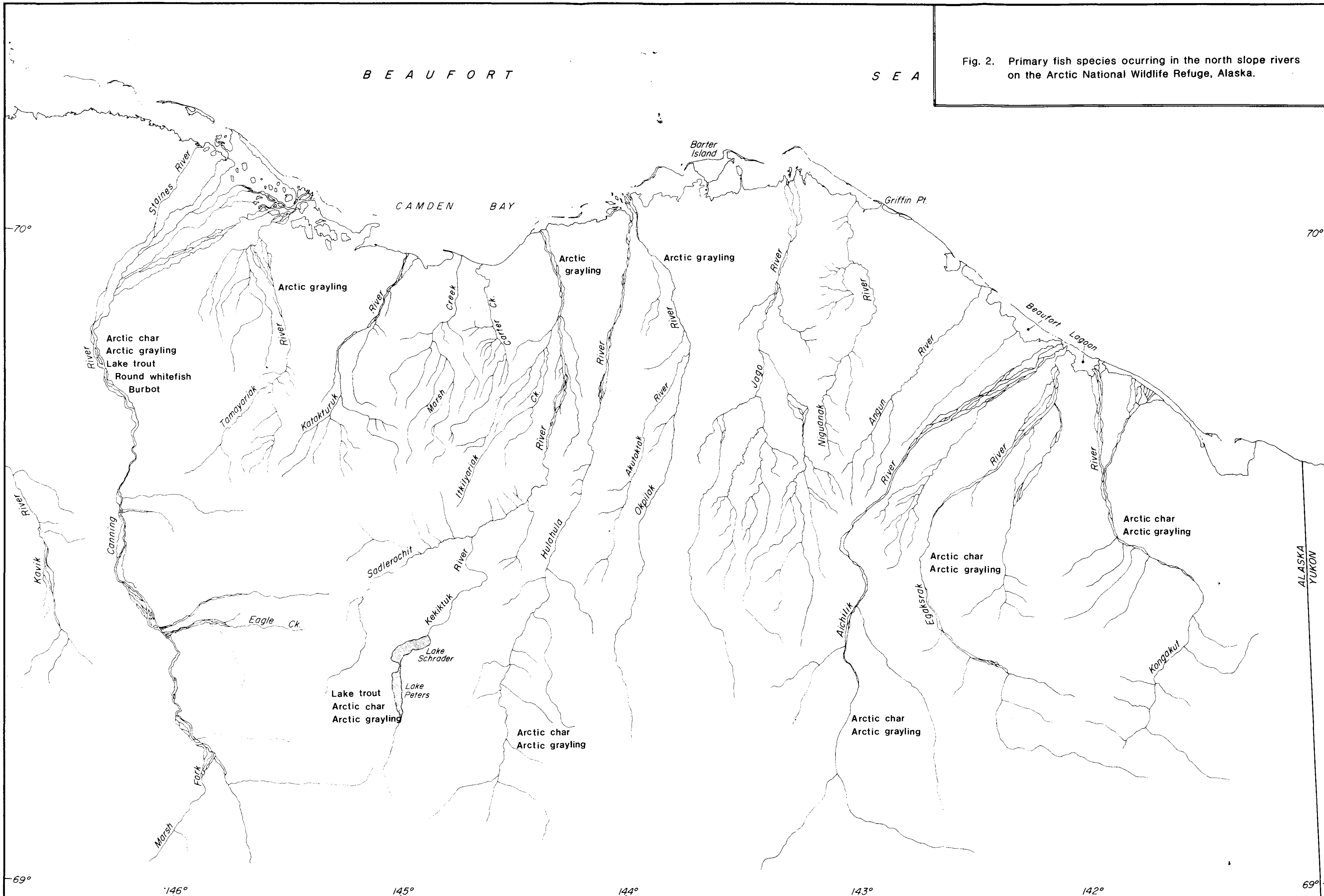


Fig. 2. Primary fish species ocurring in the north slope rivers on the Arctic National Wildlife Refuge, Alaska.

## Habitat Description

Severe winter conditions in the arctic reduce available water supplies. The resulting scarcity of overwintering habitat is perhaps the greatest limiting factor for arctic anadromous and freshwater fish populations. Many sections of river channels and coastal lakes (less than 3 m in depth) freeze solid. Winter flow is generally immeasurable (Arnborg et al. 1966, Murphy and Greenwood 1971, McCart et al. 1972). During this period water sources are limited to spring areas, deep isolated pools, deeper lakes, and brackish river delta areas (Wilson et al. 1977). Known and potential overwintering areas are depicted in Fig. 3.

Springs provide the major source of water to downstream overwintering areas (Childers et al. 1973, Craig and Poulin 1974). The importance of springs for overwintering and spawning for arctic fish populations has been well documented (Yoshihara 1972 and 1973, McCart and Craig 1973, Craig and McCart 1974, Furniss 1974 and 1975, Alt and Furniss 1976, Craig 1977b). Char at all stages of life history are present in spring areas (Glova and McCart 1974, Craig 1977c). McCart et al. (1972) found that the abundance and diversity of macroinvertebrates in springs and spring-fed sections of the channel were much greater than in other arctic lotic habitats. Glesne and Deschermeier (1984) and Deschermeier et al. (1986) found macroinvertebrate abundance higher in spring streams, but found diversity lower at those sites.

Many springs have been identified on and adjacent to the ANWR study area (Fig. 3). The cumulative discharge of springs on the Canning River drainage is 1 of the largest on the north slope (Childers et al. 1977). The largest spring on the Canning River is Shublik Springs, located on the southwest end of Copleston Mountain. The discharge from this spring remains fairly constant throughout the year at about 0.68 $m^3/s$ (Table 1). Sadlerochit Spring, the largest known spring on the north slope that issues from a single bedrock source, is within the ANWR study area. This spring is located on the east end of the Sadlerochit Mountains and has a fairly constant discharge of about 1.04 $m^3/s$ (Childers et al. 1977). Red Hill Spring, which drains into the Tamayariak River, is much smaller, with a discharge of 0.02 $m^3/s$ (Childers et al. 1977), but is noteworthy as 1 of the few hot springs on the north slope (32.8$^{o}$C in April). Another hot spring is located in the mountains along the Okpilak River, but no data are available for the characteristics of this spring. Three springs on the Hulahula River provide overwintering habitat for arctic char and arctic grayling. Residents of Kaktovik use the fish overwintering in these areas along the Hulahula River during the winter months, adding these fishery resources to their subsistence harvest. Small springs are located throughout the Kongakut River drainage (Deschermeier et al. 1986), with the largest spring located close to the mouth on the alluvial fan plain. Overflow from this spring in winter has produced icings as large as 50 $km^2$ (Childers et al. 1977). At least 1 spring occurs along the Egaksrak River as evidence by an icing when the rim enters the coastal plain. No data are available on the characteristics of this spring.

Icings such as those on the Kongakut River are known as aufeis, and may become several m thick. The area, thickness, and location of these icings are primarily dependent up on the volume of water supplied by the spring and to a lesser extent on the water temperature, air temperature, and topography of the ice accumulation area. Aufeis melts slower than snow cover and may persist

Table 1. Chemical and physical characteristics for selected springs on the north slope, Arctic National Wildlife Refuge (Adapted from Childers et al. 1977).

| Spring | Latitude | Longitude | Date | Discharge (cms) | Specific conductance (micromhos/cm at 25°C) | pH | Water temperature (°C) | Turbidity (JTU) | Dissolved oxygen (mg/l) |
|---|---|---|---|---|---|---|---|---|---|
| Shublik | 69°28'20" | 146°11'50" | 10 May 1973 | 0.68 | 275 | 8.0 | 5.5 | -- | -- |
| | | | 28 April 1975 | 0.68 | 270 | 7.9 | 5.5 | 1 | 9.8 |
| Red Hill | 69°37'37" | 146°01'38" | 28 April 1975 | 0.02 | 1000 | 7.0 | 33.0 | 2 | 0.4 |
| | | | 12 August 1975 | -- | 950 | 8.2 | 29.0 | -- | -- |
| Nularvik River | 69°41'42" | 145°06'33" | 28 April 1975 | 0.12 | 245 | 8.2 | 1.0 | 1 | 11.4 |
| Sadlerochit | 69°39'23" | 144°23'37" | 27 Arpil 1975 | 0.99 | 410 | 7.9 | 13.0 | 1 | 7.0 |
| | | | 7 August 1975 | 1.06 | 400 | 7.9 | 13.0 | -- | 6.2 |
| | | | 16 November 1975 | 1.10 | 360 | 7.3 | -- | -- | -- |
| Hulahula | 69°45'39" | 144°09'15" | 28 April 1975 | 0.21 | 240 | 8.0 | 1.0 | 1 | 13.6 |
| | | | 26 November 1975 | 0.13 | 225 | 7.2 | 1.0 | -- | -- |
| Okerokivik River | 69°43'06" | 143°14'25" | 24 November 1975 | 0.74 | 300 | 7.3 | 1.0 | -- | -- |
| Aichilik River | 69°31'06" | 143°02'00" | 27 April 1975 | 0.04 | 338 | 8.0 | 3.6 | 2 | 12.4 |

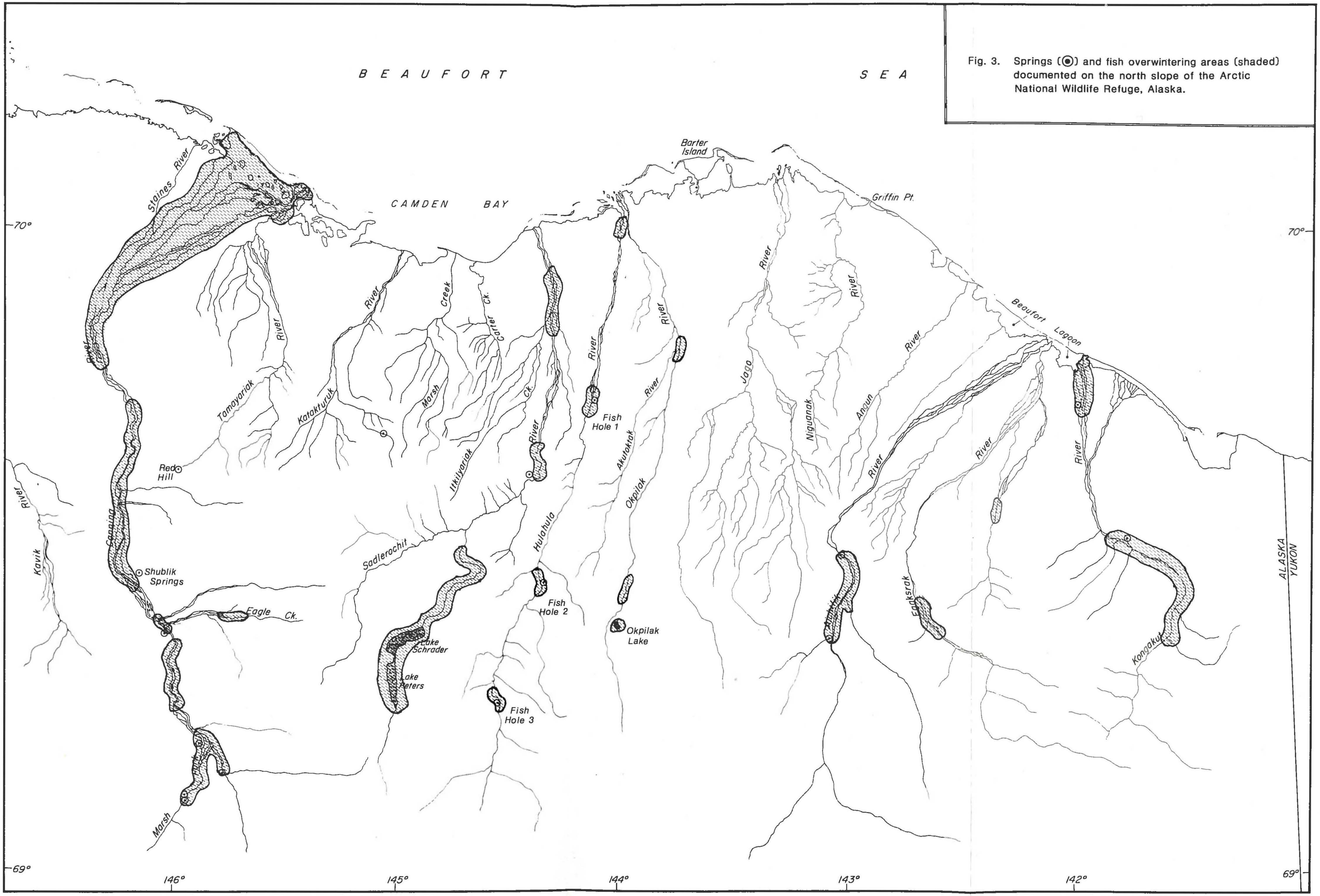


Fig. 3. Springs (◉) and fish overwintering areas (shaded) documented on the north slope of the Arctic National Wildlife Refuge, Alaska.

throughout the year. Aufeis can have major effects on stream channel configuration and riparian vegetation in the area in which they are formed. On the Canning River, patches of aufeis are extensive and are almost continuous by late winter from the upper Marsh Fork to the area adjacent to Red Hill. One of the largest aufeis formations in the study area occurs in the Canning River delta. Aufeis is common on many of the drainages in the ANWR study area (Fig. 3), and may serve as an indicator of char habitat, since it is generally the result of spring water overflow.

Deep river pools may provide overwintering habitat for arctic fishes. Furniss (1975) stated that arctic rivers generally range from 1.8 to 3.6 m in depth, but freezing can reduce available habitat to 0.3 to 0.4 m. Mann (1975) stated that fish may not be able to overwinter in water less than 0.5 m in depth. Some surveys indicate that arctic fishes inhabit pools generally deeper than 2 m (Yoshihara 1972, Furniss 1974 and 1975), but Alt and Furniss (1976) found pools in the Sagavanirktok River with depths less than 2 m harboring overwintering populations of fish. Deep pools on some drainages of ANWR appear to be relatively scarce. On the Canning River during August 1981, pools were measured by Smith and Glesne (1983) utilizing a recording fathometer. Pool depths ranged up to 4.3 m; however, only 12 pools were recorded with depths greater than 2 m between the Eagle Creek confluence with the Canning River and the Staines River divergence from the Canning (Fig. 3). Similar conditions were observed on the Sadlerochit and lower Hulahula Rivers. Spring and groundwater areas are used for overwintering on these and other streams in or adjacent to the ANWR study area.

Several parameters are intimately involved with the suitability of river pools for overwintering. These ultimately effect dissolved oxygen concentration and include: density of organisms in the pool area, species' physiological tolerances, volume of the pool, temperature, organic matter, and spring influence. Dissolved oxygen concentrations of river pools in which live fish have been found range from 0.6 to 15 mg/l (Yoshihara 1972, Shallock and Lotspeich 1974, Alt and Furniss 1976, Bendock 1976 and 1980). Physical and chemical characteristics of drainages on or adjacent to the ANWR study area are presented in Table 2. Spring flooding during breakup dramatically increases discharge rates from these drainages and lowers dissolved solids concentrations (Table 3). Smith and Glesne (1983) investigated physical characteristics of several rivers in ANWR in relation to potential overwintering habitat. They concluded greatest potential was in fourth and fifth order streams where gradient is less than 4% and an unbraided channel pattern existed. These characteristics are probably more applicable predicting grayling winter locations, since grayling do not always depend on perennial groundwater sources for overwintering and spawning as char do.

Overwintering of fishes in river deltas and coastal waters influenced by freshwater dilution has been documented. Marine nearshore waters have been shown to be important spawning and overwintering areas for marine fishes such as arctic cod, fourhorn sculpin, saffron cod, and snailfish (Craig and Haldorson 1981). The importance of river deltas as overwintering areas for freshwater and marine fishes has been examined by Kogl and Schell (1975), Bendock (1979), and Dew (1982). Percy (1975) documented fish overwintering in the Mackenzie River delta. Arctic and least cisco have shown a preference for habitats with brackish water during the ice free period and this trend

Table 2. Chemical and physical characteristics for selected streams on the north slope, Arctic National Wildlife Refuge, 1975 (Adapted from Childers et al. 1977).

| River or Stream | Latitude | Longitude | Date | Discharge (cms) | Specific conductance (micromhos/cm at 25°C) | pH | Water temperature (°C) | Turbidity (JTU) | Dissolved oxygen (mg/l) |
|---|---|---|---|---|---|---|---|---|---|
| Canning River | 69°48'29" | 146°23'25" | 8 November | 6.46 | -- | 7.7 | -- | -- | -- |
| Canning River | 69°50'38" | 146°42'10" | 12 August | 70.80 | 240 | 7.7 | 9.0 | 1.3 | 11.8 |
| Canning River delta, E. channel | 70°04'38" | 145°42'35" | 30 November | 0.00 | -- | 6.7 | 0.0 | -- | -- |
| Katakturuk River | 69°52'25" | 145°12'00" | 10 August | 11.33 | 250 | 7.8 | 3.0 | 20.0 | 13.2 |
| Marsh Creek | 69°47'33" | 144°49'00" | 10 August | 0.42 | 425 | 7.5 | 3.5 | 2.0 | 12.2 |
| Sadlerochit River | 69°39'13" | 144°22'56" | 7 August | -- | 155 | 7.1 | 7.0 | 0.3 | 11.6 |
| Hulahula River | 69°41'47" | 144°12'10" | 7 August | 20.93 | 210 | 7.5 | 4.0 | 2.0 | 12.9 |
| Jago River | 69°50'38" | 146°27'10" | 8 August | 7.56 | 193 | 7.7 | 4.5 | 1.0 | 12.9 |
| Okerkovik River | 69°42'07" | 143°14'23" | 8 August | 2.41 | 275 | 7.5 | 8.0 | 0.0 | 11.6 |
| Aichilik River | 69°35'23" | 142°58'03" | 11 August | 22.66 | 235 | 7.5 | 3.5 | 1.0 | 12.9 |
| Aichilik River | 69°40'30" | 142°46'52" | 25 November | 0.00 | 370 | 7.2 | 0.0 | -- | -- |
| Aichilik River | 69°48'50" | 142°10'00" | 23 November | 0.00 | 700 | 7.2 | 0.0 | -- | -- |

Table 3. Flood characteristics on selected rivers in the Arctic National Wildlife Refuge (Adapted from Childers et al. 1977).

| | Bankfull Channel | | | | | | Maximum Evident Flood | | Flood Characteristics | |
|---|---|---|---|---|---|---|---|---|---|---|
| Stream site | Streambed material | Slope (%) | Width (m) | Mean depth (m) | Max depth (m) | Discharge (cms) | Width (m) | Discharge (cms) | $Q_2$(cms) | $Q_{50}$(cms) |
| Canning River 69°50'38" 146°27'10" | large cobble | 0.12 | 292 | 2.1 | 4.3 | 877.92 | 351 | 1500.96 | 124.61 | 382.32 |
| Katakturuk River 69°52'25" 145°27'10" | coarse gravel | 0.64 | 207 | 1.1 | 2.1 | 481.44 | 204 | 283.2 | 18.69 | 79.30 |
| Marsh Creek 69°47'32" 144°49'00" | coarse gravel | 1.48 | 171 | 1.0 | 1.8 | 396.48 | 85 | 14.16 | 21.24 | 87.79 |
| Sadlerochit River 69°39'13" 144°12'10" | boulders | 0.62 | 85 | 1.4 | 2.1 | 311.52 | 85 | 311.52 | 39.65 | 147.26 |
| Hulahula River 69°41'47" 144°12'10" | coarse gravel | 0.50 | 76 | 2.2 | 2.7 | 651.36 | 73 | 283.2 | 50.98 | 178.42 |
| Jago River 69°37'02" 143°41'06" | boulders | 1.32 | 55 | 1.8 | 2.1 | 396.48 | 55 | 396.48 | 28.32 | 101.95 |
| Okerokovik River 69°42'07" 143°14'23" | coarse gravel | 0.33 | 180 | 1.0 | 2.1 | 283.2 | 110 | 65.14 | 18.41 | 73.63 |
| Aichilik River 69°35'23" 142°58'03" | coarse gravel | 0.54 | 250 | 1.7 | 2.4 | 934.56 | 249 | 764.64 | 53.81 | 178.42 |

continues during winter when they move into brackish waters of the Colville Delta (Craig and Haldorson 1981). Suitability of delta overwintering areas depends on the salinity and tolerances of species using the area. Arctic char may overwinter in delta areas that are not hypersaline (Alaskan Arctic Gas 1974).

The nearshore brackish-water region adjacent to the mainland generally extends less than 10 km offshore and may include coastal lagoons and river deltas. It is formed by the mixing of marine waters with freshwater from spring breakup in rivers and is driven by the prevailing easterly winds and northwesterly longshore current. The ice-free season is usually between early July and late September or early October. Open leads occur first near freshwater inundations. Water temperatures are cold (less than 5°C) and salinities are low (under 10 ppt) during the early open water season. Temperatures and salinities increase to 7-10°C and 18-25 ppt, respectively, during the mid-summer period of mid-July to mid-August. In late summer, temperatures decrease and brackish conditions prevail. This general scheme presented by McCart (1980) for Simpson Lagoon is also applicable to Beaufort Lagoon, with the exception that salinities in late August were not above 14.0 ppt (West and Wiswar 1985). This phenomenon was probably due to the proximity of the Aichilik River to Beaufort Lagoon and its freshwater intrusion being retained within the lagoon by barrier islands. Beaufort Lagoon is characterized as a limited exchange type lagoon: whereas Simpson Lagoon was characterized as an open system (Hachmeister and Vinelli 1983). Lower salinities were also reported in Kaktovik Lagoon than Simpson Lagoon (Griffiths et al. 1977).

The nearshore region is important habitat to fish for migration, feeding, overwintering, and spawning. This region serves as a migration corridor for anadromous fish. Juvenile arctic cisco apparently prefer the relatively warmer water associated with this band (Fechhelm et al. 1983). The abundance of least cisco near the Sagavanirktok River delta was positively correlated with temperature (Griffiths et al. 1983). The coastal lagoons contain major feeding areas for anadromous fish and those marine fish that migrate into the nearshore area during the summer. In Simpson Lagoon, Griffiths and Dillinger (1981) estimated that the biomass of invertebrate organisms used as major prey items (mysids and amphipods) was 1-2 orders of magnitude greater than the daily requirements of the vertebrate consumers. Arctic cisco, least cisco (Craig and Haldorson 1981) and arctic grayling (West and Wiswar 1985, Wiswar et al. 1986) utilized lower river sections and river deltas for overwintering. Fourhorn sculpins and arctic flounder are both nearshore spawners (Morrow 1980).

Arctic lakes have been classified by 3 geographic areas: coastal plain, foothill, and mountain. Coastal plain lakes are generally less than 5 m in depth (Carson and Hussey 1962, Prescott 1963, Kaliff 1968, McCart et al. 1972). Glacial foothill lakes and mountain lakes generally exceed 5 m in depth (Kaliff 1968). The numerous, shallow coastal plain lakes generally offer unsuitable habitat in winter. Many, with maximum depths less than 3 m, freeze solid; others exhibit high ionic concentrations and low dissolved oxygen (Wilson et al. 1977). Lake overwintering suitability generally increases going from coastal to the mountainous regions. Walker (1960) noted that arctic lakes that drain into streams often have open water near the outlet with concentrations of fish being found in these areas. Lakes Peters and Schrader in the Sadlerochit Mountains and Okpilak Lake in the Romanzof

Mountains (Fig. 2) are overwintering sites for lake trout, arctic char, and grayling (Ward and Craig 1974, West and Wiswar 1985, Wiswar et al. 1986).

Although overwintering habitat is of primary importance to arctic fishes, those areas that are unsuitable in winter may play an important role as feeding, rearing, spawning, and migration passages during ice free periods. Ward and Craig (1974) stated that some coastal lakes may serve only as feeding areas. DeBruyn and McCart (1974) found that grayling spawn primarily in tundra and foothill streams that freeze solid in winter. Arctic grayling and arctic char migrate through brackish river delta waters en route to overwintering areas in fall, but neither has been found in these areas in winter. Therfore, many locations which appear to sustain no fish populations may be used for only a short, essential period in the life cycle of a species.

## Species Description

Craig (1984) lists 62 species of fish inhabiting arctic marine, estuarine or freshwater environments of the Beaufort sea coast. Twenty-two of these species have been reported in marine, estuarine, and fresh water environments on or adjacent to the ANWR study area (Table 4, Fig. 2). There is a great amount of variation in habitat preference and life history requirements between these species and within particular species. Some species such as arctic cod occupy strictly marine-estuarine habitats. Other species occupy only freshwater habitats. Anadromous species may occupy all 3 types of habitat. As a result, the habitat required at various stages of their life cycle (spawning, rearing, feeding, or overwintering) may be widely distributed throughout the north slope. For this reason the following species descriptions emphasize seasonal distributions of fishes. Information on arctic char, arctic grayling, and arctic cisco dominate this section; these fish are abundant in the refuge and received the most attention.

Arctic char. The arctic char is a popular sport fish and also comprises a large portion of north slope subsistence fisheries. This species has a circumpolar distribution; it is common along the Beaufort Sea coast and inhabits many north slope rivers and lakes (Fig. 3).

Taxonomic classification of the north slope arctic char is complicated. McCart (1980) recognized 2 forms of the *Salvelinus alpinus* complex in ANWR: an eastern lake-dweller form reported only in 2 lakes in the lower Canning drainage, and a western form which is distributed throughout ANWR in streams, springs, and lakes.

Four different life history types have been observed for the western arctic char in the ANWR:

1) non-anadromous lake residents,

2) non-anadromous spring residents,

3) non-anadromous stream dwellers known as "residual" char (usually males),

4) anadromous stream-dwellers.

Table 4. Fishes reported in freshwater, estuarine and marine habitats on the north slope of the Arctic National Wildlife Refuge[a].

| Common name | Scientific name |
| --- | --- |
| Freshwater species: | |
| arctic grayling | *Thymallus arcticus* |
| round whitefish | *Prosopium cylindraceum* |
| lake trout | *Salvelinus namaycush* |
| burbot | *Lota lota* |
| Anadromous species | |
| arctic char | *Salvelinus alpinus* |
| arctic cisco | *Coregonus autumnalis* |
| least cisco | *Coregonus sardinella* |
| broad whitefish | *Coregonus nasus* |
| humpback whitefish | *Coregonus pidschian* |
| pink salmon | *Oncorhynchus gorbuscha* |
| chum salmon | *Oncorhynchus keta* |
| rainbow smelt | *Osmerus mordax dentex* |
| ninespine stickleback | *Pungitius pungitius* |
| Marine species | |
| capelin | *Mallotus villosus* |
| fourhorn sculpin | *Myoxocephaleus quadricornis* |
| arctic sculpin | *Myoxocephaleus scorpioides* |
| arctic flounder | *Liopsetta glacialis* |
| arctic cod | *Boreogadus saida* |
| saffron cod | *Eleginus gracilis* |
| snailfish | *Liparus* sp. |
| Pacific sand lance | *Ammodytes hexapterus* |
| slender eelblenny | *Lumpenus fabricii* |
| stout eelblenny | *Lumpenus medius* |
| eelpout | *Lycodes* spp. |

[a]Sources: Roguski and Komerek 1972, Ward and Craig 1974, Craig 1977a, Craig 1977b, Griffiths et al. 1977, Wilson et al. 1977, Griffiths 1983, Smith and Glesne 1983, Daum et al. 1984, West and Wiswar 1985.

All 4 of these types exist in the Canning River drainage (Craig 1977a). Spring residents have been identified in Shublik Springs (Craig 1977a), a tributary of the Canning, and in Sadlerochit Spring which drains into the Sadlerochit River (Craig 1977b). Baseline surveys revealed residual populations in the Canning, Hulahula, and Aichilik Rivers; lake resident char were found in lakes of the Jago River, in the lower portion of the Canning River drainage, and in Peters and Schrader Lakes (Smith and Glesne 1983, Daum et al. 1984). The Canning, Hulahula, Aichilik, Egaksrak, and Kongakut Rivers contain anadromous populations of arctic char. These anadromous char move freely along the entire coastline of ANWR and have been captured in most major lagoons (Roguski and Komerek 1972, Griffiths et al. 1977, Griffiths 1983, West and Wiswar 1985, Wiswar and West 1986).

The general life history cycle of anadromous char is as follows: mature spawners migrate up-river beginning in mid-summer and continuing until fall; spawning begins in late summer, peaks in October, then ends in November; fry emerge from gravel the next May. Anadromous char will remain in freshwater for 2 to 5 years before going to sea. Migration to the sea begins in late May to early June. During summer, anadromous char feed in shallow nearshore, coastal waters, sometimes traveling great distances from their overwintering habitat. Migration back to the spawning grounds begins as early as late June, with larger size spawners moving up river first, followed by immatures and non-spawners. Mature adults may not spawn every year. Segregation of non-spawners and spawners into different overwintering areas has been reported (McCart et al. 1972, Furniss 1975, Smith and Glesne 1983).

Overwintering habitat is a limiting factor for char on the north slope. Identification of these areas is difficult. Some winter habitat has been presumed, based on observations from aerial surveys of fall concentrations of fish prior to freeze-up. A few winter "fish holes" are known from traditional subsistence use. Deep pools in rivers have been located by fathometer and confirmed as suitable overwintering areas by radio-tracking fish which have had transmitters surgically or esophageally implanted. Although radio-tracking has been a very effective method of following migration and identifying spawning and overwintering habitat, pinpointing exact positions is diffcult when ice, snow and darkness obscure landmarks and pattern of river beds.

Aerial surveys were conducted on the Canning, Tamayariak, Katakturuk, Hulahula, Okpilak, Jago, and Aichilik Rivers in September 1982 and 1983 (Smith and Glesne 1983, Daum et al. 1984) and of the Niguanak and Angun Rivers, and Marsh and Carter Creeks in July 1983 (Daum et al. 1984). Char spawning redds were located in the upper Canning River and in the Marsh Fork of the Canning River. Concentrations of spawners and non-spawners were observed from the mid- to upper Canning. In the Aichilik River, 2 groundwater sources provide what appear to be suitable overwintering locations; however, concentrations of char were observed only at the upstream spring. Large groups of char were spotted at Fish Holes 1, 2, and 3 on the Hulahula River. No fish were observed during aerial surveys of the Katakturuk, Okpilak, Jago, Niguanak, and Angun Rivers and both Marsh and Carter Creeks. Arctic char were found in winter in 2 tributaries of the Egaksrak River (Ward and Craig 1974).

Radio-telemetry projects have resulted in more specific identification of overwintering habitat. Twelve winter locations along the Canning River were recorded by monitoring radio-tagged char. Winter movements of char in the

Canning River were considerable, up to 24 km downstream from the September tagging site. Radio-tagged char in the Hulahula River, on the other hand, remained at the September tagging site (Fish Hole # 2) with the exception of 1 fish which moved upstream about 18 km towards Fish Hole #3. Char in spawning condition radio-tagged at the mouth of the Aichilik River in August 1984 were relocated downstream from a spring site in the foothills which had been previously identified as probable overwintering habitat during aerial surveys.

Arctic char that inhabit the lakes of the ANWR are non-anadromous (McCart 1980). However, when breakup occurs in late May and early June, adult arctic char overwintering in many of the streams begin to leave. Stream-resident char (mostly the "residual" males) and pre-smolt anadromous char move to feeding and rearing areas downstream, while anadromous char head for the sea. McCart (1980) reported that juvenile char are most common in mountain and spring streams; however, juveniles were collected from foothill and tundra tributaries to the Canning, Hulahula, Aichilik, and Kongakut Rivers (Smith and Glesne 1983, Daum et al. 1984, Deschemeier et al. 1986). Fish 0+ to 4+ years of age collected in tundra stream tributaries to the Canning River were as much as 20 km from the nearest known overwintering area. Based on this observation it was speculated that the lower river area near the delta may also contain overwintering habitat.

Once in coastal waters, char stocks from many rivers of the north slope probably mix to a certain extent. The results of tagging studies indicate char from ANWR streams may move considerable distances west and east. Char from the Hulahula River have been recaptured in Foggy Island Bay and Beaufort Lagoon, char tagged in Beaufort Lagoon have been recaptured near the Sagavanirktok River delta, and char tagged in the Firth River, Canada, were caught in the Canning and Kongakut Rivers (Glova and McCart 1974). Some studies indicate char apparently prefer the nearshore brackish waters to the adjacent marine waters (Bendock 1977, Griffiths et al. 1977, Griffiths et al. 1983). At Beaufort Lagoon, char appeared to be more abundant along the inside of the barrier islands than they were in the nearshore waters (West and Wiswar 1985, Wiswar and West 1986). Arctic char have also been found to be the most abundant anadromous fish on the seaward side of the barrier islands (Craig 1984). This distribution indicates they have a greater tolerance for varying temperature and salinity conditions than other anadromous species, such as arctic and least ciscoes and broad and humpback whitefishes.

Although anadromous char begin moving back into spawning or overwintering streams of ANWR as early as late June, most migration into freshwater takes place in late July and August. Peak movement into the Canning River occurred between middle and late August during 1981 and 1982 (Smith and Glesne 1983). Investigations along the Hulahula River in 1983 (Daum et al. 1984) found a peak movement of smaller char up river in late August; however, most of the spawners probably moved in prior to 5 August, when sampling began.

Some investigators have suggested that not all potential spawners go to sea the summer before they spawn (Glova and McCart 1974, Furniss and Alt 1976, Craig 1977a). Arctic char in spawning condition were captured in late June in the Kongakut River about 50 km from the mouth (Deschermeier et al. 1986). The presence of spawners this far up river in early summer indicates that they may not migrate to the coastal waters or spend a very short time there in the year(s) that they will spawn.

Growth of fish is most often viewed in terms of both length and weight. Since weight fluctuates dramatically in arctic char during their life cycle, this discussion focuses primarily on fork length as a measure of growth. Arctic char sizes in ANWR vary considerably depending on location and life history type. Stream and spring residents are slower growing and small; anadromous char are the fastest growing and attain the greatest lengths. The slowest growing population of record (Craig 1977a) is in Big Lake in the headwater area of the Canning River. The largest char taken from this lake was 189 mm long at age 13; the oldest char collected was 16 years old, but only 160 mm long. In contrast, lake resident char from Peters/Schrader Lakes have been found up to 408 mm (Fischer, unpublished data).

Slow growth in stream residents is evident when comparing anadromous char of the Aichilik River with stream residents collected from the same area. A 9 year old resident had achieved a length of 320 mm, while age 9 anadromous char were 479 to 506 mm long (Smith and Glesne 1983). Perhaps the fastest growing and largest anadromous char are in the Kongakut River. Char to 688 mm were recorded in 1985 (Deschermeier et al. 1986), while Furniss (1975) reported a fish 740 mm long that weighed 3200 g. The anadromous char from streams in the rest of ANWR appear to have growth rates similar to char from north slope drainages to the west and east of the Refuge.

Most fish captured in lagoons are of unknown origin. The largest char caught was taken from Beaufort Lagoon in July 1985. It was a male non-spawner that was 817 mm long and weighed 4820 g (Wiswar and West 1986). In a review of capture data from the north slope, McCart (1980) noted that the largest char taken from the study area are males. Comparisons have not been made for fish from ANWR streams, but in other nearby rivers, it seems that older males tend to be larger than females of the same age (Yoshihara 1973, Bain 1974, Griffiths et al. 1975).

A bimodal length frequency distribution was reported for arctic char in Beaufort Lagoon in 1984 and 1985 (West and Wiswar 1985, Wiswar and West 1986). The predominant size classes were the 150-250 mm and 400-500mm lengths. The predominant age classes were ages 4 and 7. In Simpson Lagoon, Craig and Haldorson (1981) found a bimodal age-frequency distribution with the dominant classes containing 3-5 and 10-11 year olds. Age at sexual maturity may be as early as 2 years, but most fish do not mature until about age 5, and almost all fish are mature by age 8 (McCart 1980).

All known spawning sites for anadromous char on the north slope are associated with springs or groundwater seeps that insure an adequate winter water supply for egg and fry survival (Fig. 3). Several locations on the Canning River have been identified by Craig (1977a) and Smith and Glesne (1983) as spawning sites for arctic char. Some anadromous populations may utilize lakes for spawning but none have been documented.

Length of incubation time for char eggs has been estimated at 7 to 9 months in the Sagavanirktok River (McCart et al. 1972). Craig (1977a) estimated the same incubation time requirements for Canning River char although he speculated that fry in perennial springs might emerge sooner. In a Canning River spring (Craig (1977a), peak emergence occurred during the last few days of May and the first part of June.

The age at which north slope char make their first seaward migration is variable. Craig (1977a) found most char smolting around age 4 or 5, but some smolts were as young as age 2. In the 1985 sampling period at Beaufort Lagoon the dominant length class of arctic char in fyke nets was the 151-200 mm group, which corresponds to an age class of 3 year olds. Fish in this category were probably smolting in the lagoon; faint parr marks were observed on many, while others had already attained a silvery coloration. Forty char under 150 mm long were caught in the same period, with 1 fish only 68 mm long. Although some of these fish may have been early smolts, another explanation is that some of the small juveniles were "washed out" of the Aichilik River when heavy rainfall raised water levels. They were able to survive in the lagoon environment because of the low salinities found inside of the barrier islands.

Arctic char are opportunistic feeders. Diet staples of char which feed in lagoons are similar from Prudhoe Bay to the Mackenzie River Delta; crustaceans (mainly amphipods and mysids), fish, and varying amounts of insects, depending on the degree of fresh water contribution to the feeding area. Stomachs of char taken from Beaufort Lagoon (West and Wiswar 1985) contained mostly gammarid amphipods and fish. Adult spawners apparently cease feeding once they re-enter freshwater to spawn. Residual and juvenile char living in streams feed mainly upon insect larvae. Virtually all char from ANWR streams rely heavily on larvae of the family Chironomidae (midges), of the order Diptera (Stevens and Deschermeier 1986). Other common food items are Plecopteran (stonefly) and Ephemeropteran (mayfly) nymphs.

Lake Trout. Lake trout are widely distributed across the north slope where suitable habitat exists. They are found in rivers such as the Colville and deeper coastal lakes such as Teshekpuk Lake west of ANWR. Within the north slope of ANWR, they are known from coastal plain lakes near the Canning River drainage (Ward and Craig 1974), Okpilak Lake (Daum et al. 1984), and from Peters and Schrader Lakes (Fig. 2).

Lake trout up to 890 mm and weighing 6400 g have been reported from Lakes Peters and Schrader Lakes (Fischer unpublished). Kaktovik residents ice-fish at these lakes (also known as the Neruokpuk Lakes) and have reported similar sizes in their catch (Jacobson and Wentworth 1982). In contrast, the lake trout population of Okpilak Lake appears to be stunted, as the largest fish taken was only 394 mm at age 13. Measurements for lake trout in lakes of the Canning River drainage are not available.

Spawning generally occurs in the fall over a large boulder or rubble bottom in inland lakes at depths less than 13 m (Scott and Crossman 1973). Incubation and hatching vary depending on habitat conditions but usually require 4 to 5 months.

Lake trout overwinter on the north slope in deep lakes and in rivers. Bendock (1980) found a lake trout in the Colville River in a pool 2.4 m deep with dissolved oxygen of 2.4 mg/l. Overwintering locations on the north slope of ANWR other than Peters and Schrader Lakes and Okpilak Lake are unknown.

Hablett (1979) reported that of the lake trout captured during summer in the western arctic, only 49% had food in their stomachs, consisting of the following in descending order of frequency: least cisco, snails, aerial insects, round whitefish, slimy sculpin, and voles.

Arctic Cisco. The Arctic cisco is one of the most abundant and widely distributed fish along the Beaufort Sea coast (Furniss 1975, Bendock 1979, Craig and Haldorson 1981, Griffiths and Gallaway 1983, Griffiths et al. 1983). It is found in northern coastal waters and lower rivers in Europe, Asia, and western North America. In Alaska its range extends from Demarcation Point to Point Barrow (Fig. 1). It has been reported from along the ANWR coast in lagoons and river mouths (Roguski and Komerek 1972, West and Wiswar 1985, Wiswar and West 1986), and in the lower Canning River (Craig 1977a). Craig and Mann (1974) found arctic cisco distribution restricted to marine or brackish water in the Beaufort Sea.

The arctic cisco inhabiting the Alaskan coastal waters of the Beaufort Sea possess a complicated life history. Most arctic cisco are mature by age 7 and thereafter spawn every second year. Spawning in the Mackenzie River system occurs from late September to early October (Percy 1975). Fry emerge from the gravel in spring and migrate to the Mackenzie River delta and spend their first winter within the delta. As yearlings they migrate west to the Sagavanirktok and Colville River deltas and associated nearshore areas, where they have been particularly abundant in 1980, 1983 (Envirosphere 1984) and 1985. The age classes 2 through 6 years comprise the larger portion of the cisco population in these western Beaufort Sea waters and are rare in the Mackenzie River delta (Envirosphere 1984). Older mature arctic cisco begin their migration back to the Mackenzie River in late June through mid-July. Craig and Haldorson (1981) reported that those cisco remaining in Simpson Lagoon throughout the open water season had moved out by mid-September presumably to overwinter in the deltas of the Colville, Sagavanirktok, and Kuparuk Rivers (Fig. 1).

Major movements of arctic cisco in Beaufort Lagoon within ANWR, occurred during the latter half of July (West and Wiswar 1985, Wiswar and West 1986). Most fish were captured along the lagoon side of the barrier island. The modal length class was 376-400 mm during the 1984 and 1985 sampling seasons. These lengths correspond to ages 8-10 year olds with females comprising 47% in 1984 and 66% in 1985. The arctic cisco captured in Beaufort Lagoon are longer in each age class than those reported from the western Beaufort Sea (i.e. Prudhoe Bay and Colville River delta) (Bendock 1979, Craig and Haldorson 1981, Griffiths et al. 1983), but appear similar to age-length classes taken from the outer MacKenzie River delta (Percy 1975). The number of juvenile arctic cisco captured in Beaufort Lagoon was low in both 1984 and 1985. Sampling did not begin in Beaufort Lagoon until after the first week of July and it is possible that juvenile arctic cisco had moved through by this time or migrated outside the barrier islands where no sampling effort occurred.

Studies of juvenile arctic cisco from Prudhoe Bay have shown they prefer temperatures of $11.5^{o}$-$15.4^{o}C$ at salinities of 5-30 ppt (Fechhelm et al. 1983). Movements of adult and juvenile arctic cisco were delayed 1 to 2 weeks around the west dock causeway probably due to the intrusion of cold water and persistence of ice around the outer extension (Envirosphere 1984).

Overwintering locations of arctic cisco have only been documented in 2 Alaskan rivers. Craig and Haldorson (1981) found arctic cisco overwintering in brackish (18-32 ppt) water of the Colville River delta and speculated that more overwintering was probably occurring in brackish river deltas and nearshore than previously thought. Arctic cisco have been reported overwintering in the Sagavanirktok River delta in Alaska (Envirosphere 1984) and the Mackenzie River delta in Canada (Percy 1975). The Canning River delta could possibly overwinter Arctic cisco but no sampling has been conducted.

In Beaufort Lagoon, mysids and the amphipods Gammarus setosus and Gammaracanthus loricatus were the predominant prey items of the arctic cisco. Mysids were found in over 60% of those ciscoes examined and comprised 40% of the total number of prey items. The amphipods also occurred frequently (in 58% of all ciscoes examined), but represented a smaller percentage (38%) of total number of prey items (West and Wiswar 1985). The most common prey of arctic cisco in Simpson Lagoon in summer was the mysids Mysis litoralis and M. relicta (Craig and Haldorson 1981). Amphipods were also important and became the major food in winter. Other predominant food items included fish, small epibenthic isopods, chironomids, and copepods (Griffiths et al. 1975, West and Wiswar 1985).

Least cisco. This species is found in coastal waters and some inland lakes and streams in northern Europe, Asia and North America. In the Beaufort Sea, least cisco appear to be abundant from Barrow to Prudhoe Bay (Furniss 1975, Craig and Haldorson 1981, Griffiths and Gallaway 1982, Griffith et al. 1983) and near the Mackenzie River (Percy 1975), but are relatively scarce between these two areas (Craig and Haldorson 1981). Least cisco have been documented in and near the Canning River delta (Craig 1977a, Ward and Craig 1974) and juvenile least cisco (less than 180 mm) were captured in Beaufort Lagoon (West and Wiswar 1985, Wiswar and West 1986). Roguski and Komerek (1972) sampled along the entire coast of ANWR during the summer of 1970 and did not catch least cisco. It is doubtful that this species occurs in large numbers in nearshore waters of ANWR, but where they do occur, they are more common along the mainland shoreline than they are in waters further offshore (Bendock 1979), preferring warm (10-12°C), low salinity waters (Envirosphere 1984). Their abundance may be positively correlated with temperature (Griffiths et al. 1983).

Least cisco found in Prudhoe Bay and the Sagavanirktok River delta are from the Colville River (Fig. 1). The Sagavanirktok River delta is thought to be the furthest easterly movement of this stock (Craig and Haldorson 1981). The movement of least cisco around the west dock causeway near Prudhoe Bay was reportedly hindered by ice build up and intrusion of colder water (Envirosphere 1984). The Mackenzie River in Canada also supports a least cisco population whose westerly distribution is the Herschel Island area (Griffiths et al. 1975). The river of origin for least cisco captured in Beaufort Lagoon on ANWR is unknown.

Least cisco in the Beaufort Sea have been reported up to 490 mm (Griffiths et al. 1983) and Bendock (1979) found the mean length of least cisco in Prudhoe Bay was 272 mm, with a maximum length of 364 mm. Age range of these fish was 1 to 12 years with the majority between age 7 and 10 years. Age at maturity for Simpson Lagoon cisco was found to be 6 to 7 for males and 7 to 10 for females (Craig and Haldorson 1981).

The spawning behavior of least cisco is complicated by the existence of freshwater and anadromous life history patterns. Spawning generally takes place in the fall over sand and gravel in shallows of rivers or along lake shores (Scott and Crossman 1973). Kogl (1972) reported mature least cisco in the Colville River delta in July that were potential spawners. Ripe and spawned-out least cisco have been caught in the commercial fishery on the Colville River. Mature potential spawners were also found in the main Colville River and in nearby coastal lakes (Craig and Haldorson 1981). It is likely that some spawning occurs in both lakes and stream drainages along the Beaufort Sea coast; however, spawning in or near the ANWR area is probably minimal.

Overwintering locations are unknown along the ANWR coast. Least cisco are known to overwinter in both freshwater and brackish water of the Colville River delta in similar habitat utilized by arctic cisco (Craig and Haldorson 1981, Griffiths and Gallaway 1982). Mann (1975) found overwintering least cisco in the lower Mackenzie River delta.

Food habits are similar to arctic cisco. Craig and Haldorson (1981) reported mysids comprised 60-66% of the summer diet, while amphipods were the major prey in the Colville River overwintering population.

<u>Broad whitefish</u>. The broad whitefish is found throughout the interior, western, and northern regions of Alaska from the Alaska Range north. It is frequently caught in nearshore waters of the Beaufort Sea and anadromous runs occur in the Colville and Sagavanirktok Rivers (Fig. 1). Broad whitefish have been reported in the lower Canning River (Griffiths et al. 1984); however, Roguski and Komerek (1972) did not catch broad whitefish in 1970 off the coast of the ANWR and broad whitefish was not caught in USFWS baseline surveys in the 1002 (c) study area.

Overwintering locations have been reported in pools from the lower Sagavanirktok River (Bendock 1979) and from the Colville River in the vicinity of Umiat (Bendock 1980) (Fig. 1).

<u>Round Whitefish.</u> This species is distributed widely in lakes and streams throughout northern North America and northeastern Asia. In ANWR, this species has been documented only from the Canning River drainage, including 4 lakes in the delta region. Round whitefish are able to tolerate brackish waters and have been caught in lagoons of the outer Mackenzie River delta (Percy 1975) (Fig. 1).

The largest round whitefish reported from the Canning River measured 462 mm. Over 30% of the round whitefish captured by gill net were between 380 and 419 mm (Smith and Glesne 1983). These lengths correspond to ages of 7 to 10 years. Sexual maturity is reached at age 7 in round whitefish in lakes of the Brooks Range (Furniss 1974) and in those from streams of the central arctic coastal plain (Bendock and Burr 1984). Spawning generally takes place in the fall in the shallow water of lakes or streams over a gravel substrate (Scott and Crossman 1973). Preliminary information on round whitefish from the Colville River indicated an in-stream migration to spawning areas from mid-August to mid-September with spawning occurring from mid-September through the first week of October (Hablett 1979). Characteristic of whitefish, the eggs are broadcast and receive no parental care.

Whitefish overwintering locations in ANWR have not been well documented. One round whitefish tagged in the lower Canning in 1981 was recaptured in 1982 at Shublik Springs, a documented overwintering area for arctic char. Round whitefish have been reported in late winter in deeper pools on the Colville River (Bendock 1980) and pools on the lower Kuparuk and Sagavanirktok Rivers (Bendock 1977).

Food of round whitefish from the Colville River included snails, bivalves, aerial insects, chironomid larvae, caddis fly larvae, and phytoplankton, similar to diet of grayling and resident char Hablett (1979).

Arctic Grayling. Grayling are 1 of the most widely distributed freshwater fishes in Alaska. On the arctic coast most of the drainages that have been surveyed contain grayling. Within the ANWR study area (Fig. 2), grayling have been reported from the Canning, Tamayariak, Sadlerochit, Hulahula, Okpilak, and Aichilik Rivers and their tributaries (Ward and Craig 1974, Smith and Glesne 1983, Daum et al. 1984, West and Wiswar 1985). Grayling were caught by Roguski and Komerek (1972) in coastal areas of ANWR in June in locations where salinities did not exceed 1 ppt. Grayling were captured in Beaufort Lagoon in July 1985 where salinities were 4.0-7.0 ppt (Wiswar and West 1986). During migration to overwintering locations in some areas, grayling travel through the brackish waters of river deltas (West and Wiswar 1985, Wiswar et al. 1986).

Grayling taken from the Canning River in July and August 1981 and 1982 ranged from 63 to 479 mm fork length (capture methods consisted of seining, angling, and gillnetting). Forty percent of these fish were in the 340 to 379 mm length class, which corresponded to ages 6-10 (Smith and Glesne 1983). Age classification for this sample may be inaccurate in older fish due to the use of scales, which may underestimate age in northern, slow growing fish species. Otoliths were used to age all other grayling samples. In the adjacent Tamayariak River, grayling captured in August 1981 by experimental gillnet and hook and line ranged from 117 to 444 mm fork length. The predominant size class in the upper river (300-319 mm, ages 6-7) was much smaller than in the lower river, 360-379 mm (ages 8-10). The oldest grayling caught during baseline surveys was a 20 year old male, 433 mm long taken from the Tamayariak River: (Smith and Glesne 1983). Grayling captured by hook and line and gillnet from the Sadlerochit River and its main tributary the Itkilyariak River were predominantly within the 300 to 359 mm length group, ages 7 to 12 (Smith and Glesne 1983). In the Hulahula River, grayling adults were relatively rare except in Fish Hole 2 during August and September. Only 2 juvenile grayling were captured and none were observed in tributary streams. In the neighboring drainage, the Okpilak River and its main tributary, the Akutoktak River, grayling were abundant at all life stages, juveniles and fry particularly numerous in the Akutoktak River. Fork lengths of grayling from the system ranged from 122 to 375 mm (age 2-10) with the predominant class in the 260-280 mm group (Daum et al. 1984). Grayling captured with gillnets and hook and line in the Aichilik River in September 1982 ranged in length from 108 to 380 mm, representing ages 2 to 14 years (Smith and Glesne 1983). When the Kongakut River was surveyed in late June and early July 1985, grayling adults and fry were observed throughout the drainage. Sample size for age determination was small; lengths of fish caught by angling ranged from 268 to 337 mm for ages 5 to 8 (Deschemeier et al. 1986). A small number of grayling were captured in fyke nets in Beaufort Lagoon in July 1985. Their lengths ranged from 285 to 359 mm (West and Wiswar 1986).

Grayling are typically spring and early summer spawners. On Weir Creek, a tributary to the Kavik River (Fig. 1), grayling spawned from 11-18 June (Craig and Poulin 1974). Similar timing for spawning would be expected for coastal streams across the ANWR study area. Grayling movements to spawning locations are associated with spring thawing and higher flows in late May and early June. Preferred spawning habitat consists of small gravel or rock bottom tributaries, but spawning can occur in gravelly areas on the main rivers (Scott and Crossman 1973). There appears to be some variation on length of time the adults spend in the spawning stream depending on the size of the stream. Data obtained by Craig and Poulin (1974) indicated that adults depart the smaller tributaries immediately after spawning and return to the main river. In other locations some have been reported to stay until midsummer or autumn (Reed 1964; Tripp and McCart 1974, as cited in Craig and Poulin 1974).

Generally juvenile grayling and fry remain in smaller streams longer than adults. Warmer water temperatures, more abundant food, and reduced competition for food in smaller streams provide favorable conditions for growth of these smaller fish. Most fry and juveniles move out of the smaller streams by October and presumably move to deeper pools on the main river for overwintering. Craig and Poulin (1974) reported that in northern streams most movement of fry downstream occurs during September. Grayling fry were well distributed in the Tamayariak River in July 1982 and most abundant in the upper reaches (Smith and Glesne 1983). Fry and juvenile grayling were reported in the Itkilyariak Creek, Akutoktak River, and upper Okpilak River and Peters and Schrader Lakes (Smith and Glesne 1983, Daum et al. 1984) (Fig. 2).

Grayling overwintering locations in ANWR have only recently been identified through the use of radio telemetry. Radio tags were surgically implanted in grayling in 3 drainages within the study area in late July and August of 1984 and 1985. These fish, tracked at 3 to 4 week intervals, left their summer feeding areas in mid-August to early September. Nearly all had arrived at overwintering locations by the end of September.

Grayling from the Tamayariak and Okpilak Rivers changed drainages to reach overwintering areas. Tamayariak grayling were relocated in pools in the mainstem Canning River within 10 km of its divergence with the Staines River, in the east channel of the Canning River, and in the delta area near the confluence of the Canning and Tamayariak Rivers (Fig. 2) Grayling tagged in the Akutoktak River moved down the Okpilak River and west into the Hulahula River to Fish Hole 1, 32 km from the mouth, and Fish Hole 2, 68 km from the mouth of the Hulahula River; overall total migrations of 62 km and 98 km, respectively, from the tagging site.

Grayling tagged in the Sadlerochit River and its main tributary, the Itkilyariak Creek, moved upstream adjacent to Sadlerochit Springs, and to the Kekiktuk River, and to Lakes Peters and Schrader.

Food habits of grayling have received much study in Alaska. On the Colville River during the summer, the following prey were found in grayling stomachs in descending order of abundance: caddis fly larvae, chironomid larvae, terrestrial and aquatic beatles, aerial insects, snails, bivalves, amphipods, and ninespine sticklebacks (Hablett 1979). Scott and Crossman (1973) reported the food of young grayling to be composed mostly of zooplankton with a gradual shift to immature insects as size of the fish increases.

Burbot. Burbot are widely distributed throughout the Northern Hemisphere from about 40° N latitude to the Arctic Ocean. They are found throughout Alaska in freshwater lakes and streams and have been captured in brackish coastal waters of the Yukon Territory (Kendal et al. 1975). Within the ANWR study area (Fig.2) they have been documented only from the Canning River (Craig 1977a, Smith and Glesne 1983).

Burbot age and length data are not available for fish from the ANWR study area. Hablett (1979) reported Colville River burbot up to 915 mm in length and weighing 4000 g, with average length and weights of 658 mm and 1724 g. Burbot seldom live longer than 15 years according to Morrow (1980).

Spawning generally takes place in winter, probably in January and February. Burbot caught in March in the Colville River had completed spawning (Bendock 1980). Burbot spawning habitat is described by Scott and Crossman (1973) as 0.3-3.7 m of water over sand in streams or in gravel shoals 1.5-3.1 m deep in lakes.

Burbot utilize some of the same overwintering locations as other freshwater species. Bendock (1979, 1980) and Bendock and Burr (1984) documented burbot in intermittent pools from the Colville, Sagavanirktok, and Kuparuk Rivers.

Adult burbot are considered piscivorous. The summer diet of burbot on the Colville River consisted of, in descending order of abundance: slimy sculpin, ninespine stickleback, round whitefish, grayling, caddis fly larvae, and snails (Hablett 1979).

<u>Salmon</u>. Small runs of pink and chum salmon occur in the Colville and Mackenzie Rivers. These salmon also occasionally enter other north slope drainages such as the Sagavanirktok River. Three chum salmon and 1 pink salmon were caught in the Canning River during August 1981 (Smith and Glesne 1983). A small run of pink salmon passed through Simpson Lagoon during the early August 1978 heading eastward (Craig and Haldorson 1981). One of these fish was caught in September, 250 km to the east off shore of the ANWR in a subsistence net. A male pink salmon in spawning condition was taken from the Sadlerochit River in July 1983 (Daum et al. 1984). Craig and Haldorson (1981) also reported chinook salmon and 1 sockeye salmon from Simpson Lagoon. Sockeye salmon are extremely rare in the Beaufort Sea, but stragglers have been reported from Bathurst Inlet (Scott and Crossman 1973), and 1 was reported from the Canning River in 1981 (Smith and Glesne 1983).

Spawning locations of salmon are unknown from the ANWR study area. The 3 chum salmon caught on the Canning River in August were in spawning condition (Smith and Glesne 1983). Pink and chum salmon taken on the Colville River between Itkillik River and Umiat (Fig. 1) during August 1978 were also in spawning condition (Hablett 1979). If spawning does occur in drainages of ANWR, it would probably be in the vicinity of springs or seepages that would insure adequate water flow for egg development during winter.

Adult spawning salmon do not normally feed during their upstream migrations. Information regarding fry development and length of time spent in fresh water prior to smolting is unknown for north slope salmon populations.

<u>Other Species</u>. Slimy sculpin (<u>Cottus cognatus</u>) are common in drainages in the western arctic but have not been reported from ANWR. Humpback whitefish (<u>Coregonus pidschian</u>) are also common to the west (Prudhoe Bay) and east (Mackenzie River delta), but apparently absent from ANWR coastal waters, most likely due to a lack of suitable spawning habitat.

Ninespine stickleback (Pungitius pungitius) are common in many lakes and drainages in the ANWR study area and have even been caught in coastal lagoons (Griffiths 1983, West and Wiswar 1985). Little information is available on the life history of this species. It apparently spawns in the summer in streams and lakes and can grow up to 6.4 cm or more. It is an important prey for many other species of fish (Scott and Crossman 1973).

Rainbow smelt (Osmerus mordax dentex) have been reported in subsistence catches in coastal waters of ANWR. Taxonomic classification of this fish is unclear, and it has been reported as boreal smelt (Osmerus eperlanus) in many studies. It is typically anadromous moving to freshwater in the spring to spawn. Smelt average 18-20 cm in length (Scott and Crossman 1973) and have reported ages of up to 15 years (Craig and Haldorson 1981). Smelt were a minor component of the nearshore fish community during summer (Craig and Haldorson 1981, Griffiths 1983, West and Wiswar 1985), but were one of the most abundant in winter (Craig and Haldorson 1981). Smelt apparently concentrate near some river mouths such as the Colville River during winter presumably to migrate up river in the spring to spawn.

Marine species that were commonly found along the ANWR coast include fourhorn sculpin (Myoxocephaleus quadricornis) and arctic flounder (Liopsetta glacialis). Arctic cod (Boreogadus saida), may be more abundant seasonally, primarily during winter.

Fourhorn sculpins are among the most widespread and numerous of all the marine fishes found along the Beaufort Sea coast. In Beaufort Lagoon on ANWR, in 1984 and 1985, they comprised 22% and 37% of the total catch respectively and were the most numerous marine species. These fish ranged in length from 38-339 mm and ranged in age from 1+ to 11+ years (West and Wiswar 1985, Wiswar and West 1986). Most sculpins captured were between 50 and 125 mm which correspond to 1 to 3 year old fish. In Simpson Lagoon larger sculpins (greater than 180 mm) comprised the major portion of the catch (Craig and Haldorson 1981). Prey items of fourhorn sculpins in Beaufort Lagoon, ANWR were primarily Gammarid amphipods. These items were found in over half of the sculpins examined and collectively comprised over 45% of the total prey numbers (West and Wiswar 1985). Isopods were also important and were found in 36% of the stomachs examined. Adult sculpins were becoming sexually mature during the summer sampling period. Sculpins have been observed overwintering in brackish river deltas and in coastal areas, indicating a wide salinity tolerance.

Arctic flounder sometimes enter fresh or brackish water. In 1984 and 1985 flounders comprised 3% and 10% respectively of the total catch at Beaufort Lagoon on ANWR and were the second most abundant marine species. These fish ranged in length from 55 to 298 mm. The length interval 100-150 mm was the most frequent. These lengths correspond to 3 and 4 year old flounder (West and Wiswar 1985, Wiswar 1986). In general these findings are similar to other studies across the Alaskan Beaufort Sea coast (Griffiths 1983, Schmidt et al. 1983). Arctic flounder generally reach maturity at ages 4+ to 5+ years and spawn in non-consecutive years in shallow coastal waters (Morrow 1980). Flounder in Beaufort Lagoon feed mainly upon Gammarid amphipods, isopods, and polychaetes (Wiswar 1986), similar to the diet observed elsewhere (Griffiths et al. 1975, Bendock 1979, Craig and Haldorson 1981).

Arctic cod are widely distributed along the Beaufort Sea coast and have been described as key species in the Arctic Ocean ecosystem because of their abundance and importance in the diets of marine mammals, birds, and other fish (Bendock 1977, Craig and Haldorson 1980). Although arctic cod are abundant in catches at other study areas in the Beaufort Sea, they appear to be rare during summer in the nearshore waters of ANWR (Roguski and Komerek 1972, Griffiths 1983, West and Wiswar 1985, Wiswar and West, 1986). Recent work (Craig et al. 1982) indicates arctic cod may prefer low water temperatures and increased salinities, and may be associated with the edge of the colder marine water mass which moves back and forth in a seaward-landward direction in shallow coastal waters. The reason for the absence of arctic cod from most ANWR sampling may also be a function of limited location of fyke nets. Evidently cod have been available to Kaktovik residents in the past and were an important food item for both villagers and their dogs in early winter (Jacobson and Wentworth 1982).

## Impacts of Human Activities

One source of mortality to fishes of the coastal plain and nearshore waters of ANWR is human fishing pressure. No commercial fishery exists in this region at present. The only continuing commercial fishery on the north slope is located on the Colville River delta. This fishery, which operates from October to December, has reported an average annual harvest from 1964 to 1976 of 65,230 fish. Of this catch, 65% has been arctic cisco and 29% least cisco. Broad and humpback whitefish compose the remaining 6% of the harvest (Craig and Haldorson 1980).

In ANWR, a subsistence fishery exists in nearshore waters and river deltas in summer and at traditional fishing locations on rivers and lakes during winter. The main species constituting this fishery are arctic cisco and arctic char during summer, and char and grayling during winter (see Chapter 7, Subsistence Section). All households in Kaktovik make use of the fishery resources of ANWR (Pederson et al. 1986). Very little is known of the numbers of fish taken annually in this fishery.

Some limited sport fishing also occurs by summer recreationists visiting the area. Sport fishing in the Prudhoe Bay development area has increased to the extent that the Alaska Department of Fish and Game has recommended the arctic char harvest from the Sagavanirktok River be monitored (Bendock 1981).

## Data Gaps

Future research should include studies of the timing and pattern of migration of anadromous fishes using the ANWR nearshore areas, with emphasis on those stocks of arctic char which originate in Refuge streams. Arctic char population sizes were estimated for the Canning River (1981) and a reach of the Aichilik River (1982). No other quantitive measurements of abundance have been made. In general, fish use of coastal waters in this part of the Beaufort Sea is not well known and requires further examination.

It appears the entire north slope arctic cisco population originates in the Mackenzie River of Canada. Juvenile arctic cisco migrate from there to the Sagavanirktok River where they have been reported in great numbers. However, few juvenile arctic cisco have been captured during investigations in ANWR lagoons. The temporal and spacial distribution along the ANWR coast has not been documented.

Arctic grayling fry have been noted in the upper reaches of tundra streams that have no known overwintering habitat. Movement of adult grayling out of these streams in fall has been documented (West and Wiswar 1985, Wiswar et al. 1986); however, movement of juvenile grayling to overwintering areas and location of these areas is unknown.

## Literature Cited

Alt, K.T., and R.A. Furniss. 1976. Inventory and cataloging of north slope waters. Alaska Dep. Fish and Game, Fed. Aid Fish Restor. Prog. Rep., Proj. F-9-8, Job G-I-O. 21pp.

Arnborg, L., H.J. Walker, and J. Peippo. 1966. Water discharges in the Colville River, Alaska, 1962. Geografiska Annaler. 48A:195-210.

Barnes, P.W., D.M. Schell, and E. Reimnitz. 1984. The Alaskan Beaufort Sea: ecosystems and environments. Academic Press, Inc., New York. 466pp.

Bendock, T.N. 1976. De-watering effects of industrial development on arctic fish stocks. Rep. for Alaska Board of Fisheries. Alaska Dep. of Fish and Game, Fairbanks. 13pp.

Bendock, T.N. 1979. Beaufort Sea estaurine fishery study. Pages 670-729 in Environmental. Assessment. Alaskan Continental Shelf. BLM/NOAA, OSCEAP. Final Report, Vol. 4. 804pp.

Bendock, T.N. 1980. Inventory and cataloging of arctic area waters. Alaska Dep. Fish and Game, Fed. Aid Fish Rest. Prog. Rep., Proj. F-9-12. Job G-I-I. Vol. 21:1-31.

Bendock, T.N. 1981. Inventory and cataloging of arctic area waters. Alaska Dep. Fish and Game, Fed. Aid Fish Restor. Prog. Rep., Proj. F-9-13. Job G-I-I. Vol. 22:1-45

Bendock, T.N., and J. Burr 1984. Inventory and cataloging of arctic area waters. Alaska Dep. Fish and Game, Fed. Aid Fish Restor. Prog. Rep., Proj. F-9-16. Job G-I-I. Vol. 25:1-45

Carson, C.E., and K.M. Hussey. 1962. The oriented lakes of arctic Alaska. Geology 70:417-439.

Childers, J.M., C.E. Sloan, and J.P. Meckel. 1973. Hydrologic reconnaissance of streams and springs in eastern Alaska, July, 1972. U.S. Geological Survey Water Resources Div., Basic Data Rep. 25pp.

Childers, J.M., C.E. Sloan, J.P. Meckel, and J.W. Nauman. 1977. Hydrologic reconnaissance of the eastern north slope, Alaska, 1975. U.S. Geological Survey Open-File Rep. 77-492. 65pp.

Craig, P.C. 1977a. Ecological studies of anadromous and resident populations of arctic char in the Canning River drainage and adjacent waters of the Beaufort Sea, Alaska. Pages 1-116 in P.J. McCart, ed. Fisheries investigations along the North slope and the Beaufort Sea coast in Alaska with emphasis on arctic char. Can. Arctic Gas Study Ltd. Bio. Rep. Ser. 41. Chap. 1

Craig, P.C. 1977b. Arctic char in Sadlerochit Spring, Arctic National Wildlife Range. Pages 1-29 in P.J. McCart, ed. Fisheries investigations along the north slope and the Beaufort Sea coast in Alaska with emphasis on arctic char. Can. Arctic Gas Study Ltd. Bio. Rep. Ser. 41 Chap. 3.

Craig, P.C. 1977c. Fisheries research in the Shaviovik drainage with emphasis on arctic char in the Kavik River, Alaska. Pages 1-27 in P.J. McCart, ed. Fisheries investigations along the north slope and the Beaufort Sea coast in Alaska with emphasis on arctic char. Can. Arctic Gas Study Ltd. Bio. Rep. Ser. 41. Chap. 3.

Craig, P.C. 1984. Fish use of coastal waters of the Alaskan Beaufort Sea: a review. Trans. Amer. Fish Soc. 113:265-282.

Craig, P.C., and L. Haldorson. 1981. Beaufort Sea-barrier island-lagoon ecological processes studies. Final Rep. Simpson Lagoon. Part 4: Fish. Pages 384-678 in Environ. Assess. Alaskan Cont. Shelf. BLM/NOAA, OCSEAP, Vol 7.

Craig, P.C. and P.J. McCart. 1974. Fall spawning and overwintering areas of fish populations along routes of proposed pipeline between Prudhoe Bay and Mackenzie Delta, 1972-73. Pages 1-36 in P.J. McCart, ed. Fisheries research associated with proposed gas pipeline routes in Alaska, Yukon, and Northwest Territories. Can. Arctic Gas Study Ltd. Bio. Rep. Ser. 15. Chap. 3.

Craig, P.C., and G.J. Mann. 1974. Life History and distribution of the arctic cisco (Coregonus autumnalis) along the Beaufort Sea coastline in Alaska and the Yukon Territory. Pages 1-33 in P.J. McCart, ed. Life histories of anadromous and freshwater fish in the western arctic. Can. Arctic Gas Study Ltd. Bio. Rep. Ser. 20 Chap. 4.

Craig, P.C., and V. Poulin. 1974. Life history and movement of arctic grayling (Thymallus arcticus) and juvenile arctic char (Salvelinus alpinus) in a small tundra stream tributary to the Kavik River, Alaska. Pages 1-53 in P.J. McCart, ed. Life histories of anadromous and freshwater fish in the western arctic. Can. Arctic Gas Study Ltd. Bio. Rep. Ser. 20. Chap.2.

Craig, P.C., W.B. Griffiths, L. Haldorson, and H. McElderry. 1982. Ecological studies of arctic cod (Boreogadus saida) in Beaufort Sea coastal waters, Alaska. Can. J. Fish. Aquat. Sci. 39:395-406.

Daum, D., P. Rost, and M. Smith. 1984. Fisheries studies on the north slope of the Arctic National Wildlife Refuge, 1983. Pages 464-522 in G.W. Garner and P.E. Reynolds, eds. 1983 update report baseline study of the fish, wildlife and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. 614pp.

DeBruyn, M., and P. McCart. 1974. Life history of the grayling (Thymallus arcticus) in Beaufort Sea drainages in the Yukon Territory. Pages 1-39 in P.J. McCart, ed. Fisheries research associated with proposed gas pipeline routes in the Alaska, Yukon, and Northwest Territories. Bio. Rep. Ser. 15. Chap. 2.

Deschermeier, S.J., T. Stevens, D. Wiswar, and R. West (1986). Fisheries investigations on the Kongakut River, Arctic National Wildlife Refuge, Alaska, 1985. Pages _____ in G.W. Garner and P.E. Reynolds, eds. 1986 update report baseline study of the fish, wildlife and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak.___pp.

Dew, C.B. 1982. Marine and anadromous fish. In Kuparuk waterflood environmental studies. Final Rep. Prepared for ARCO Alaska, Inc. by Woodward Clyde Consultants.

Envirosphere. 1984. Prudhoe Bay waterflood project environmental monitoring program 1983 synthesis. Prepared for the Dep. of the Army Alaska Dist., Corps of Eng., Anchorage, Ak.

Fechhelm R., W. Neill, and B. Gallaway. 1983. Temperature preference of juvenile arctic cisco (Coregonus autumnalis) from the Alaskan Beaufort Sea. Bio. Pap. Univ. of Alaska. 21:24-38.

Furniss, R.A. 1974. Inventory and cataloging of arctic waters. Alaska Dep. Fish and Game, Fed. Aid Fish Restor. Prog. Rep. Proj. F-9-6, Study G-I. 45pp.

Furniss, R.A. 1975. Inventory and cataloging of arctic area waters. Alaska Dep. Fish and Game, Fed. Aid Fish Restor. Prog. Rep. Proj. F-9-7, Study G-I-I. 47pp.

Gallaway, B.J., W.B. Griffiths, P.C. Craig, W.J. Gazey, and J.W. Helmericks. 1983. An assessment of the Colville River Delta stock of arctic cisco-migrants from Canada? Bio. Pap. Univ. Alaska. 21:4-23.

Glesne, R., and S.J. Deschermeier. 1984. Abundance, distribution, and diversity of aquatic macroinvertebrates on the north slope of the Arctic National Wildlife Refuge, 1982 and 1983. Pages 523-552. in G.W. Garner and P.E. Reynolds, eds. 1983 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. 614pp.

Glova, G., and P.J. McCart. 1974. Life history of arctic char (Salvelinus alpinus) in the Firth River, Yukon Territory. Pages 1-50 in P.J. McCart, ed. Life histories of anadromous and freshwater fish in the western arctic. Can. Arctic Gas Study Ltd. Bio. Rep. Ser. 20. Chap. 3.

Griffiths, W.B. 1983. Fish investigations in Angun and Beaufort Lagoons, Eastern Beaufort Sea, Alaska. Report by LGL Environ. Res. Assoc. for Minerals. Manager. Ser., Bur. Land Manager. and Nat. Oceanic Atmos. Admin., Outer Cont. Shelf Envir. Assess. Prog.

Griffiths, W.B., and B.G. Gallaway. 1982. Prudhoe Bay waterflood project, fish monitoring program. Report by LGL Alaska Research for Woodward-Clyde Consultants, Anchorage, Ak. and the U.S. Army Corps of Eng., Anchorage, Ak.

Griffiths, W., P.C. Craig, G. Walder, and G. Mann. 1975. Fisheries investigations in a coastal region of the Beaufort Sea (Nunaluk Lagoon, Yukon Territory). Pages 1-219 in P.C. Craig, ed. Fisheries investigation in a coastal region of the Beaufort Sea. Can. Arctic Gas Study Ltd. Bio. Rep. Ser. 34. Chap. 2.

Griffiths, W.B., J. DenBeste, and P. Craig. 1977. Fisheries investigations in a coastal region of the Beaufort Sea (Kaktovik Lagoon, Barter Island, Alaska). Pages 1- , in P.J. McCart, ed. Fisheries investigations along the north slope from Prudhoe Bay, Alaska to the Mackenzie River delta, Northwest Territories. Can. Arctic Gas Study Ltd. Bio. Rep. Ser. 40. Chap.22.

Griffiths, W.B., D.R. Schmidt, R.G. Fechhelm, and B.J. Gallaway. 1983. Fish ecology. Pages 1-342 in B. Gallaway and R. Britch, eds. Environmental summer studies (1982) for the Endicott development, fish ecology. Vol. 3. Report by LGL Alaska Research and Northern Technical Services for Sohio Ak. Pet. Co., Anchorage, Ak.

Hablett, T. 1979. Fish inventories conducted within the National Petroleum Reserve on the north slope of Alaska, 1977-1978. Rep. by U.S. Fish and Wildl. Serv. for Bur. of Land Manage. 89pp.

Hachmeister, L.E., and J.B. Vinelli. 1983. Environmental characterization and biological use of lagoons in the eastern Beaufort Sea. Pages 501-579 in Physical oceanography. Final Rep. In OSSEAP: NOAA, Office of Marine Pollution Assessment. Juneau, Ak.

Hollis, E.H. 1964. A literature review of the effects of turbidity and siltation on aquatic life. Staff Rep. Dept. of Chesapeake Bay Affairs, Annapolis, Maryland. 20pp.

Jacobson, J., and C. Wentworth. 1982. Kaktovik subsistence:land use values through time in the Arctic National Wildlife Refuge area. U.S. Fish and Wildl. Ser., No. Ak. Ecol. Serv., Fairbanks, Ak. 142pp.

Kaliff, J. 1968. Some physical and chemical characteristics of arctic freshwater in Alaska and Northwestern Canada. J. Fish. Res. Bd. of Can. 25:2575-2587.

Kendea, R.E., R.A.C. Johnston, U. Lobsiner and M.D. Kozak. 1975. Fishes of the Yukon coast. Beaufort Sea Tech. Rep. 6. Dept. of the Environ. Fish. and-Mar. Serv., Whitehorse, Yukon, Canada. Beaufort Sea Tech. Rep. 6.

Kogl, D.R. 1972. Monitoring and evaluation of arctic waters with emphasis on the north slope drainages: Colville River. Alaska Dept. of Fish and Game, Fed. Aid Fish Restor. Prog. Rep., Proj. F-9-3, Job G-III-A, p. 23-61.

Kogl, D.R., and D. Schell. 1975. Colville River delta fisheries research. Environmental studies of an arctic estaurine system -- Final Report. Inst. of Marine Sci., Univ. Alaska, Fairbanks, Report 74-1: 483-504.

Mann, G.J. 1975. Winter fisheries survey across the Mackenzie delta. Pages 1-54 in P.C. Craig, ed. Fisheries investigations in a coastal region of the Beaufort Sea. Can. Arctic Gas Study Ltd. Bio. Rep. Ser. 34. Chap. 3.

McCart, P.J. 1980. A review of the systematics and ecology of the arctic char, Salvelinus alpinus, in the western arctic. Can. Tech. Rep. Fish. Aquat. Sci. 935.

McCart, P.J., And P.C. Craig. 1973. Life history of two isolated populations of arctic char (Salvelinus alpinus) in spring-fed tributaries of the Canning River, Alaska. J. Fish Res. Bd. Can. 30:1215-1220.

McCart, P.J., P.C. Craig, and H. Bain. 1972. Report on fisheries investigations in the Sagavanirktok River and neighboring drainages. Rep. for Alyeska Pipeline Serv. Co. 170pp.

Morrow, J.E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publ. Co., Anchorage, Ak. 248pp.

Murphy, R.S., and J.K. Greenwood. 1971. Implications of waste treatment processes and arctic receiving waters. Proc. First Internat. Conf. on Port and Ocean Eng. Under Arctic Conditions., Tech. Univ. of Norway, Trondheim. Vol. 2: 909-915.

Norton, D., and G. Weller. 1984. The Beaufort Sea: background, history, and perspective. Pages 3-19 in P.W. Barnes, D.M. Schell, and E. Reimnitz, ed. The Alaskan Beaufort Sea: ecosystems and environments. Academic Press, Inc., New York. 466pp.

Percy, R. 1975. Fishes of the outer Mackenzie delta. Canada Dep. of the Environment. Beaufort Sea Proj. Tech. Rep. 8. 114pp.

Pederson, S., M. Coffing, and J. Thompson. 1986. Subsistence land use and place name maps for Kaktovik, Alaska. Alaska Dep. Fish and Game, Div. Subsis. Tech. Pap. 109.

Prescott, G.W. 1963. Ecology of Alaskan freshwater algae: II. Introduction: general considerations. Amer. Microscop. Soc. Trans. 82:83-98.

Reed, R.J. 1964. Life history and migration patterns of arctic grayling Thymallys arcticus, (Pallus) in the Tanana River drainage of Alaska. Alaska Dept. Fish and Game Res. Rep. No. 2: 1-30.

Roguski, E.A., and E. Komerek. 1972. Monitoring and evaluation of arctic waters with emphasis on the north slope drainages. Alaska Dept. Fish and Game. Fed. Aid Fish. Restor. Prog. Rep., Proj. F-9-3, Job G-III-A. p. 1-22.

Schmidt, D.O., R. McMillan, and B. Gallaway. 1983. Nearshore fish survey in the western Beaufort Sea: Harrison Bay to Elson Lagoon. Report by LGL for MMS-NOAA OCSEAP.

Shallock, E.W., and F.B. Lotspeich. 1974. Low winter dissolved oxygen in some Alaskan rivers. U.S. EPA Ecol. Res. Ser. Rep. EPA-660/3-74008. 33pp.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Can. Bull. 184. 966pp.

Smith, M.W., and R.S. Glesne. 1983. Aquatic studies on the north slope of the Arctic National Wildlife Refuge 1981 and 1982. Pages 291-364 in G.W. Garner and P.E. Reynolds, eds. 1982 update report baseline study of the fish, wildlife and their habitats. U.S. Fish and Wildl. Ser. Anchorage, Ak. 379pp.

Stevens, T.M., and S.J. Deschermeier. 1986. Notes on the summer food habits of pre-smolt and residual Arctic char in streams of the Arctic National Wildlife Refuge. Pages _____ in G.W. Garner and P.E. Reynolds, eds. 1986 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak.___.

Tripp, D.B., and P.J. McCart. 1974. Life Histories of grayling (Thymallus arcticus) and longnose suckers (Catastomus catastomus) in the Donnelly River system, Northwest Territories. Pages. 1-91 in P.J. McCart, ed. Life histories of anadromous and freshwater fish in the western Arctic. Can. Arctic Gas Study Ltd Bio. Rep. Ser. 20. Chap. 1.

Walker, H.J. 1960. The changing nature of man's quest for food and water as related to snow, ice and permafrost in the American arctic. PhD Thesis, Louisiana State Univ., Baton Rouge.

Ward, D.L., and P.C. Craig. 1974. Catalogue of streams, lakes and coastal areas in Alaska along routes of the proposed gas pipeline from Prudhoe Bay, Alaska to the Alaskan/Canadian Border. Can. Arctic Gas Study Ltd. Bio. Rep. Ser. 19. 381pp.

West, R.L., and D.W. Wiswar. 1985. Fisheries investigations on the Arctic National Wildlife Refuge, Alaska, 1984. Pages 727-777 in G.W. Garner and P.E. Reynolds, eds. 1984 update report baseline survey of the fish, wildlife, and their habitats. Vol. 2 U.S. Fish and Wildl. Serv., Anchorage, Ak. 777pp.

Wilson, W.J., E.H. Buck, G.F. Player, and L.D. Dreyer. 1977. Winter water availability and use conflicts as related to fish and wildlife in arctic Alaska. A synthesis of information. AEIDC. Anchorage, Ak. FWS/OBS - 77/06. 222pp.

Wiswar, D.W. 1986. Notes on the age, growth, distribution and summer feeding habits of arctic flounder in Beaufort Lagoon, Arctic National Wildlife Refuge, Alaska. Pages ____ in G.W. Garner and P.E. Reynolds, eds. 1986 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. ___pp.

Wiswar, D.W., and R.L. West. 1986. Fisheries investigations in Beaufort Lagoon, Arctic National Wildlife Refuge, Alaska, 1985. Pages ____ in G.W. Garner and P.E. Reynolds, eds. 1986 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorge, Ak. ___pp.

Wiswar, D.W., R.L. West, T.M. Stevens, and M.W. Smith. 1986. Fall movements and overwintering of arctic grayling in the Arctic National Wildlife Refuge, Alaska, 1985. Pages ____ in G.W. Garner and P.E. Reynolds, eds. 1986 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. ___pp.

Yoshihara, H.T. 1972. Monitoring and evaluation of arctic waters with emphasis on the north slope drainages. Alaska Dep. Fish and Game. Fed. Aid Fish Restor. Prog. Rep., Proj. F-9-4, Job G-III-A. 44pp.

Yoshihara, H.T. 1973. Monitoring and evaluation of arctic waters with emphasis on the north slope drainages. Ann. Rpt. of Progress, 1972-1973. Fed. Aid Fish Restor. Sport Fish Invest. of Alaska. Project F-9-5, Job G-III-A. 83pp.

CHAPTER 7

# HUMAN CULTURE AND LIFESTYLE

This chapter discusses the historical and present day human uses of the Arctic National Wildlife Refuge (ANWR) study area and adjacent areas. The archaeology and history of the area are presented first, followed by historic and present day subsistence use patterns of Kaktovik and other affected villages outside the study area. Recreational use of the area is presented next and is followed by a discussion of wilderness values and proposed natural landmarks within the study area.

## Archaeology

Archaeological investigations in or near the ANWR study area were summarized by Hall (1982) (Table 1). One of the first archaeological surveys to be conducted in the ANWR study area covered the coastline from Flaxman Island at the mouth of the Canning to Barter Island (Giddings 1954). This survey located only 1 small prehistoric mound "on the eastern shore of Camden Bay, a few miles south of Anderson Point" and an unreported number of historic sites (Giddings 1954). The site was described as a single half-underground house with a shallow midden surrounding it, partially eroded into the sea. The styles of bow frames, arrow stems of antler, sealing darts, and other artifacts present indicated the site may be earlier than a site dated using dendrochronology to the late 14th and early 15th centuries (Giddings 1952). No information about other sites or photographs of artifacts from the reported site were included.

The divide between the Kongakut and Firth River drainages, Mancha Creek, a tributary of the Firth River, and 64 km of the upper Kongakut River were superficially covered by a survey in 1953 (Ricciardelli 1954) (Table 1). Several caves located 122 to 244 m above the valley floor were examined and were sterile of cultural evidence. Creek banks, old terraces, weathered ridges, willow patches, confluences of tributary streams, and other favorable spots were examined for prehistoric sites with the same results. Several sites associated with gold mining were located, but no details were given. Vague reference was made to "cultural material...of the post-contact period" (Ricciardelli 1954).

During the summer of 1961, a survey was conducted in the vicinity of Peters and Schrader Lakes and the adjacent foothills and valleys of the Shublik and Sadlerochit Mountains (Solecki et al. 1973) (Table 1). The major objective of this project was to test the hypothesis that the this narrow zone of unglaciated treeless tundra between the mountains and the sea was a natural route for prehistoric man (Solecki et al. 1973). Solecki (1951) had hypothesized that this area held a high potential for early sites in North America. Although they were far from definitive, the results of this survey did little to support the hypothesis. During the survey, a total of 12 prehistoric sites were located. Four were termed multicomponent, but none were stratified. Components were identified by extracting artifacts that appeared to fit into traditions that had been previously defined based on work done elsewhere. One of these sites contained British Mountain, Denbigh Flint Complex, and Eskimo components. One consisted of British Mountain and Eskimo components, while another contained Denbigh and Eskimo artifact groups. One of the Denbigh sites had an unidentified component with it. The remaining prehistoric sites either yielded single components or were not identified; 2 were Eskimo, 4 were Denbigh, and 3 were unidentifiable. Seven historic tent rings were also located and mapped (Solecki et al. 1973).

Table 1. Summary of archaeological work conducted on and adjacent to the Arctic National Wildlife Refuge study area, 1914-1982 (source: Hall 1982).

| Year work conducted | Location | Type of work | Source |
|---|---|---|---|
| 1914 | Barter Island | Excavation | Jenness 1914 |
| 1924 | East end of Barter Island | Excavation | Mathiassen 1930 |
| 1931 | Coast from Barrow to Barter Island | Brief survey | Ford 1959 |
| 1952 | Coast from Flaxman Island to Barter Island | Survey | Ricciardelli 1953 Giddings 1954 |
| 1952 | Schrader and Peters Lakes | Survey and excavation | Irving n.d. |
| 1953 | Kongakut River | Survey | Ricciardelli 1954 |
| 1961 | Schrader and Peters Lakes Schublik Valley to Sadlerochit mountains | Survey | Solecki et al. 1973 |
| 1972-1974 | Coast from Point Lay to Canadian border | Whaling site Survey | J. Bockstoce, pers. comm. to Hall |
| 1977 | Hulahula and Kongakut Rivers; Demarcation Bay | Survey | C. Wilson, pers. comm. to Hall |
| 1978 | Kaktovik | TLUI inventory | Wentworth 1979 |
| 1978 | Middle Canning River Demarcation Bay | Survey | C. Wilson, pers. comm. to Hall |
| 1979-1980 | Lorenz Overlook | Survey and test excavation | C. Wilson pers. comm. to Hall |
| 1980 | Brownlow Point | Site evaluation | D. Libbey field notes, 1981 |
| 1982 | ANWR coast | Survey | Libbey (1982) |
| 1982 | ANWR coastal plain | Survey | Hall (1982) |

Some of these sites were termed settlement types (Solecki et al. 1973), however, the criteria for these types were not discussed. It appears that sites located on good vantage points for spotting game and having few artifacts were called hunting sites, while sites containing larger numbers of artifacts or those in more sheltered areas were defined as habitation sites. One site was designated as a hunting site that was also a workshop. Many of these sites were either multi-component or were located in close proximity, and indicated similar adaptations to similar environments. This conclusion was based on scattered results from fragmentary glacial geology studies which suggest that the last glaciation did not effect much of the foothill/coastal plain area.

The U.S. Fish and Wildlife Service (USFWS) conducted archaeological investigations on ANWR for several years (Wilson n.d.) (Table 1). A survey and limited testing of selected areas of the upper Hulahula River, the foothills around the Kongakut and Canning Rivers, and along the coast in the Demarcation Bay and Barter Island areas were completed in 1978. These investigations resulted in the identification of more than 40 archaeological and historic sites which in aggregate represent the last 6000 years. Unfortunately, those sites that may represent an early occupation did not yield quality or types of artifacts to provide secure dating. These possible early sites are exclusively small lithic scatters, with no "type specimens" present and without charcoal or other material dateable by the C-14 method.

At least 2 and possibly 3 Thule village sites have been identified in and adjacent to the study area. These sites are scattered along the coast with 1 located at Barter Island, 1 at Arey Island, and 1 at Icy Reef in the Demarcation Bay area. Only the site at Barter Island has been dated, through commparison by Whistler (1916) and Jenness (1928) to collections from Barrow. Unfortunately, little remains of this site because it was almost totally destroyed by the construction of the airport on the island. Only a few scattered remains can be identified, and occasionally an isolated artifact erodes from the runway. The site on Arey Island was placed in the Thule period, based only on the feeling of the observer during a brief visit that it is "old" Eskimo. The site at Icy Reef is also not dated with any confidence because it also was visited briefly. Several of the sites located in the foothills may result from older Eskimo occupation, but, again, not enough material was collected to place these sites in a cultural tradition with any degree of confidence.

Most of the sites found during USFWS surveys were occupied sometime during the last 200 years (Wilson n.d.). They range in size and importance from a large semi-permanent caribou hunting village with several associated burials, to concentrations of several tent rings or some sod houses which have 1 or 2 associated burials, to caribou fences, and single tent rings.

The most important of these sites is the Turner River Overlook, located in the northern foothills of the Brooks Range (Wilson n.d.). In addition to providing a view of the Turner River and its tributaries, Demarcation Bay, and the arctic coast, it provides an excellent location at which to await the spring and post-calving migrations of the Porcupine caribou herd. Limited testing at the site provided evidence of an intensive occupation over an extended period of time. At least 3 living floors have been identified as having several firepits. Resting on these floors are structural remains such as medium sized wood structural members that are usually associated with semi-permanent dwellings. The remains of what appeared to be sod also were identified. Many artifacts made from wood, bone, metal, and lithics have been recovered along with the partial remains of at least 18 people. Thousands of fragmented caribou bones have also been identified.

Artifacts that are similar in material and construction to those found at Turner River have been found at 2 fences, presumably used for caribou hunting, and at tent rings in the Demarcation Bay area. It is possible that these sites were used by the same group of people exploiting a variety of resources in the area (Wilson n.d.).

Although the artifacts present in these sites suggest that they were occupied sometime during the middle to late 1800's, there is no memory of them in the traditions of Native people presently living in the nearby village of Kaktovik (Wilson n.d.). This fact, and the report of Stefansson (1919) that the Mackenzie Eskimos were almost extinct by the beginning of this century, indicate that these sites may represent that last occupation by Mackenzie Eskimos in northeastern Alaska. Other sites found during the survey represent the remains of the Native and White communities present in the area in the last 80 years. Traditional Land Use Inventory (TLUI) sites (see subsistence section, Fig. 1 and Table 1) are described in U.S. Fish and Wildlife Service (1982), Jacobson and Wentworth (1982), and Libbey (1982).

In 1982, Libbey (1982) (Table 1) made on-site inspections of almost all coastal TLUI sites within ANWR for the purpose of ethnohistoric documentation and verification of actual locations. The report includes a description of Kaktovik's origins and early history, based on historical documents and narratives from older residents of the area. Maps, photographs and descriptions of 22 TLUI sites along the arctic coast adjacent to or within the ANWR study area were presented.

In 1982, Hall (1982) conducted a preliminary archaeological and historic resource reconnaissance of the ANWR coastal plain for the FWS. Objectives of this study were to complete a literature review, to conduct a preliminary helicopter survey of the study area, to describe and evaluate cultural resource sites, to evaluate the effects of oil and gas exploration on sites and areas with high probabilities of containing sites, and to recommend additional investigations. The report summarized cultural identification research conducted north of the Brooks Range between Point Lay and the Canadian border from the 1800's to 1982, including investigations in or near the ANWR study area (Table 1).

Prior to Hall's survey, relatively few cultural resource sites had been identified in the study area. No sites were thought to have been occupied earlier than 800 A.D., and only 4 sites were prehistoric: 1 contained material similar to that from the Birnirk culture (Giddings 1954, as cited in Hall 1982) and 3 were apparently late Prehistoric Eskimo or Western Thule (Jenness 1914, as cited in Hall 1982). All other sites were from the historic period, most from the 20th century. Hall (1982) found no new early sites or new cultural complexes during this survey, although many previously unknown sites within ANWR were recorded. Four new prehistoric sites found by Hall (1982) were lithic scatters, which contained little information about their cultural affinities. Most sites described were historic Inupiat (Table 2). Sod house ruins and other standing structures were commonly found along the coast during this survey and, according to Hall (1982), are an exceedingly valuable resource for future studies.

Tent ring sites were found throughout the area. The cultural identity and temporal placement of these rings is uncertain, although most of them appear to be relatively recent.

Table 2. Estimated age, cultural affiliation and number of cultural resource sites found on or near the Arctic National Wildlife Refuge study area (Hall 1982).

| CULTURAL COMPLEX | | | | |
|---|---|---|---|---|
| Prehistoric (flake scatters) | Late Prehistoric Inupiat | Historic Inupiat/white | Modern Inupiat/white | Unknown (tent rings) |
| 4 | 6[a] | 75[b] | 2 | 27 |

[a] all contained historic and/or modern components, 4 were questionable
[b] 15 contained modern components, 16 were questionable

A provisional outline of North Alaskan culture history in northern Alaska and northwest Canada (Table 3) proposed by Hall (1981 and 1982) represents an attempt at synthesizing information available in the literature. Establishment of a chronology for this area must include a set of compromises, according to Hall (1981). The lack of scientific archaeological investigations in northern Alaska has resulted in areas of disagreement between archaeologists about some of the criteria used to place assemblages into groups. For example, there are disagreements about which sites should be included in Inupiaq culture and about the relationship of the modern Inupiat to the cultures that make up the Arctic Small Tool Tradition (ASTT). Some archaeologists see a continuum from the ASTT to modern Eskimo, while others suggest these may only be related in some indirect way that is not well understood. In addition, the relationships between Norton, Choris, and Denbigh cultures are confusing at best. Finally, there are discrepancies in radio-carbon dating that have not been adequately addressed.

Two omissions from Hall's (1981) outline should be mentioned: the British Mountain Tradition and finds from the Old Crow basin. The British Mountain Tradition, originally identified in a site located on the northern Firth River, Yukon Territory, was thought it to be quite old by MacNeish (1956). Later work in Canada indicated a date of 5400 B.P. (Gordon 1971) which was more recent than originally thought. Finds in the Old Crow basin include a caribou bone flesher dated at 27,000 B.P. (Irving and Harrington 1978). The flesher was secondarily deposited and very much resembles tools seen in modern Athabaskan camps during the historic period.

Table 3. Provisional outline of North Alaska culture history (Source: Hall 1981 and 1982).

| Tradition | Complex | Date[a] | Radiocarbon dates | Representative sites[a] |
|---|---|---|---|---|
| Eskimo (Ilatka) | Historic Inupiat | 1838-present | | Turner River (Lorenz) Overlook, Prudhoe Bay #1, Nuwuk, Utkiavik, Sikoruk, Siraagruk, Anaktuvuk Pass sites, Anigarnigurak |
| Eskimo (Ilatka) | Late prehistoric Inupiat (Western Thule) | A.D. 900-1838 on coast; ca. 1300-1838 in interior. | Walakpa: 840±90 B.P.=A.D. 1110. Some radiocarbon dates from Alyeska Pipeline corridor may date sites occupied during this period. | Barter Island, Nuwuk, Utkiavik, Walakpa, Nunagiak, Liberator Lake, Swayback Lake, Betty Lake Kinyiksukvik, Etivluk Lake, Pingok Island, Sikorak |
| Athabaskan (Kutchin) | Kavik | A.D. 1450-1850 | Atigun: 115±140 B.P.=A.D. 1835; 360±100 B.P.=A.D. 1519; 310±140 B.P.=A.D. 1640; 168±34 B.P.=A.D. 1782, etc. | Kavik, Atigun. |
| Eskimo (Ilatka) | Punuk | ca. A.D. 900 | --- | Nunagiak |
| | Birnirk | A.D. 500-900 on coast | Anderson Point: 1130±200 B.P.= A.D. 820; 1160±240 B.P.=A.D. 797; 1090±300 = 867 A.D. South Meade #1: 1260±65 B.P.=A.D. 690; 1340±55 B.P.=A.D. 610; 1420±110 B.P.=A.D. 530. | Anderson Point, Birnirk, Walakpa, South Meade #1. |
| | Old Bering Sea | ca. A.D. 500 | --- | Birnirk, Utkiavik |
| Arctic Small Tool | Ipiutak | A.D.O. - A.D.700; may have co-existed with Birnirk for some time. | Feniak Lake site, (Noatak drainage), comparable to Anaktuvuk Pass Ipiautak, average A.D. 500, N=5. | Anaktuvuk Pass, Itkillik Lake. |

Table 3. Continued.

| Tradition | Complex | Date[a] | Radiocarbon dates | Representative sites[a] |
|---|---|---|---|---|
| | Norton Choris | 1500B.C.-A.D. or slightly later | Gallagher Flint Station: (Hearth 1 2920±155 B.P.=970 B.C.; (loc. 1A) 2620±175 B.P.=670 B.C.; (Loc. 5) 1975±125 B.P.=25 B.C.; 2540±185 B.P.=590 B.C.; (Loc. 7) 1735±150 B.P.=A.D. 215; 2640±180 B.P.=690 B.C. and others. Avingak: 1500-3000 B.P. | Barrow sites, BAR-095, Walakpa, Sisraruq, Avak Point, Tukuto Lake, Kayuk, Avingak, Gallagher Flint Station, Itkillik Lake, Croxton, South Meade #1 + 2, Putuligayuk River Delta Overlook |
| Arctic Small/ Tool/Northern Archiac | Denbigh | 2500 B.C.-200B.C. | Walakpa: 3400±520 B.P.=1450 B.C. Punyik Point: 3660±150 B.P.= 1710 B.C.; No Name: 3440±160 = 1490 B.C.; 3855±155 = 1905 B.C. Blip: 3480±180 = 1530 B.C. Mosquito Lake: A.D. 20-40±150 to 880-900±165 B.C. N=5. | Walakpa, Coffin, Putuligayuk River Delta Overlook, Croxton, Sikoruk, Imaigenik, Kurupa Lake, Punyik Point, Mosquito Lake, Anaqpak, Blip, No Name, Shoreline Bluffsite |
| | Tuktu/Naiyuk | ? 4500 B.C.-? area may have been uninhabited for a period before Denbigh times. | Tuktu: 4500 B.C. - 200B.C., Mesa: 7620 + 95+ B.C. Putu: 6090±150 B.P.; 4140 B.C. 8554± 130 B.P.; 11,470±500 B.P.= 9520 B.C. | Tuktu/Naiguk, Ribdon, Mesa, Putu, Utukok sites. |
| American Paleo-Arctic | Tunalik | ca. 8500 B.C.- 6500 B.C. | Gallagher Flint Station: 10,540± 150 = 8590 B.C. | Tunalik, Lisburne, Gallagher Flint Station, Shoreline Bluffsites |

[a] Sites in the Arctic National Wildlife Refuge are underlined.

The limited amount of archaeological work completed in and adjacent to the ANWR study area leaves many questions about the chronology of the cultural sequence, the processes which produced this chronology, and the behavioral significance of the cultural remains. Information on population size and the structure of social relations is also lacking.

Some archaeological sites in northern Alaska (Table 3) appear to be much older than those found in the ANWR study area. This may be due to the limited amount of archaeological investigation completed in the study area, or these cultural traditions may never have been present. The status of the Arctic Small Tool Tradition in the study area is unclear. The few sites identified in and near the ANWR study area have not yielded collections large enough to document whether they belong to this tradition. Assigning these sites to specific cultures has not been possible. But future work, covering a wide geographic area, may yield additional sites.

The relationship of the older sites at Barter and Arey Islands to the Birnirk sites to the west (Table 3) is also not clear. Jenness (1914) thought the collection from Barter Island was similar to collections from Birnirk, but the Barter Island site has been almost totally destroyed. Excavations at Arey Island may provide material which could be compared to the Birnirk collection, and may resolve some tentative conclusions about the presence of Old Bering Sea and Punuk peoples in the Barter Island area. Excavations at Arey Island would also provide valuable information about the historic trading site located there.

Athabaskan Tradition sites identified by Hall (1982) (Table 3) are all in the Brooks Range. Future work will probably not find sites from this tradition in the ANWR study area. However, Stefansson (1914) indicates that Athabaskan Indians from the Arctic Village area used the Hulahula River as a travel route when attending the trade fair at Arey Island. Surveys on this river may identify Indian sites.

## Human History

### The Inupiaq Eskimo

The Inupiaq Eskimo of northern Alaska are descendants of proto-Mongoloid peoples who migrated across the Bering Land Bridge at the close of the Pleistocene Epoch. The Inupiat are composed of 2 distinct, but interacting ethnological groups: the Nunamiut and the Tagiugmiut. The Nunamiut were nomadic, and ranged over the northern slopes and foothills of the Brooks Range following the migrating caribou upon which they subsisted. The Tagiugmiut occupied small villages along the coast from which they hunted marine mammals, principally bowhead whales and seals. Although the 2 groups of Inupiaq depended primarily upon distinct resources, there was significant overlap of resource utilization and considerable cultural interaction (Gubser 1965, Schneider and Libbey 1979). The Tagiugmiut regularly traveled inland along the major river drainages to take fish, caribou, and other furbearers. The Nunamiut journeyed along the same rivers to the coast, where they traded caribou meat and hides for food and materials produced by the coastal people from their marine resources.

Prior to 1885, the inland Nunamiut are thought to have been more numerous than the coastal Tagiugmiut, reaching a peak of more than 1,000 in scattered bands of 50-150 people in the river valleys of the arctic mountains and foothills (Gubser 1965). However, as the effects of an expanding white culture increased, their numbers dwindled. By 1920, the lure of employment in whaling and trapping, and the effects of disease and declining caribou herds had reduced the Nunamiut population to less than 20, and these soon moved to the coast. In the late 1930's, several Nunamiut families returned inland to settle at Anaktuvuk Pass in the central Brooks Range. At present, this village is the sole remaining Nunamiut settlement. The coastal Tagiugmiut faced similar problems during this period and are now concentrated in a few larger villages, principally Point Hope, Wainwright, Barrow, and Kaktovik.

Early History

Written history of the ANWR study area begins with Captain John Franklin's report of exploration in 1826 (Franklin 1828). The Royal British Navy sent Franklin on an overland expedition to map the arctic seacoast in connection with efforts to find the northwest passage between the Atlantic and Pacific Oceans. Franklin traveled from the Mackenzie River west along the Beaufort Sea coast intending to rendezvous with Captain F.W. Beechey, who was sailing east towards Pt. Barrow. While members of Beechey's crew did reach Pt. Barrow, Franklin was forced to turn back after reaching the Return Islands near Prudhoe Bay (Franklin 1828). He spent the months of July and August on the arctic coast between the mouth of the Mackenzie River and Foggy Island. He named the Clarence River, Demarcation Point, the British and Romanzoff mountains, Mt. Copleston, the Canning River, and many other geologic features. He reported visiting a trade fair located on what he called Barter Island. Since that time, however, this location has become known as Arey Island (Leffingwell 1919).

Franklin returned to England at the end of this second expedition, but disappeared on his next journey into the north. However, his work, and that of those who followed him investigating his disappearance, led to the completion of the basic mapping of the arctic coast of Canada and, to a lesser extent, Alaska. Franklin's journal provides much information about the country between the Mackenzie and Foggy Island as well as the first descriptions of the Natives who inhabited that part of the coast (Franklin 1928).

In 1939 an expedition, commissioned by the Hudson's Bay Company, was led by Dease and Simpson (Dease and Simpson 1837). Its purpose was to explore the northern coast and close the gap between the maps of Franklin and Beechey. The Franklin Mountains were named after John Franklin and a Native village was reported at Demarcation Bay, but much information collected was regarded as inaccurate or unreliable by later investigators (Leffingwell 1919).

This expedition was followed by several others sent in search of information about the disappearance of Franklin. Reports of these trips were written by several junior military officers (see Leffingwell 1919 for bibliographic references). Of special interest is the journey of the Enterprise (Collinson 1855), the first vessel to overwinter near the study area when the ship was frozen in at Flaxman Island not far from the mouth of the Canning River. Collinson attempted to travel from Flaxman Island to Barter Island but turned back due to bad weather. He did report several possible Native village sites between the 2 islands. The observations of Collinson during his 3 winters (1851-1854) in the arctic had far-reaching effects. Although he found no sign of Franklin, his information on anchorages and the abundance of bowhead whales in the Beaufort Sea, together with similar reports from other investigators, spurred the expansion of American and European whaling efforts into the Arctic Ocean east of Pt. Barrow (Leffingwell 1919).

Collinson's work encouraged others to sail eastward from Barrow. Whalers advanced further east each year and eventually reached Herschel Island, Canada, where 7 ships were reported overwintering during 1894-95. Hunting parties from these ships traveled as far west as the Aichilik River in the study area. More importantly, the concentration of these ships required large quantities of meat. While these needs were met partly by the efforts of the ships' crews, the Native population was also heavily relied upon to provide meat and other goods in return for trade items. The presence of these goods, including guns, drew Eskimos from as far as Anaktuvuk Pass. Along with these goods, the Natives for the first time encountered alcohol and a variety of diseases carried by the whalers. In 1865, a measles epidemic among the Mackenzie Eskimo substantially reduced the size of the population.

The growth of the arctic whaling industry had profound economic and social effects on the Native inhabitants of the area. Opportunities for employment on whaling ships and the introduction of trade goods altered the economic base of the coastal Inupiat, while the introduction of disease and alcohol had significant social and cultural consequences. The use of firearms acquired from White traders and whalers permitted the Eskimo to take increasingly large numbers of caribou, which depleted populations. This decline of caribou, together with the sudden increase in whale harvests, in many instances caused people to starve (Spencer et al. 1979) or migrate east to Canada.

Contact between Natives and Whites became more intense during the late 1860's, and relatively major changes in demographic and subsistence patterns occurred. McGhee (1974) summarizes the occurrences of the next 40 years:

> "After the appearance of the American whaling fleet along the Mackenzie Delta coast in 1889, and with the increasing association between the indigenous population and the whalers wintering at Herschel Island and elsewhere, the effects of epidemic disease and the disruption of aboriginal social patterns accelerated rapidly...At the same time as Eskimos were being decimated by disease, local aboriginal culture was being submerged beneath a wave of American and Alaskan Eskimo introductions...The latter were either brought to the area as caribou hunters by the whaling ships, or had moved in on their own in search of new hunting and trapping grounds after the North Alaskan caribou herds had been killed off to supply the excess demands of the whaling fleet...Aborginal Mackenzie Eskimo culture could probably be considered to have become extinct between 1900 and 1910."

Very little was known of the Mackenzie Eskimo before they disappeared. They are mentioned only infrequently in the literature of the explorers, and little or no effort was made to learn their customs and history. In 1908, the first scientific expedition to study the northern Eskimos arrived in the area, led by V. Stefansson and R. Anderson under the auspices of the American Museum of Natural History. Anderson spent a winter living with the Natives on the Hulahula River and collected much ethnographic information (Anderson 1919). These people were apparently mostly Eskimos that had moved from Barrow and the Anaktuvuk Pass areas.

Stefansson was able to reconstruct some information about the Mackenzie people from 2 informants (Stefansson 1919). He indicated that there were 5 distinct groups scattered from about 160 km east of the Mackenzie River to the Demarcation Point or Icy Reef area. The group was called the Kigisktarugmiut, which were named for the main village of Kiguklayuk on Herschel Island. They occupied the area from Shingle Point east of Herschel Island to Demarcation Bay, according to Stefansson (1919). However, it appears that these people's territory may have extended as far west as Barter Island (McGhee 1974).

In 1913, Stefansson and Anderson returned to the arctic with the Canadian Arctic Expedition (Leffingwell 1919). Stefansson lost his ship, the Karluk, to the ice although he was not on board at the time. Anderson's ship made it to Camden Bay where it overwintered at Collinson Point. The crew included D. Jenness who conducted the first scientific archaeological excavations at Barter Island. These excavations were brief but established the fact that the spit running east from Barter Island, where the modern landing strip is now located, was a large archaeological site. The artifacts he recovered resembled those found in the Barrow area that have been assigned to an early Eskimo tradition named the Thule (Jenness 1914).

At about the same time as Anderson entered the country, N. Arey, S.J. Marsh, and F.G. Carter arrived to prospect for gold. Arey, who spent 11 years in the study area, was the first White man to enter the headwaters of the Canning, Hulahula, Okpilak, and Jago Rivers, and the only non-Native resident in the area. Carter and Marsh wintered at Camden Bay in 1901 and spent most of the following 2 years prospecting the Canning River as far south as Cache Creek. Their lack of success led them back to interior Alaska via the upper Canning and Chandalar Rivers. Many geographic features along this route were first named by or after Carter and Marsh (Leffingwell 1919).

Other scientific parties also entered the area. In 1890, Turner discovered the Firth River. He was followed by Funston in 1894 and Peters and Schrader in 1901, who were mostly interested in the geography and geology of the area. In addition, a surveying team of the United States Government established the border between the United States and Canada (Leffingwell 1919).

The most extensive early survey of northeast Alaska was conducted by E.D. Leffingwell, a geologist with the U.S. Geological Survey who established a permanent camp on Flaxman Island between 1907 and 1912. During this period he collected data on the geology and geomorphology of the Canning River area and explored the drainages of the Okpilak and Hulahula Rivers (Leffingwell 1919). His original camp on Flaxman Island was placed on the National Register of Historic Places in 1972. He first entered the north in 1906 as a co-leader of the Mikkelson-Leffingwell expedition which was less than successful when their ship was trapped and crushed in the ice. Mikkelson departed, but Leffingwell spent 9 summers and 6 winters in the study area during the next decade. Leffingwell (1919) prepared the first accurate chart of the north Alaskan coast, a detailed study of ground ice, a detailed discussion of physiography including past and present glaciation, and an analysis of the processes of erosion and deposition under polar conditions. In addition to scientific data, he provided excellent discussions of techniques for living and working in the harsh arctic environment, and accurate descriptions of the process used in mapping the coast and some of the interior mountains. Native names were used when possible for many features on his maps.

## Early Oil Exploration

The presence of oil seeps on the arctic coastal plain had long been known to the Native inhabitants of the region, and was noted in early geological surveys (Leffingwell 1919). This information, together with an increasing demand for oil to fuel the Navy's ships, led President Warren G. Harding to issue an executive order on 27 February 1923 withdrawing 9,315,000 ha north of the Brooks Range and west of the Colville River as Naval Petroleum Reserve No. 4 (NPR-4). Public Land Order 82, issued by the Department of the Interior in 1943, closed NPR-4 and an additional 10,125,000 ha to the west and east (including the present area of ANWR) to appropriation under any public land laws and reserved mineral rights for use by the Secretary of the Interior in "the prosecution of the war." Between 1944 and 1953, the Navy and a civilian contractor (ARCON) conducted exploration for oil and gas on lands set aside by PLO 82. Although several minor and a few larger discoveries were made, the high potential costs of development and transportation led the Secretary of the Navy to discontinue the exploration program in 1953 (U.S. Department of the Navy 1977). Apparently, no seismic exploration or drilling was carried out within the ANWR study area, although between 1947 and 1953, geologic mapping was conducted on the Canning River, Marsh and Carter Creeks, the upper Katakturuk and Tamayariak drainages, the Sadlerochit Mountains, and the Kongakut and upper Firth Rivers (Reed 1958). Naval oil exploration also prompted initiation of scientific investigations to begin in the Alaskan arctic. The Arctic Research Lab (ARL) began operations in Barrow in 1947 and was later renamed the Naval Arctic Research Laboratory (NARL). A NARL field station was established at Peters and Schrader Lakes to provide support for geologists and biologists working in the eastern arctic (Ritchie and Childers 1976).

## Post-War Military Development

World War II and early oil exploration activity apparently had little effect upon the northeastern Alaskan arctic and its inhabitants. However, during the military defense buildup which followed the war, a Distant Early Warning (DEW Line) system was constructed along the Alaskan and Canadian arctic coastlines. Barrow was the main supply base during construction, and Barter Island was selected as a site for a large DEW Line installation.

Construction and support of the DEW Line stations had a significant effect upon both the arctic coastal environment and its people. The establishment of the DEW Line site on Barter Island resulted in 3 relocations of the village of Kaktovik between 1947 and 1964, to accommodate changes in the layout of the installation (Wentworth 1979). DEW Line construction and operation brought social and economic changes to the Native residents of the arctic coast on a scale not experienced since the decline of the whaling industry. Increased job opportunities once again caused immigration and concentration of the nomadic Native populations in villages such as Kaktovik (Wentworth 1979).

DEW Line construction and operation also affected the Beaufort Sea coastal environment. Between the Canning River delta and Demarcation Point, 1 principal DEW Line station (Barter Island) and 2 intermediate stations (at Camden Bay and Beaufort Lagoon) were constructed, as well as lesser structures at Brownlow and Demarcation Points. Only the Barter Island installation remains active today. Abandoned materials include numerous rusting steel fuel drums located primarily at Camden Bay and Beaufort Lagoon, but also scattered along the coast and inland within the boundaries of ANWR (Thayer 1979).

### Establishment of the Arctic National Wildlife Refuge

In 1949, the National Park Service (NPS) began a survey of Alaska's recreational potential, directed by G. L. Collins, Chief of the State and Territorial Recreation Division for Region 4 of the NPS. In 1954, following aerial surveys, field verification, and consultation with prominent conservationists such as O. Murie and A. S. Leopold, Collins recommended that the northeast corner of Alaska be preserved for its wildlife, wilderness, recreational, scientific, and cultural values. Collins also recommended that the area be an international park, to include contiguous lands between the Alaska-Canada border and the Mackenzie Delta (Ritchie and Childers 1976, Spencer et al. 1979).

On 20 November 1957, Secretary of the Interior Seaton announced plans to repeal Public Land Order 82 of 1943. The action would leave NPR-4 and neighboring areas open for development, but specified that approximately 3.6 million ha of Alaska's northeastern arctic be considered for establishment of a national wildlife range. On 6 December 1960, Secretary Seaton signed Public Land Order 2214, creating the Arctic National Wildlife Range. On 2 December 1980, President Carter signed into law the Alaska National Interest Lands Conservation Act (ANILCA). This legislation created the 7.2 million ha Arctic National Wildlife Refuge which encompassed the existing 3.6 million ha Arctic National Wildlife Range and an additional 3.6 million ha of adjoining lands west to the Trans-Alaska Pipeline and south to the Yukon Flats. An area of approximately 3.1 million ha, comprising most of the original Arctic National Wildlife Range, was designated wilderness, while approximately 0.5 million ha of coastal plain within the refuge was opened to seismic exploration for oil and gas.

Public support in both the United States and Canada has continued to grow for the establishment of an International Arctic Wildlife Range. In 1984, the Canadian government established a new national park adjacent to the eastern boundary of ANWR.

## Subsistence

Title VIII of the Alaska National Interest Lands Conservation Act (ANILCA) passed by Congress in 1980, defined subsistence as:

> "The customary and traditional use 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 by-products of fish and wildlife resources taken for personal or family consumption; for barter or sharing for personal or family consumption, and for customary trade."

This law provides the opportunity for rural residents engaged in a subsistence way of life to continue to do so, establishes a priority for customary and traditional consumptive uses of fish, wildlife, and other renewable resources on public lands, requires that subsistence concerns be incorporated into land use decisions affecting national wildlife refuges and other federal lands in Alaska, and specifies that maintaining the opportunity for continued subsistence uses by local residents is one of the purposes for which ANWR shall be managed. Worl and McMillan (1982) defined subsistence as the production, consumption, distribution and exchange of natural resources which are necessary for the physical, social, and cultural maintenance of a society.

In 1977, the North Slope Borough (NSB) Commission on History and Culture, prepared a "Traditional Land Use Inventory" (TLUI) of historic and cultural sites in the Beaufort Sea coastal area (Nielson 1977a, as cited in Jacobson and Wentworth 1982). From 1977 to 1980, Jacobson and Wentworth (1982) collected information in the village of Kaktovik for the USFWS and the NSB as part of a study to determine native historical, cultural, and livelihood values. Traditional sites used by or with special significance to the people of Kaktovik were identified, information on the local economy was recorded, and subsistence resource use areas of selected Kaktovik residents were mapped as part of a larger subsistence mapping effort for the entire north slope. A sample of 13 Kaktovik hunters representing about one-forth of Kaktovik households, were interviewed to determine the extent of areas used in hunting, fishing, trapping, and gathering (Jacobson and Wentworth 1982). Kaktovik land use patterns, determined from these individual responses, were combined with data from other villages to provide a picture of land use across the north slope (Pedersen 1979). In 1982, Worl and McMillan (1982) completed a sociocultural assessment of proposed petroleum exploration in ANWR for the village of Kaktovik, and Lonner and Beard (1982) did a similar assessment for Arctic Village.

Comprehensive research by the Division of Subsistence, Alaska Department of Fish and Game (ADF&G) also contributed to knowledge of Kaktovik's subsistence land use patterns. Pedersen et al. (1985) delineated the contemporary spatial requirements of the hunting, fishing, trapping, and gathering sector of Kaktovik's economy. Pedersen and Coffing (1984) and Coffing and Pedersen (1985) detailed caribou hunting patterns and harvest.

This section describes land use patterns and the use of biotic species present or adjacent to the ANWR coastal plain study area by rural residents. Emphasis is on the village of Kaktovik, the only community located immediately adjacent to the ANWR coastal plain study area. Subsistence use of the Porcupine caribou herd, polar bears and beluga whales by other villages is also discussed. Much of the material presented here was summarized from Jacobson and Wentworth (1982), Pedersen et al. (1985), and Arctic Environmental Information and Data Center (1982).

## Kaktovik

### Location and History

Kaktovik is the easternmost village on the Alaskan north slope. Most of its residents are Inupiaq Eskimos who are part of the broad cultural group of Inuit peoples stretching from Siberia to Greenland. Kaktovik is located on

Barter Island, less than 0.5 km offshore in the Beaufort sea of the Arctic Ocean, 15 km north of ANWR, 580 km east of Barrow, and 115 km west of the United States-Canadian border.

Historically, the area near Barter Island was apparently an important center for meeting and trading. Canadian Inuit people met here to trade with Barrow area residents, inland people came from the mountains to trade, and Indians from south of the Brooks Range visited here occasionally (Nielson 1977b, as cited in Jacobson and Wentworth 1982). A large prehistoric village once existed on the island. At least 30 to 40 old house sites were there in 1914 (Leffingwell 1919, as cited in Jacobson and Wentworth 1982). Many whalebones were found among the sod house ruins, suggesting that the people were whalers (Kaveolook 1977, as cited in Jacobson and Wentworth 1982). One legend says these prehistoric people, the Qanmaliurat, were driven east to what is now Canada by other Inupiat. Oral accounts recall that people did not live at Barter Island after the Qanmaliurat killed one couple's only son, whose body was fished out of the water with a seining net. The name Qaaktugvik (Kaktovik) means "seining place" (Kaveolook 1977; Okakok 1981, as cited in Jacobson and Wentworth 1982). Another legend states Pipsuk was fished out of the water after drowning in the lagoon while fishing from a kayak (Jacobson and Wentworth 1982).

Barter Island was an important stop for commercial whalers to trade with Inupiaq people during the 1890's and early 1900's (Nielson 1977b, as cited in Jacobson and Wentworth 1982), but was never a rendezvous for the local population according to Jenness (1914, as cited in Pederson et al. 1985). In 1917, Tom Gordon from Barrow established a fur trading post at Demarcation Point, east of Barter Island, as part of a series of trading posts along the Beaufort seacoast. In 1923, Gordon and his brother-in-law Akootchook established a trading post at Barter Island, and other families moved there to be near relatives and good hunting (Kaveolook 1977, as cited in Jacobson and Wentworth 1982). The trading post was the beginning of Kaktovik as the permanent settlement of today (Nielson 1977a, as cited in Jacobson and Wentworth 1982).

During the 1920's and 1930's, people living in the Barter Island area congregated at the fur trading post on holidays and other occasions. But most of the time they were semi-nomadic, living along the coast and following the animals on which hunting, fishing, and trapping depended. Arctic fox was a good source of cash income and many people were involved in reindeer herding. Three herds were kept at Camden Bay, Barter Island, and Demarcation, and the reindeer were taken to the foothills of the Brooks Range during winter months (Jacobson and Wentworth 1982). During the winter of 1935-1936, 58 people in 10 families were reportedly living at Barter Island, while 122 people in 20 families were living along the sea coast between Brownlow Point and Demarcation Bay (U.S. Bureau of Indian Affairs 1936, as cited in Pederson et al. 1985). Reindeer herding ended in 1938, the price of fox fur fell in the late 1930's, and most of the Alaskan trading posts closed by the early 1940's. People from the Barter Island area then traded at Aklavik, Canada, and moved to Herschel Island, Canada or built houses at Barter Island. People relied primarily on local resources for food into the mid-1940's (Jacobson and Wentworth 1982).

In 1945-1951, mapping of the Beaufort sea coast by the U.S. Coast and Geodetic Survey and construction of a radar site for the DEW Line system provided jobs for area residents. In 1947, the U.S. Air Force built an airport runway and hangar facility on the prehistoric village site, and several houses had to be moved. In 1951, the entire area around Kaktovik (1,823 ha) was made a military reserve, and some people were moved again. In 1964, the village was moved a third time, and received title to their present site (Jacobson and Wentworth 1982).

As a result of employment opportunities and the establishment of a school in 1951, the Kaktovik population increased from 46 people in 1950 (U.S. Bureau of the Census 1950, as cited in Pederson et al. 1985) to 140-145 people in 1953 (Kaveolook 1977, as cited in Jacobson and Wentworth 1982). People moved in from the surrounding area and 5 families living in Canada returned to Barter Island (Kaveolook 1977, as cited in Jacobson and Wentworth 1982). During the 1960's, Kaktovik remained an isolated village, dependent on the DEW Line installation for jobs and communication with the outside world. In 1968, however, oil was discovered at Prudhoe Bay, less than 200 km west of Kaktovik. In December 1971, the Alaska Native Claims Settlement Act granted Alaska Natives, including north slope Inupiat, 16.2 million ha of land and a one-billion-dollar cash settlement. The Arctic Slope Regional Corporation (ASRC) and the Kaktovik Inupiaq Corporation (village corporation) were formed and Kaktovik was allotted surface rights to 37,394 ha, mostly within ANWR. When the North Slope Borough (NSB) was formed in 1972, with the power to tax the Prudhoe Bay oil fields, a substantial source of revenue existed. Kaktovik, the easternmost village in the Borough, was incorporated as a second class city, with a mayor and city council. By the late 1970's, new Borough-funded housing, street lights, a power plant, and a high school with a gym and small swimming pool were built in Kaktovik. Borough and related construction and service jobs became available so that villagers were no longer economically dependent on the DEW Line site. Some former Barter Island residents living in Barrow moved back to Kaktovik with their families and the population of Kaktovik increased. At the same time, however, petroleum exploration expanded east of Prudhoe Bay towards Kaktovik's traditional subsistence area. Exploratory drilling took place on Flaxman Island near the Canning River mouth bordering the ANWR. In December 1979, the first offshore lease sale was held in the Beaufort Sea, including tracts to within 6 km of the ANWR boundary. Further offshore lease sales have been planned for tracts in the Beaufort Sea north of Kaktovik. In December 1980, the Alaska National Interest Lands Conservation Act (ANILCA) mandated oil and gas surface exploration of the coastal plain of ANWR, which was conducted during the period 1983 to 1985. In 1984-1986 the Kaktovik Inupiaq Corporation approved an agreement between their regional corporation (ASRC) and Chevron USA Inc. to drill an exploratory well near the mouth of the Niguanak River on village lands adjoining ANWR.

The U.S. Census placed Kaktovik's population at 120 in 1960 and 165 in 1980 (Pedersen et al. 1985). NBS censuses in Kaktovik found 195 people in 1980 and 201 people in 1981 and a population of 218-226 was projected for 1985 (Worl and McMillan 1982). In 1983, Pedersen (et al. 1985) counted 185 persons in Kaktovik, including 46 households averaging 4.0 persons per household. Eighty-three percent of the population was of Eskimo descent (Pedersen et al. 1985).

## Traditional Land Use Inventory Sites

Historic Traditional Land Use Inventory (TLUI) sites referred to throughout this section are associated with present as well as historic use. Traditional sites on or adjacent to the ANWR study area important to Kaktovik residents are identified in Table 4 and Fig. 1. Descriptions of these sites can be found in Jacobson and Wentworth (1982) and U.S. Fish and Wildlife Service (1982). Sites west of ANWR between the Canning and the Colville Rivers can be found in North Slope Borough (1980). Inupiaq place name spellings in use today are often different from those appearing on U.S. Geological Service (USGS) maps, and locations may differ slightly as well. Both names are listed in Table 1, but for clarification, names appearing on USGS maps are used in the text. At locations where only Inupiaq names exist, TLUI site names are used and underlined. Where differences in Inupiaq spelling exists between Jacobson and Wentworth (1982) and Pederson et al. (1985), the former is used. Inupiaq letters are also not found in the text, but are used in Fig 1 and Table 4.

Although historic sites are associated with present land use, subsistence activities are not limited to these sites. Some subsistence activities are site-specific, such as fishing, but other activities cover broad areas. Often, the historic site is used as a camping area for pursuing activities which are much more far-reaching. The traditional sites mentioned in this section are not the only sites used by Kaktovik people.

## The Subsistence Economic System

The Inupiaq Eskimo living in or near the area of what is now ANWR have always sustained themselves by living off resources taken directly from the land and sea. Their culture is based on this close economic relationship with the natural environment, defined by Jacobson and Wentworth (1982) as the "subsistence economic system". Today, the Kaktovik economic system is merging subsistence with modern monetary elements, operating within the Inupiaq cultural context, according to Jacobson and Wentworth (1982). Worl and McMillan (1982) also described Kaktovik's economy as an interrelationship of subsistence and Market (cash) economies. Wolfe and Ellanna (1983), as cited in Caulfield (1983) described the subsistence socio-economic system as being "mixed", comprised of both market (cash) and subsistence sectors, with a domestic mode for production, seasonal activities, a network of distribution and exchange through sharing, and systems of land use and oral traditions encompassing beliefs, knowledge and values associated with resource use.

The subsistence component of the Kaktovik economic system can be separated in to three parts: economic, social and cultural (Worl and McMillan 1982). The economic aspects of subsistence, defined by Worl and McMillan (1982), include production (hunting, fishing or gathering) and distribution of natural resources for food, clothing, shelter, fuel, utilitarian tools and equipment, ceremonies, art and crafts. Some importation of resources not readily available in Kaktovik (eg: walrus and smelt) and exportation of surplus products (eg: maktak and sheep) occurs, and today, unlike aboriginal times, the economy is integrated and dependent on the capital system. The purchase of equipment such as snowmoblies, boats, outboard motors, fuel, rifles, and ammunition, which are necessary for the procurement of subsistence resources requires cash (Worl and McMillan 1982). Distribution and exchange of services and goods, including commercially manufactured and natural resource

Table 4. Traditional Land Use Inventory Sites in the Arctic National Wildlife Refuge (sources: Jacobson and Wentworth 1982, Pederson et al. 1985).

| Inupiaq or local name | Meaning | Name on USGS maps (location) |
|---|---|---|
| Sirak | | Flaxman Island |
| Agliġuaġruk | "Big jawbone" | Brownlow Point |
| Tigutaaq | | (Tamayariak delta) |
| Kayutak | | (Coast between Tamayariak and Katakturak Rivers) |
| Kaŋigñiivik | "Meeting at the end" | Konganevik Point |
| Katakturuk | | Katakturuk |
| Nuvugaq | "Point" | Collinson Point |
| Kunagrak | | (Mouth of Marsh Creek) |
| Aanallaq | | Anderson Point |
| Salliġutchich | | Sadlerochit Springs |
| Sanniqsaaluk | | (Kajutakrok Creek) |
| Patkotak | Paul Patkutaq's place | (Nataroarok Creek) |
| First Fish Hole | | (Hulahula River) |
| Second Fish Hole | | (Hulahula River) |
| Third Fish Hole (Katak) | "To fall" | (Upper Hulahula River) |
| Kaŋich | | (headwater of Hulahula River) |
| Uqpillam Paaŋa | | (Okpilak delta) |
| Naalagiagvik | "Place where one can come to listen" | Arey Island |
| Iglukpaluk | | (NW Barter Island) |
| Tikluk-Akootchook house site | | (S Barter Island) |
| Qaaktuġvik | "Seining place" | Kaktovik (first location) |
| Qaaktuġvik | "Seining place" | Kaktovik (second location) |
| Qaaktuġvik | "Seining place" | Kaktovik (present location) |
| Pipsuk | | Pipsuk Point |
| Qikiqtaq (Drum Island) | | Manning Point |
| Tapkak | | Bernard Spit |
| Kanigiluk | | (Jago River delta) |
| Tapqauraq | "Little sand spit" | Martin Point and Tapkaurak Spit |
| Uqsruqtalik | "Place with some oil" | Griffin Point |
| Qapilooraug | | (Pokok lagoon) |
| Pukak | | (Pokok lagoon) |
| Imaignaurak | "Place of little water" | (Pokok Bay) |
| Iglugruatchiat | "Place of sod houses" | Humphrey Point |
| Aŋŋun | "Pitch" | Angun Point |
| Nuvagapak | "Big point of land" | Nuvagapak Point |
| Atchilik | "Place with skin tents" | Aichilik River |
| Siku | "Ice" | Icy Reef |
| Piŋuqsraluk | "Big mounds" | (between Kongakut and Demarcation Bay) |
| Kuvluuraq | "Little thumb" | Kulurak |
| * | | Demarcation Bay -- west side |
| Old Man Store | | (S. Demarcation Bay) |
| Kaniġluaqpiat | "Way at the end" | (SE Demarcation Bay) |
| Pattaktuq #1 | "Big toe" | Demarcation Point |
| Pattaktuq | "Big toe" | Gordon |

* No local name.

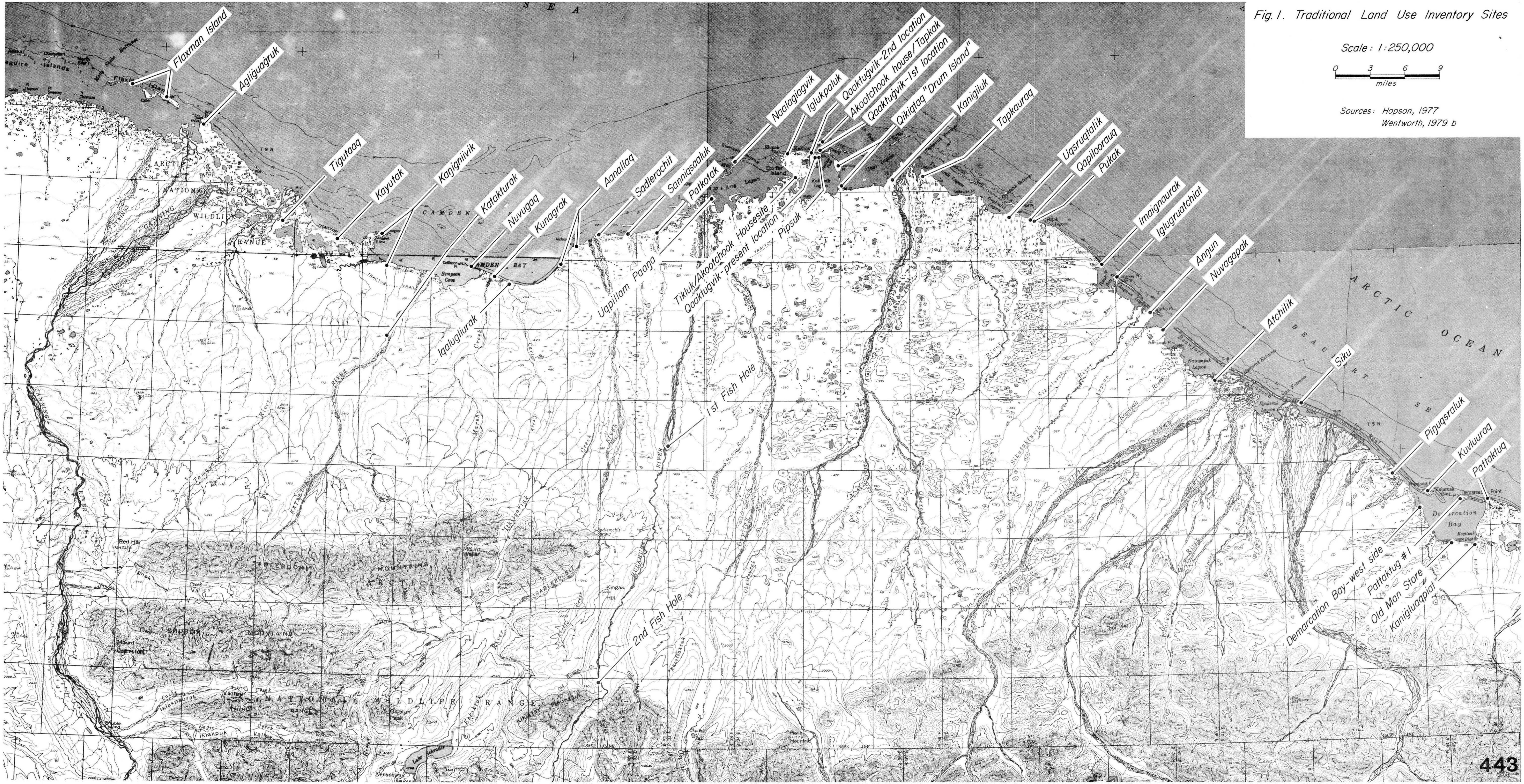


Fig. 1. Traditional Land Use Inventory Sites

products and cash, occur within a social or kin-based network (Worl and McMillan 1982). The social sphere of this economic system includes harvesters who actively engage in subsistence activities, recipients (eg: the elderly or families without active hunters), and financial sponsors who provide cash, equipment, or supplies to harvesters. Cooperation and sharing of resources binds and integrates the community as a social unit. Cultural components of this subsistence economic system dictate relationships between people, animals and the environment (Worl and McMillan 1982).

The north slope Inupiat have lived with an economy which combines subsistence and cash since the late 1800's. Some of the ancestors of Kaktovik residents, both Native and White, were commercial whalers at Barrow and Herschel Island. Commercial whaling declined by about 1910, and fur trapping took its place as the main source of cash income. In the 1930's, Kaktovik subsistence was combined with trapping and reindeer herding. In the late 1940's, Kaktovik people began working for wages, which increased their economic security. But hunting and fishing still remained the main source of protein, the foundation of the Native diet, and the source of some arctic cold-weather clothing, and also provided the basis for the relationship with the land, the group activities, and the sharing of resources that is central to the Inupiaq culture (Jacobson and Wentworth 1982). From the 1950's until the 1970's, a few jobs at the post office, store, school, the Barter Island DEW Line site, and related construction were the main sources of local wage employment (Jacobson and Wentworth 1982). The DEW line provided 68% of the employment during this period (Worl and McMillan 1982).

After 1972, government became the dominant employer on Kaktovik, accounting for 62% of all employment in 1977, and 84% in 1982. Job availability increased 87% between 1974 and 1977 and at least another 60% between 1977 and 1982, due to employment primarily by the NSB and associated construction projects funded by the Borough Capital Improvements program (Worl and McMillan 1982). A 1982 job count identified 67 full-time jobs in Kaktovik (Alaska Consultants, Inc. 1983, as cited in Pedersen et al. 1985). However, seasonal or temporary employment was the norm for most workers (Pedersen et al. 1985). Worl and McMillan (1982) found that although jobs were available, few residents worked steadily, not only because work was seasonal, but also because of personal preference. Many individuals voluntarily left work during hunting and fishing seasons.

Worl and McMillan (1982) found that estimated medium income for 20 Kaktovik families was $16,500 in 1973, and estimated mean income ranged from $17,824 in 1975 to $15,000 - $16,684 in 1977. In 1980, the medium income for the entire community of Kaktovik was $25,000, compared to $25,421 for households statewide (Alaska Consultants, Inc. 1983, as cited in Pedersen et al. 1985). In March 1982, average salaries ranged from $2400 per month for permanent NBS employees to $3000 per month for village corporation employees to $4000 per month for construction workers. Kruse et al. (1981, as cited in Pedersen et al. 1985) documented that although many Kaktovik residents are employed, individuals still actively participate in subsistence activities.

Recently rapid changes have occurred in Kaktovik. In addition to new housing for almost every family, new facilities include a modern school with a gymnasium and small swimming pool, a well equipped health clinic, public safety building, and fire station. Other facilities include the U.S. Post Office and USFWS ANWR office, the village cooperation office and store, the community hall and Presbyterian Church. Water delivery, electricity, sewage and trash pickup, maintenance and storage facility, satellite television, and telephones are available for every home, (Jacobson and Wentworth 1982).

Although people in Kaktovik now earn more money, gains have been offset by the cost of living in northern Alaska. In 1982, food and fuel costs were 72% higher in Kaktovik than in Anchorage (Pedersen et al. 1985, Worl and McMillan 1982). Almost all consumer goods must be flown into Kaktovik. In spite of economic changes, substantial changes in sociocultural values have not occurred. Strong kinship ties and alliances of the extended family have been maintained and sharing remains a major element of the economic system (Jacobson and Wentworth 1982, Worl and McMillan 1982). People can still return to traditional camping, hunting, and fishing sites - places where they grew up - and find them much as they remember them. And they can do the same activities at these sites as they have always done, in a familiar setting. This provides the opportunity to strengthen family and kinship ties and the community values of sharing and helping each other. To the Inupiat, land in its natural state is an economic provider as well as a source of pleasure, and outings on the land are a significant part of economic reality, even though most people also work for wages (Jacobson and Wentworth 1982).

The nutritional importance of subsistence is well documented. Subsistence-harvested meats and birds are high in protein and low in fat, and contain essential vitamins and minerals. Caribou and seal meat have more protein per ounce than fat-marbled beef. Marine mammal meat has more vitamin A and more iron than beef, and ptarmigan has twice the thiamine of chicken. Unlike other mammal fat, seal and whale oil is polyunsaturated and does not contain high levels of cholesterol (Cooperative Extension Service 1974, Hurwitz 1977, Nobmann 1978, Milan 1979, Worl 1979).

The economic value of subsistence harvested food is substantial. In 1982, 86.5% of Kaktovik households reported that they obtained all or most of the meat they ate by hunting and fishing, and nearly 80% of Kaktovik households report consuming meats 7 days of the week from hunting and fishing (Alaska Consultants Incorporated 1983; Alaska Consultants Incorporated and Stephen Braund and Associates 1984, as cited in Pedersen et al. 1985). Pedersen (et al. 1985) presented an estimated annual harvest of the primary subsistence species (Table 5), which was based on few data, but provided a guess as to what the average harvest levels may have been. Assuming that each Kaktovik person consumes 219 kg of subsistence harvested meat and fish each year (Table 5) at an average price of $9.92 per kg (E. Ahlers, pers. comm.) the cost of subsistence foods consumed would be $2173 per person per year.

Skills and abilities of individuals which contribute to an economic system are largely determined by culture. Within the framework of the wage economy, Kaktovik wage earners operate in an environment that does not often utilize their skills as hunters or give them many chances to excel. The opposite situation occurs when people are hunting, fishing, or traveling across the land. These subsistence skills and survival abilities are sources of Inupiaq identity and pride (Jacobson and Wentworth 1982). Hurwitz (1977, as cited in Jacobson and Wentworth 1982) found that subsistence activities contribute to mental health by strengthening the family unit, providing meaningful work, and fulfilling needs for personal self-reliance, self-esteem, and self-fulfillment.

Table 5. Annual subsistence resources harvested in Kaktovik averaged for the period of 1962-1982 (modified from Stoker 1983, as cited in Pedersen et al. 1985, Table 14).

| Species | Number | Utilizable weight (kg) | Percentage of total village harvest |
|---|---|---|---|
| Bowhead whale | 1 | 8,900 | 27.5 |
| Fish | - | 7,045 | 21.7 |
| Caribou | 75 | 5,250 | 16.2 |
| Dall sheep | 27 | 1,227 | 3.8 |
| Moose | 5 | 1,125 | 3.5 |
| Birds | - | 1,045 | 3.2 |
| Bearded seal | 30 | 2,400 | 7.4 |
| Ringed seal | 70 | 1,330 | 4.1 |
| Beluga whale | 5 | 2,000 | 6.2 |
| Walrus | 3 | 1,050 | 3.2 |
| Polar bear | 4 | 900 | 2.8 |
| Small game | - | 136 | 0.4 |
| Vegetation | no data | no data | no data |
| Total harvest | | 32,408 | 100.0 |
| Per capita/per year | | 219 | |

The Inupiat are actively seeking to obtain material goods and other aspects of modern societies, but wish to continue their relationship to the land and maintain the subsistence economy and culture (Worl and McMillan 1982). In summary, money and jobs are important elements of life in modern Kaktovik, but do not replace the land and its resources as a permanent source of security and well-being (Jacobson and Wentworth 1982). Kaktovik's Mayor Archie Brower stated: "The Brooks Range all the way to the ocean is our garden. We feed on that - the sheep, caribou, fish, seals, and whales" (Brower 1979, as cited in Jacobson and Wentworth 1982). The economic importance of the fish and wildlife to Kaktovik people is not only the need and preference for subsistence foods, but also the ability to provide their own food from the area in which they live (Jacobson and Wentworth 1982).

Yearly Cycle

The following description of Kaktovik people's yearly cycle of subsistence activities is summarized from Jacobson and Wentworth (1982) and is based on observations made in Kaktovik in 1977-1980. As no information of numbers of people hunting and trapping was presented in Jacobson and Wentworth (1982), quantitative comparisons of subsistence use were not possible. A general pattern of activity has been followed since the early part of this century (Fig. 2), but hunting techniques have changed with the availability of new technology. The relative emphasis on certain species has also changed. For example, bowhead whales were not hunted at Kaktovik until 1964, and fewer seals are hunted today compared to the mid-1960's, when people had dog teams to feed.

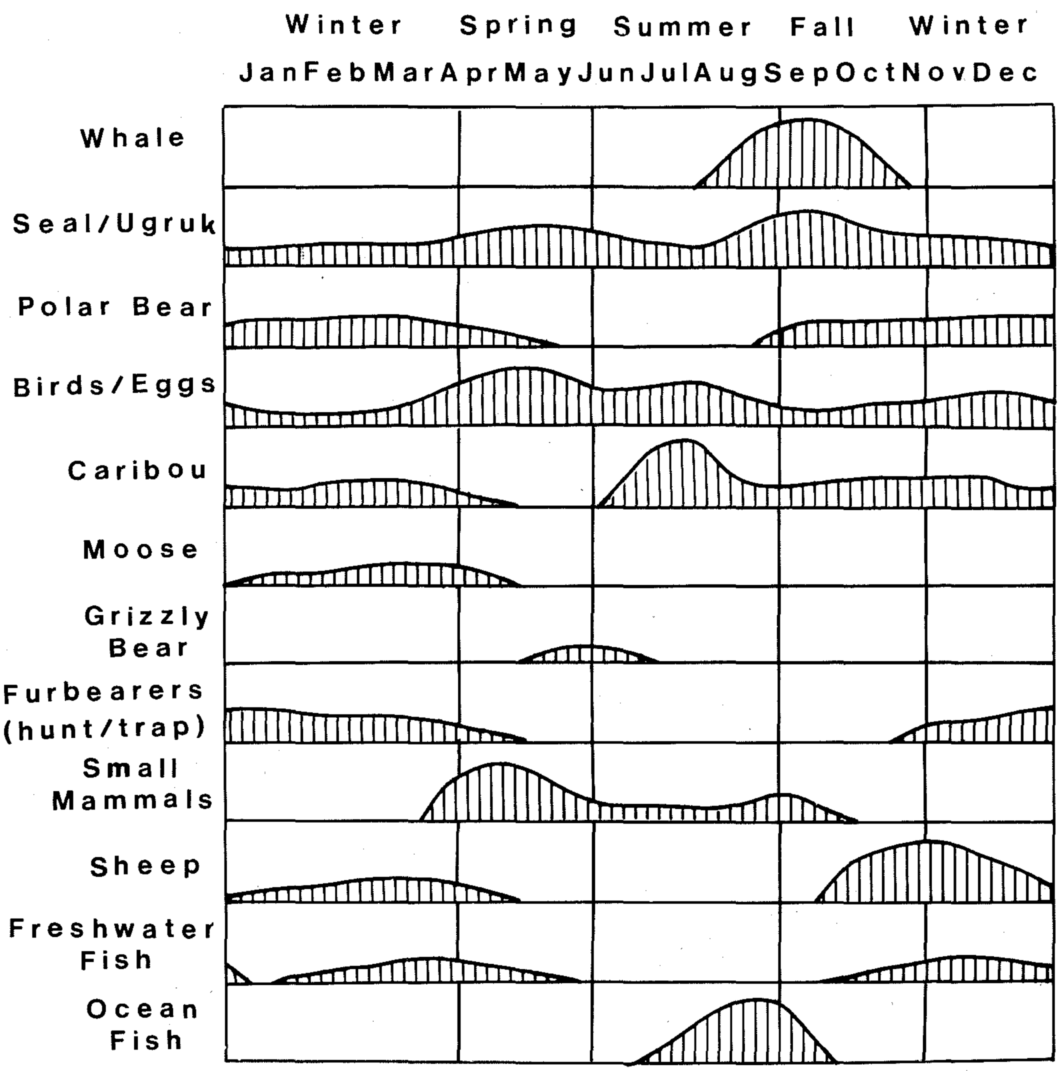


Fig. 2. Kaktovik yearly cycle of resource use. (Source: Jacobson and Wentworth 1982)

Subsistence activities at Kaktovik vary both by season and by year, due to changing environmental and access conditions, the abundance of animals and their movements, regulations regarding hunting and trapping seasons, changing condition of the meat, hide or fur, and other opportunities available to villagers as well as time available for hunting, individual preference, and degree of hunting success. Travel and access is limited by season. During the ice-free or summer months, usually early July through September, people travel by outboard-powered boat, and subsistence activities are confined to the coastline. Shallow water precludes access along rivers to inland areas. But after freezeup and during the winter snow season, from October through May, people travel overland by snowmachine, across the tundra of the coastal plain. Participation in subsistence activities is greatest during spring and summer months, as this is the time of long days, mild weather, and species abundance. Also school is out and entire families can camp and hunt and fish together.

The yearly cycle begins during the colder days of late August at the onset of the whaling season. Whaling occurs only in the fall at Kaktovik, not during the spring as in other north slope villages. Hunting can last for several weeks before whales are taken. Cutting up and transporting the whale meat, maktak (whale blubber), and baleen may take another week.

After freeze-up of the lagoon between Barter Island and the mainland, and after sufficient snow has fallen (usually by mid-October), people use snowmachines to travel into the mountains to hunt, fish, and trap for periods ranging from a few days to a month at a time. The average stay is 1 to 2 weeks. Trips to the mountains peak in early November and extend into mid-December, after which hunting decreases due to lack of daylight. The principal "snow season" camps of Kaktovik people are along the Hulahula River, near First, Second, or Third Fish Holes for convenient ice fishing, and on the Sadlerochit River, north of Sadlerochit Springs to the Kekiktuk River and beyond. Wall tents are heated with either wood-burning stoves fueled by willows gathered nearby, or small oil stoves fueled by heating fuel. At Thanksgiving and during the Christmas holidays, everyone returns from the mountains to the village to celebrate with Eskimo dances, games, snowmachine races, and feasts at which meat and maktak are distributed. In January and February, some people return to mountain camps for fishing, hunting, and trapping. Trips to the mountains increase in March and peak in April and May when long hours of daylight, warmer temperatures, and good snow cover prevail. In late May or early June, migratory waterfowl hunting begins along the coast. In early June, waterfowl hunting usually takes place closer to Barter Island, as travel by snowmachine becomes more difficult. People may set up camps on the mainland southeast of Barter Island, on Arey Island, or at other locations, depending on where the flocks are flying by. Stays at these camps range from overnight to two weeks. Seals can be taken also, and some people may get an occasional caribou. Later in June, subsistence activities decline because the lack of snow prevents travel by snowmachine, and the coastal waters are still frozen, making boat travel impossible. Prior to the 1970's, when the people used dog teams for transportation, they traveled out over the ice to hunt seals in June, and also put packs on the dogs and traveled inland to hunt caribou or small game. As soon as the ice goes out in July, subsistence activities increase as many people travel along the coast by boat to hunt caribou and fish. The entire coast from Foggy Island to Demarcation Bay is used for summer subsistence activities.

Resources Harvested and Areas of Use

The fish, wildlife, and other biotic resources used by Kaktovik residents in 1977-1980 were described by Jacobson and Wentworth (1982). Resource use described by Pedersen et al. (1985) encompassed the period 1923-1983, but current use patterns were not differentiated. Resource use presented in this section was compiled from both of these sources and assumes that patterns observed in 1977-1980 continue today. Table 6 lists biotic resources used by Kaktovik residents and gives English, Inupiaq, and scientific names for these resources.

Table 6. Biotic resources used by Kaktovik residents (source: Jacobson and Wentworth 1982, Pedersen et al. 1985).

| English name | Inupiaq name | Scientific name |
|---|---|---|
| Big game | | |
| *Caribou | Tuttu | *Rangifer tarandus* |
| *Dall sheep | Imnaiq | *Ovis dalli* |
| *Moose | Tuttuvak | *Alces alces* |
| *Brown bear | Akłaq | *Ursus arctos* |
| *Furbearers | | |
| Arctic fox | Tiġiganniaq | *Alopex lagopus* |
| Red fox | Kayuqtuq | *Vulpes vulpes* |
| Wolf | Amaġuq | *Canis lupus* |
| Wolverine | Qavvik | *Gulo gulo* |
| Mink | Itiġiaqpak | *Mustela vison* |
| Weasel | Itiġiaq | *Mustela erminea* |
| *Small mammals | | |
| Arctic ground squirrel | Siksrik | *Spermophilus parryii* |
| Alaska marmot | Siksrikpak | *Marmota broweri* |
| Marine mammals | | |
| *Seals | | |
| Bearded seal | Ugruk | *Erignathus barbatus* |
| Ringed seal | Natchiq | *Phoca hispida* |
| Spotted seal | Qasigiaq | *Phoca largha* |
| *Whales | | |
| Beluga whale | Qilalugaq | *Delphinapterus leucas* |
| Bowhead whale | Aġviq | *Baleana mysticetus* |
| *Polar bear | Nanuq | *Ursus maritimus* |
| *Walrus | Aiviq | *Odobenus rosmarus* |
| *Birds | | |
| Common eider | Amauligruaq | *Somateria mollissima* |
| King eider | Qiŋalik | *Somateria spectabilis* |
| Black brant | Nigliŋaq | *Branta bernicla* |
| Snow goose | Kaŋuq | *Anser caerulescens* |
| Canada goose | Iqsraġutilik | *Branta canadensis* |
| Pintail | Kurugaq | *Anas acuta* |
| Oldsquaw duck | Aaqhaalig | *Clangula hyemalis* |

Table 6. Continued.

| English name | Inupiaq name | Scientific name |
|---|---|---|
| *Birds (continued) | | |
| Ptarmigan | Aqargik | |
| Willow ptarmigan | Akrigivik | Lagopus lagopus |
| Rock ptarmigan | Niksaaqtuŋiq | Lagopus mutus |
| Snowy owl | Ukpik | Nyctea scandiaca |
| Birds' eggs | Mannik | |
| *Fish | Iqaluk | |
| Arctic char | Iqalukpik | Salvelinus alpinus |
| Whitefish | | |
| Arctic cisco | Qaaktaq | Coregonus autumnalis |
| Least cisco | Iqalusaaq | Coregonus sardinella |
| Broad whitefish | Aanaakłiq | Coregonus nasus |
| Round whitefish | Savigunaq | Prosopium cylindraceum |
| Ling cod (burbot) | Tittaaliq | Lota lota |
| Grayling | Sulukpaugaq | Thymallus arcticus |
| Chum salmon | Iqalugruaq | Oncorhyncus keta |
| Pink salmon | Amaqtuq | Oncorhyncus gorbuscha |
| Arctic flounder | Nataaġnaq | Liopsetta glacialis |
| Fourhorned sculpin | Kanayuq | Myoxocephalus quadricornis |
| Lake trout | Iqaluakpak | Salvelinus namaycush |
| Pike | Paiġłuk | (not positively identified) |
| Arctic cod ("tomcod") | Uugaq | Boreogadus saida |
| Rainbow smelt | Iłhuagniq | Osmerus mordax |
| Blackfish ("old man fish") | Aŋayuqaksrauraq | Dallia pectoralis |
| *Edible plants | | |
| Blueberry | Asiaq | Vaccinium uliginosum |
| Cloudberry | Aqpik | Rubus chamaemorus |
| Cranberry | Kimmiŋñaq | Vaccinium vitis-idaea |
| Wild potato | Masu | Hedysarum alpinum |
| Wild rhubarb | Quŋulliq | Oxyria digyna |
| Willow leaves | Akutuq | Salix sp. |
| *Fuel/structural material | | |
| Driftwood | Qiruk | |
| Brush, willow | Uqpik | |
| Sod | Ivruq | |
| Coal | Aluaq | |

*Resource categories identified by Pederson et al. (1985)

Fish, caribou, Dall sheep, and whales are the most important subsistence species, based on an estimated percent of meat harvested (circa 1962-1982), percent household use (circa 1923-1983), and relative use (1977-1982) (Table 7). Migratory birds are also hunted, but relatively few seals are taken today now that snowmachines have replaced dog teams (Jacobson and Wentworth 1982).

Pedersen et al. (1985) found most Kaktovik households relied on a wide variety of resources. The average of 12.4 resource categories were utilized per household, 13 of 15 resource categories were used by more than 50% of the households, and fish, caribou, birds, and sheep were used by 95-100% of interviewed households between 1923-1983 (Table 7).

Table 7. Relative importance of biotic resources used by Kaktovik residents.

| Resource category | Estimated contribution to total harvest (1962-1982)[a] % | rank | Household use (n=21) (1923-1983)[b] % | rank | Relative use (1977-1980)[c] rank[d] | Rank sum |
|---|---|---|---|---|---|---|
| Fish | 21.7 | 2 | 100 | 1 | 1 | 4 |
| Caribou | 16.2 | 3 | 95 | 2 | 1 | 6 |
| Dall sheep | 3.8 | 5 | 95 | 2 | 1 | 8 |
| Whales | 33.7 | 1 | 67 | 7 | 1 | 9 |
| Seals | 11.5 | 4 | 90 | 3 | 2 | 9 |
| Birds | 3.2 | 7 | 95 | 2 | 1 | 10 |
| Moose | 3.5 | 6 | 76 | 5 | 3 | 14 |
| Small game | 0.4 | 9 | 86 | 4 | 2 | 15 |
| Polar bear | 2.8 | 8 | 86 | 4 | 3 | 15 |
| Furbearers | 0.0 | 10 | 76 | 5 | 2 | 17 |
| Walrus | 3.2 | 7 | 29 | 9 | 3 | 19 |

[a] from Stoker 1983 as cited in Pedersen et al. 1985 (Table 3)
[b] from Pedersen et al. 1985 (Table 15)
[c] based on Jacobson and Wentworth 1982, U.S. Fish and Wildlife Service 1982
[d] 1=hunted or taken often; 2=hunted or taken moderately, 3=hunted or taken infrequently

The entire ANWR study area is included within the area identified by Pedersen et al. (1985) as that used from 1923-1983 by Kaktovik residents to obtain all subsistence resources (Fig. 3). But variation exists between both the size of the area used and the number of resource categories utilized by different households. The household with the least extensive use harvested 7 resource categories and covered a minimum area of about 200,000 ha, while the household with the most extensive use harvested 12 resource categories and utilized a minimum of 1.5 million ha. Household use areas overlap and there appears to be no exclusive household territories (Pedersen et al. 1985).

## Big Game

Caribou. Caribou is the staple and most preferred land mammal in Kaktovik's subsistence diet. A source of fresh meat throughout the year, which provides high levels of protein, vitamins and minerals, it is also eaten frozen and dried, and is a very important part of holiday feasts (Jacobson and Wentworth 1982). Pederson et al. (1985) found that caribou may represent 16% or more of the total village subsistence harvest, and 95% of Kaktovik households used caribou (Table 7).

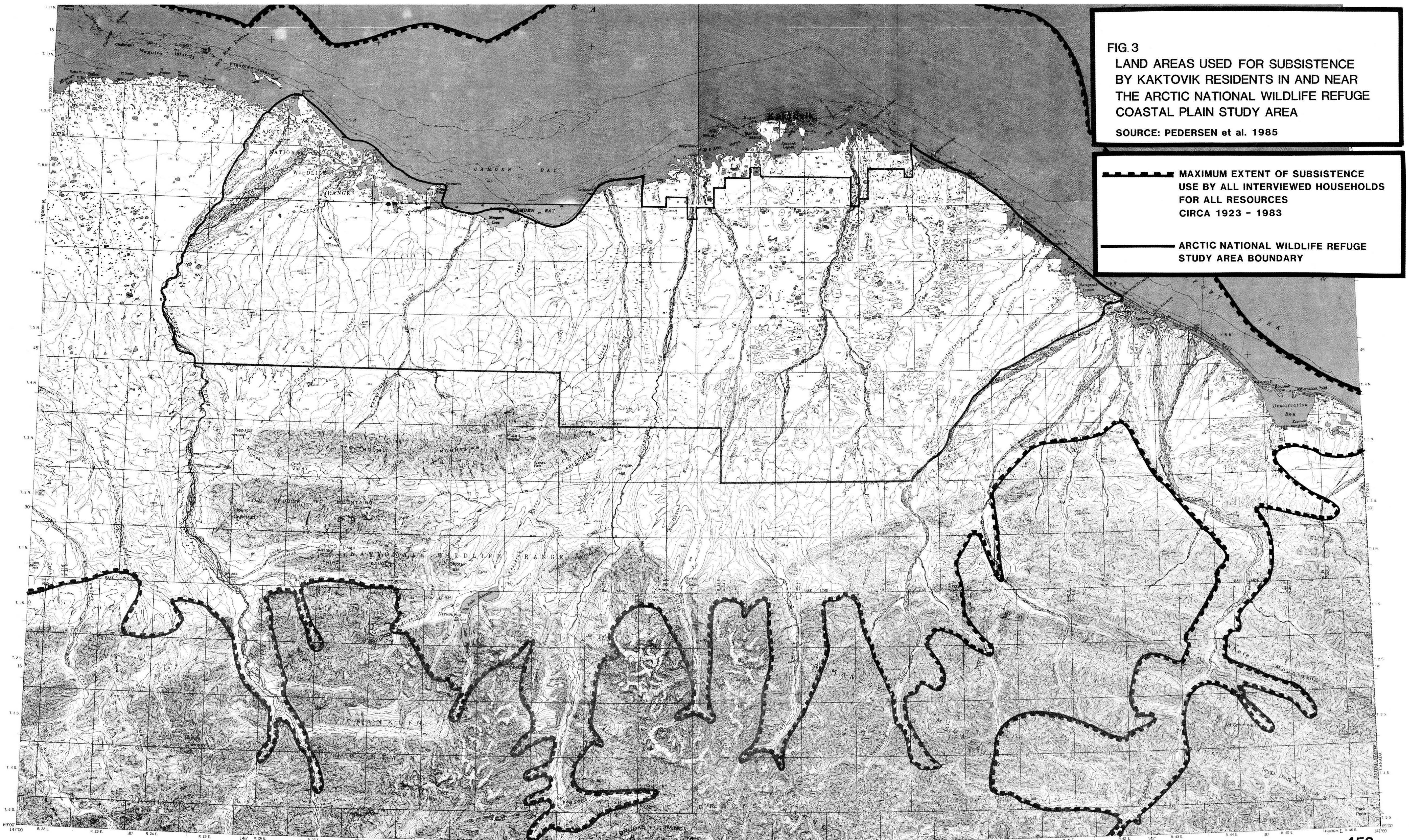
FIG. 3
LAND AREAS USED FOR SUBSISTENCE
BY KAKTOVIK RESIDENTS IN AND NEAR
THE ARCTIC NATIONAL WILDLIFE REFUGE
COASTAL PLAIN STUDY AREA
SOURCE: PEDERSEN et al. 1985
MAXIMUM EXTENT OF SUBSISTENCE
USE BY ALL INTERVIEWED HOUSEHOLDS
FOR ALL RESOURCES
CIRCA 1923 - 1983
ARCTIC NATIONAL WILDLIFE REFUGE
STUDY AREA BOUNDARY
Kaktovik
CAMDEN BAY
Flaxman Island
Demarcation Bay

Prior to the 1960's, when dog teams were the principal mode of transportation in Kaktovik, people hunted caribou for dog food. But the replacement of dog teams with snowmachines by 1972 has probably led to a decrease in the number of caribou taken per family (Jacobson and Wentworth 1982).

Kaktovik residents harvest animals from 2 caribou herds: the migratory Porcupine herd and the resident Central Arctic herd. Pedersen and Coffing (1984) estimated that half the animals taken during the regulatory years 1981-1983 were taken from each herd. Caribou from the Porcupine herd are usually available on the coastal plain from May to July when calving and post-calving movements occur. Central Arctic caribou are present between the Canning River and Hulahula River throughout the year. A detailed description of the range and movements of these 2 herds is presented in Chapter 5.

Kaktovik's caribou hunting range from the period 1923-1982 was the community's largest resource category use area and covered almost 2 million ha (Pedersen and Coffing 1984). It included the entire ANWR study area (Fig 4). Within this area, about 750,000 ha (38%) are considered to be intensively used: about 150,000 ha are used in summer when people hunt along the coast by boat, and about 60,000 ha are used in winter when people hunt inland with snowmobiles (Fig. 4). Most caribou were harvested in July-August and March-April in 1981-1984 (Pedersen and Coffing 1984).

Caribou hunting opportunities are usually greatest in summer, from early July to late August, but can fluctuate widely depending on sea ice conditions and movements of the herds. When there is open water in July, people use boats to hunt for caribou extensively along the coast. Hunters usually cannot go inland by boat, as rivers are too shallow, with the exception of the lower Canning River. Hunters are reluctant to walk more than 1-3 km inland, but commonly go ashore to scan the surrounding terrain for caribou (Jacobson and Wentworth 1982).

Jacobson and Wentworth (1982) found the coastal area directly south of Barter Island and eastward to the Jago River delta was one of Kaktovik's most intensely used summer caribou hunting areas after the ice had gone out of the lagoon. In May and June, small numbers of caribou are taken in conjunction with spring waterfowl hunting, though access may be limited due to break-up conditions and lack of snow. The mainland southwest of Barter Island along Arey Lagoon and the coastal area east of Barter Island from Tapkaurak Point to Pokok Bay is heavily used for summer caribou hunting. Griffin Point, probably the most popular campsite, is used in July, when people spend several weeks there fishing and hunting. Martin Point, Tapakaurak Spit, and Pukak (near Pokok Lagoon) are also popular places to camp. At least 1 family hunts waterfowl at Pukak each spring, and returns in July to hunt caribou. Caribou hunting extends beyond Pukak to the Kogotpak River mouth and Nuvagapak Lagoon. People may also hunt caribou at Demarcation Bay. West of Barter Island, Anderson Point, Collinson Point, and Sanniqsaaluk (near Kajutakrok Creek) are used as bases for caribou hunting in July and August. Although the entire coast is used, the area from Nataroarok Creek to the eastern shore of Camden Bay is very important (Jacobson and Wentworth 1982).

Jacobson and Wentworth (1982) found that winter caribou hunting can begin in late October, after enough snow has accumulated, and Kaktovik Lagoon has frozen, although a few people may take snowmobiles over to the mainland by boat. Hunting effort decreases during the dark months of November through

February, but increase in March and April, as daylight and temperatures increase (Jacobson and Wentworth 1982, Pedersen et al. 1985). Most winter caribou hunting occurs in the mountains along river valleys, but people occasionally hunt caribou on the coastal plain, at locations like Konganevik Point. The Hulahula River's Second Fish Hole is one of the most intensely used areas as a base for winter caribou hunting, according to Jacobson and Wentworth (1982). From here, many people hunt downriver to First Fish Hole, upriver to Kolotuk Creek, and south to Katak Creek, Karen Creek, Kekiktuk River, along the north side of Lake Schrader, west to the upper Sadlerochit River and Fire Creek, and north to the southern slopes of the Sadlerochit Mountains. Hunters often camp along the Sadlerochit River. Other winter caribou hunting areas identified by Jacobson and Wentworth (1982) are the southern Okpilak River drainage and the Okpirourak Creek drainage. These areas may be approached directly from Barter Island along the Okpilak River or from Second Fish Hole on the Hulahula River. The foothill area from Kingak Hill near the Hulahula to the Okpilak and Okpirourak drainages is another important winter caribou hunting area (Jacobson and Wentworth 1982).

Yearly harvest of caribou varies considerably, due to changes in availability of animals, access conditions, harvest opportunities for other species, and competing interests and opportunities not related to hunting. For example, in 1981, the Porcupine caribou herd moved east of Barter Island into the Yukon Territory after calving and were unavailable to Kaktovik hunters. Only 43 caribou were harvested that regulatory year. During the 1982-1983 season, when caribou were numerous along the coast and several hundred came onto Barter Island, 110 were taken (Pedersen and Coffing 1984).

Estimates of caribou harvested by Kaktovik residents from 1972-1980 ranged from a high of 300 animals in 1972-1973 to a low of 40 animals in 1978-1979 (Table 8). Numbers of caribou taken by Kaktovik residents from 1981-1984 were recorded by Coffing and Pedersen (1985) and ranged from 43 to 110, with a 3 year average of 85 animals (Table 8).

Table 8. Estimated numbers of caribou taken by Kaktovik residents between July 1972 and July 1984 (sources: Pedersen and Coffing 1984, Fig. 11; Coffing and Pedersen 1985, Table 5).

| Regulatory year | Estimated harvest | Source |
|---|---|---|
| 1972-1973 | 300 | LeResche 1974 |
| 1973-1974 | 100 | Reynolds 1976 |
| 1974-1975 | 100-200 | Reynolds 1977 |
| 1975-1977 | 100-300 | Reynolds 1978 |
| 1977-1978 | 100 | Whitten 1980 |
| 1978-1979 | 90 | Jacobson and Wentworth 1982 |
| 1979-1980 | 80 | Jacobson and Wentworth 1982 |
| 1980-1981 | 70-80 | Pedersen and Caulfield 1981a |
| 1981-1982 | 43 | Coffing and Pedersen 1985 |
| 1982-1983 | 110 | Coffing and Pedersen 1985 |
| 1983-1984 | 102 | Coffing and Pedersen 1985 |

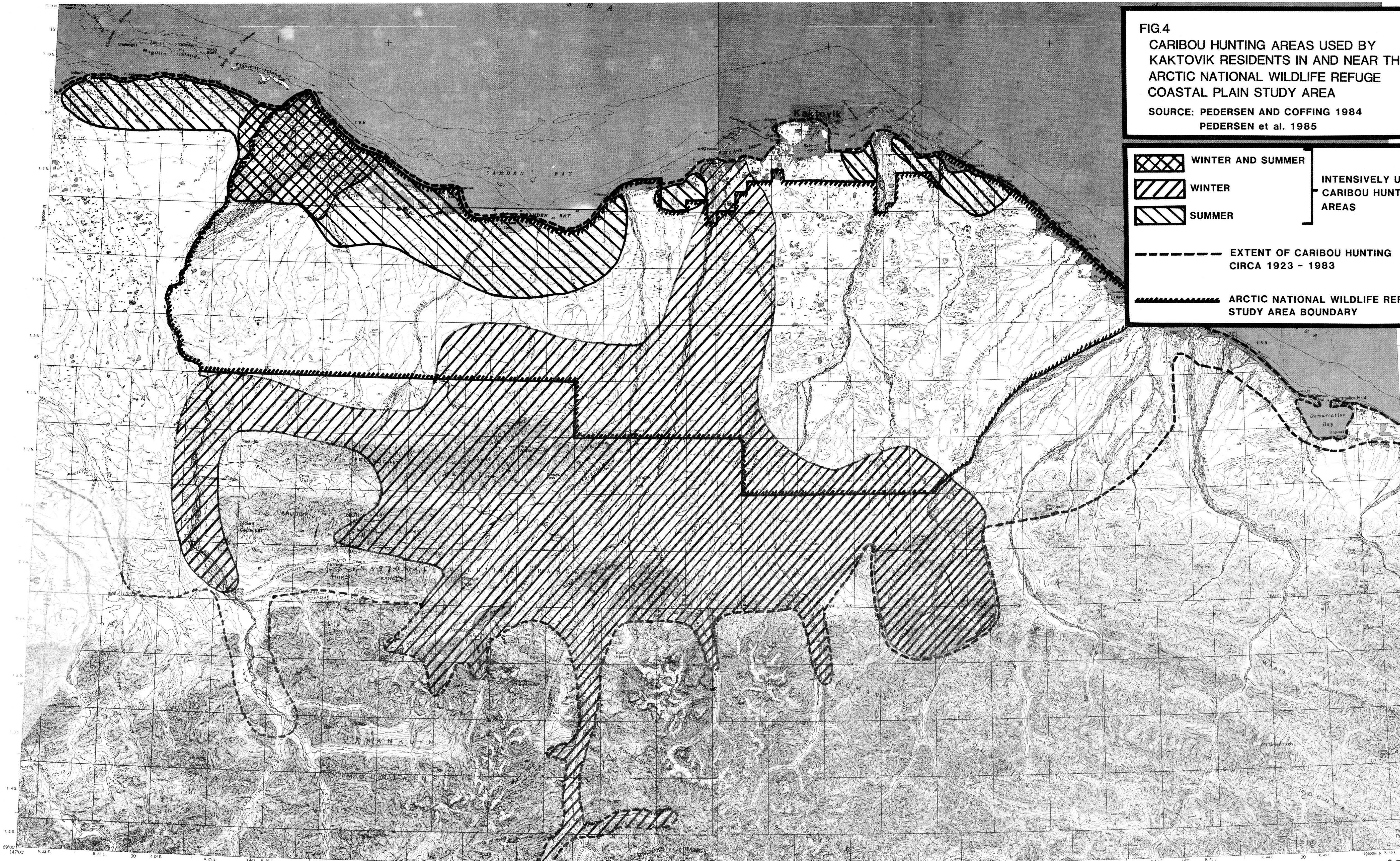
FIG.4
CARIBOU HUNTING AREAS USED BY KAKTOVIK RESIDENTS IN AND NEAR THE ARCTIC NATIONAL WILDLIFE REFUGE COASTAL PLAIN STUDY AREA
SOURCE: PEDERSEN AND COFFING 1984
PEDERSEN et al. 1985
WINTER AND SUMMER
WINTER
SUMMER
INTENSIVELY USED CARIBOU HUNTING AREAS
EXTENT OF CARIBOU HUNTING CIRCA 1923 - 1983
ARCTIC NATIONAL WILDLIFE REFUGE STUDY AREA BOUNDARY
Kaktovik
CAMDEN BAY
Demarcation Bay

Jacobson and Wentworth (1982) found that during the summer hunting season, hunters tend to select bull caribou over cows because bulls are larger and fat this time of year. By early winter, cows are preferred. Coffing and Pedersen (1985) found that bulls comprised 74% of the harvest in 1981-1983.

Although the coastal (predominately summer) hunting area was considerably smaller than the inland (winter) area (Fig. 4), it provides a significantly larger harvest (Table 9). For the years 1981-1983, over 3 times as many caribou were taken at coastal sites as inland sites (Coffing and Pedersen 1985).

Table 9. Numbers and proportions of caribou taken from coastal and inland sites by Kaktovik residents from July 1981-July 1984 (source: Coffing and Pederson 1985).

| Regulatory year | Coastal sites | Inland sites | Unknown sites | Total |
|---|---|---|---|---|
| 1981-1982 | 22 (51%) | 15 (35%) | 6 (14%) | 43 |
| 1982-1983 | 86 (78%) | 24 (22%) | 0 ( 0%) | 110 |
| 1983-1984 | 80 (78%) | 22 (22%) | 0 ( 0%) | 102 |
| 3 year average | 63 (74%) | 20 (24%) | 2 ( 2%) | 85 |

Pedersen and Coffing (1984) found that nearly all of the coastal area designated as high yield for caribou hunting during the 3 years of their study were within the ANWR study area (Fig. 4). This coastal area provided 74% of the caribou harvested by Kaktovik residents from 1981-1984 (Table 9).

Dall sheep. Jacobson and Wentworth (1982) found that Kaktovik residents hunt Dall sheep from mid-October until mid-December. Prior to 1978, legal hunting season for sheep was from early August to early September. Because animals were not accessible to Kaktovik hunters at this time, a special Dall sheep hunting season was created to meet local subsistence needs. Some sheep hunting also occurs from January to March, when people are short of meat, but the sheep are thinner and not as good at this time of year (Jacobson and Wentworth 1982).

Approximately 300,000 ha in the Brook Range between the Sadlerochit and the Kongakut Rivers were used for sheep hunting from 1923-1983 (Pedersen et al. 1985). With the exception of the northeastern corner of the Sadlerochit mountains, no sheep hunting areas are within the ANWR study area (Fig. 5). Jacobson and Wentworth (1982) found the most intensely used sheep hunting area is the upper Hulahula River and its tributaries, from the entrance to the mountains near Second Fish Hole to the headwaters. Third Fish Hole (Katak) and Kanich (headwaters of the Hulahula) are also major sheep hunting areas. A nearby stream is known locally as "200 Sheep Creek." In the early part of the century, 2 families of Eskimo sheep hunters lived on the Hulahula River according to Anderson (1919, as cited by Jacobson and Wentworth 1982). One Eskimo killed about 70 sheep from June 1908 to May 1909. Jacobson and

Wentworth reported that Kaktovik people also hunt sheep in the Sadlerochit mountains, as well as the upper Sadlerochit River, along creeks on the eastern side of the Shublik Mountains and Third Range, and in the Whistler Creek area at Neruokpuk (Peters and Schrader) Lakes. During recent years, hunting has increased in the upper Okpilak River near Okpilak Lake, on the Jago River near Marie Mountain, and on the Aichilik River near the first fish hole (Jacobson and Wentworth 1982).

In the late 1800's and early 1900's, the Kongakut River was important for sheep hunting, not only for local Inupiat, but also for overwintering commercial whalers at Herschel Island. Sheep numbers were apparently low into the 1930's, possibly due to overharvesting associated with commercial whaling, but by the late 1930's and early 1940's, sheep were common along the Kongakut River (Jacobson and Wentworth 1982). Anderson (1919, as cited in Jacobson and Wentworth 1982) felt that Dall sheep were not heavily hunted in the mountains of northeast Alaska until whaling ships began to winter at Herschel Island in 1889.

The number of sheep taken by Kaktovik hunters varies from a few to as many as 50 per year. From 1977 through 1979 the average take was about 36 animals (Jacobson and Wentworth 1982). From 1962-1982 the estimated annual harvest contributed an estimated 3.8% to the community meat harvest (Table 7). Of households interviewed, 95% harvested sheep (Table 7) sometime between 1923 and 1983 (Pedersen et al. 1985). Jacobson and Wentworth (1982) found that during 1977-1980 most sheep were taken by 4 families, who shared the meat with the rest of the village. Harvest depends upon the availability of other food sources, snow cover, weather, and travelling conditions in the mountains (Jacobson and Wentworth 1982).

The sheep harvest is a mixture of ewes and rams. Large rams are the largest and the fattest animals, but are often difficult to hunt. Unlike caribou, rams taste good even in the rut. All of the sheep meat is eaten, including parts of the intestines, feet, and head (Jacobson and Wentworth 1982). Sheep meat and sheep soup are a very important part of the communal feasts at Thanksgiving and Christmas. Sheep horns are sometimes used to make jewelry, fishing lures, and other items (Jacobson and Wentworth 1982).

Moose. People in the village of Kaktovik usually take 1 or 2 moose per year on an opportunistic basis, according to Jacobson and Wentworth (1982). Pedersen et al. (1985) estimated an average of 5 moose were taken each year between 1962-1982, which contributed 3.5% to the community meat harvest (Table 7). Of Kaktovik households interviewed, 76% harvested moose between 1923 and 1983 (Table 7). Moose were most often taken in the Sadlerochit Valley, and in the foothills along Old Man Creek, the Okpilak River, and the Okpirourak River, and were more commonly seen along the Sadlerochit River than along the Hulahula River. Moose often congregate in the Ignek, Ikiakpaurak and Ikiakpuk Valleys, and along the Canning River, where Kaktovik people sometimes make hunting trips in the spring. Moose occasionally are taken along the Kavik River and in the foothills near its headwaters (Jacobson and Wentworth 1982). Moose hunting areas used between 1923-1983 (Pedersen et al. 1985) which are within or near the ANWR study area include portions of the upper Katakturuk, Sadlerochit, Hulahula, Okpilak, and Jago Rivers.

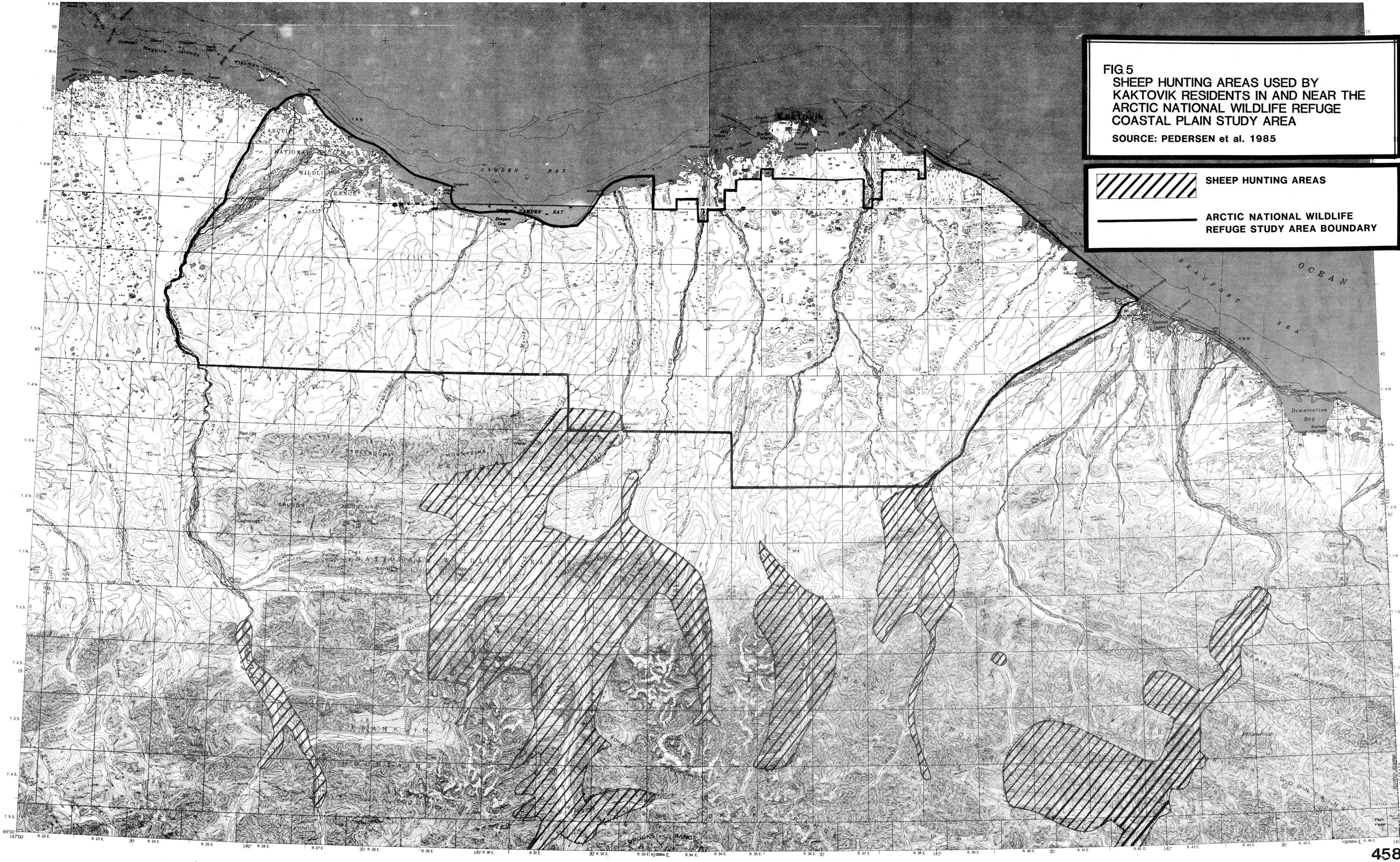


FIG. 5
SHEEP HUNTING AREAS USED BY KAKTOVIK RESIDENTS IN AND NEAR THE ARCTIC NATIONAL WILDLIFE REFUGE COASTAL PLAIN STUDY AREA
SOURCE: PEDERSEN et al. 1985

Moose are relatively recent arrivals to the north slope, but populations apparently are increasing. One middle-aged hunter, who actively hunted caribou, sheep, seal, and other animals all his life, shot his first moose in the fall of 1980 in the foothills near Okpirourak Creek. Most people prefer caribou to moose, and a few do not like moose (Jacobson and Wentworth 1982).

Brown bear. Kaktovik people occasionally take brown/grizzly bears opportunistically. Historically, neither Eskimos nor Indians made any special effort to hunt brown bears (Anderson 1919, as cited in Jacobson and Wentworth 1982). In recent years the village has taken about 2 bears per year (Jacobson and Wentworth 1982). Brown bears killed by Kaktovik hunters are generally taken inland during April or early May, but also occasionally during July, when bears are seen close to the coast (Jacobson and Wentworth 1982). Approximately 52% of the households reported having taken brown bears from 1923 to 1983, but brown bears were not listed as a frequently harvested resource (Pedersen et al. 1985). According to Jacobson and Wentworth (1982), people in Kaktovik think the Sadlerochit River drainage has many brown bears. One bear was taken near the Neruokpuk Lakes in May 1978, and another atop 1 of the hills near the Kekiktuk River in late April 1979. A present-day Kaktovik resident killed a brown bear in the Kongakut River valley in the early 1940's, and used the skin for a tent door, as did Eskimos during the early part of the century (Anderson 1919, as cited in Jacobson and Wentworth 1982). In 1975 or 1976, 3 nuisance bears were shot at a summer camp at Manning Point. In April 1980, a brown bear was shot at Second Fish Hole on the Hulahula River after it emerged from a vacant tent and chased a woman. In late July 1981, a brown bear tore up a new tent left at a Canning River delta camp (Jacobson and Wentworth 1982). Brown bear hunting areas used in 1923-1983 (Pedersen et al. 1985) which are within the ANWR study area include the area between the Sadlerochit River and the Jago River, and near the coast as far east as Pokok Lagoon.

Furbearers

Winter months are important for trapping and hunting furbearers. Some people go to the mountains to hunt or trap wolves, wolverines, and red and cross fox, while others concentrate on arctic fox on the coastal plain (Jacobson and Wentworth 1982). Pedersen (et al. 1985) found that during the period 1923-1985, up to 57% of the Kaktovik households hunted furbearers, and 76% of the households trapped furbearers (Table 7). The size of the area used in pursuit of furbearers in 1923-1983 (Pedersen et al. 1985) was second only to caribou hunting. Trapping areas extend across almost 900,000 ha, and cover more than half the ANWR study area along the Canning and Katakturuk Rivers, and between the Sadlerochit and Aichilik Rivers. Hunting areas include more than 1.5 million ha, and encompass the entire ANWR study area.

Furs are used locally in making parkas and ruffs, or are sold to the village corporation or directly to a fur buyer. Furs, particularly fur ruffs, are important components of arctic clothing.

Arctic fox. The arctic or white fox is trapped mainly along the coast and on the coastal plain, on Barter Island, and on the barrier islands, lagoon ice, and coastal area between the Sadlerochit River and Griffin Point. Skins are prime with dense white fur by November and December, but by late March or early April the hair usually begins to loosen. Traplines are usually within 16 - 24 km of the coast, but arctic foxes are sometimes taken further inland. Arctic foxes have been taken at First Fish Hole and in the Sadlerochit Valley, and have been seen as far inland as Kanich, at the headwaters of the Hulahula River (Jacobson and Wentworth 1982). Many present day Kaktovik people formerly trapped arctic fox all along the coast, from Beechy Point to the Canadian border.

The arctic fox population fluctuates widely from year to year. During the winters of 1976-1977, 1979-1980, and 1980-1981, more than 100 fox were trapped each year, but only 2 were taken in 1977-1979. During 4 trapping seasons (1978-1982), a Kaktovik woman was the most successful arctic fox trapper, taking between 35 and 50 foxes each year in the Barter Island vicinity (Jacobson and Wentworth 1982).

Arctic foxes are frequent carriers of rabies. In 1976, nearly every dog at Barter Island was destroyed after contracting rabies from an arctic fox, and an entire family had to undergo rabies vaccinations (Jacobson and Wentworth 1982).

Red fox and cross fox. Red foxes and cross foxes (a color phase of the same species) are trapped primarily in the mountains, but are caught occasionally on the coastal plain, according to Jacobson and Wentworth (1982). The Hulahula drainage from Kingak Hill to Kanich, Old Man Creek drainage, and the entire lowland area between the Hulahula and Sadlerochit Rivers, including the area around Neruokpuk Lakes, are reported to be good for fox trapping. One trapper got 5 red foxes along the Jago River in the vicinity of Marie Mountain in March 1978. Formerly, red foxes were taken inland on the Kongakut River, near Pungautilik tributary and along the Canning River (Jacobson and Wentworth 1982). Only 1 or 2 dozen red foxes are taken each year. Most red fox trappers are men, but a woman was regarded as the most skillful in Kaktovik at setting fox traps (Jacobson and Wentworth 1982).

Wolf and wolverine. Most wolves and wolverines are trapped or shot in the foothills of the Brooks Range along the Hulahula, Sadlerochit, Okpilak, and Canning Rivers. The primary hunting area is between the Hulahula and Sadlerochit Rivers, from Sadlerochit Springs to Kikiktat Mountain and the Neruokpuk Lakes, where terrain is characterized by gentle slopes and open country with good visibility and good access by snow machines. Wolves are also encountered in the upper Hulahula River area during fall sheep hunts. Occasionally a wolf has been trapped along the coast (Jacobson and Wentworth 1982).

At least 17 wolves and 14 wolverines were taken by Kaktovik residents from 1978 to 1985 (Table 10). Two village men are the most active in pursuing wolves and wolverines, but other men and women also hunt and trap them (Jacobson and Wentworth 1982).

Table 10. Known harvest of wolverines and wolves by Kaktovik residents, 1978-1985.

| Winter | Number of wolves | Number of wolverines | Source |
|---|---|---|---|
| 1978-1979 | 2 | 6 | Jacobson and Wentworth (1982) |
| 1980-1981 | 5 | 7 | Jacobson and Wentworth (1982) |
| 1983-1984 | 7 | 1 | G. Weiler, ANWR, FWS (pers. comm.) |
| 1984-1985 | 3 | 0 | G. Weiler, ANWR, FWS (pers. comm.) |
| Total | 17 | 14 | |

Other furbearers. Although rare, mink (Itigiaqpak) have been seen on the north side of the Brooks Range, especially during recent years. Mink were trapped at Second Fish Hole on the Hulahula River during the winters of 1977-1979 and were seen at the Aichilik River in the area of Second Fish Hole (Jacobson and Wentworth 1982). Anderson (1919, as cited in Jacobson and Wentworth 1982)) reported seeing mink tracks in 1908 on the Hulahula near Second Fish Hole, and a long-time Kaktovik resident captured a mink at Demarcation Point in the 1940's.

Jacobson and Wentworth (1982) reported that weasels (Itigiaq) are trapped in the Hulahula and Sadlerochit River areas incidental to other species. A few river otters (Pamiuqtuuq) were seen in the upper Hulahula River during fall 1977, and tracks have been observed along the Canning River. Porcupine (Qinagluk) are sometimes seen in the upper portion of the Hulahula River. Lynx (Niutuiyiq) have been seen on the Hulahula River between First and Second Fish Holes, and along the coastline in the summer.

Small mammals

Small mammal hunting areas used in 1923-1983 (Pedersen et al. 1985) encompass the entire ANWR study area except for small areas between the Jago and Okerokovik Rivers and between the Sikrilurak and Aichilik Rivers.

Arctic ground squirrel. Arctic ground squirrels are available for hunting from March and April until October. Traps, .22 caliber rifles, and sometimes snares are used for taking squirrels. Squirrels are eaten, and the skins are used for garment trim and parkas (Jacobson and Wentworth 1982). Hunting is best along the banks and sandy mounds of the major rivers, especially the Jago, Okpilak, Hulahula, and Sadlerochit according to Jacobson and Wentworth (1982). Two areas intensely used by the people of Kaktovik are the Jago River delta and the Hulahula-Okpilak River delta, from the coast to several miles upstream. People also hunt along the entire drainages of the Jago and Okpilak Rivers, and the Sadlerochit River up to 16 km north of Sadlerochit Springs around Neruokpuk Lakes, and south of Okiotok Peak. Ground squirrels are hunted along the Hulahula especially in the vicinities of First and Second Fish Hole, near the mouths of Marsh and Carter (Iqalugliurak) Creeks, from Camden Bay to 6-8 km inland and on the Canning River near Ignek and Nanook Creeks and the delta. East of the Jago River, Kaktovik people hunt squirrels along the Niguanak and Sikrelurak River drainages, including the

Niguanak Hills, and occasionally along the Aichilik and Egaksrak Rivers. Formerly squirrels were hunted on the Kongakut River, especially near the big bend south of VABM "Dar" (Jacobson and Wentworth 1982).

Alaska marmot. Two or 3 Kaktovik families hunt for marmots each spring, on the edge of the mountains between Itkilyariak Creek and the Sadlerochit Springs. In the spring of 1977, about 10 marmots were taken in this area. Marmots also occur in some of the rocky areas at Neruokpuk Lakes. They emerge from winter dens later in May than ground squirrels (Jacobson and Wentworth 1982).

Marine Mammals

Bowhead whale. Bowhead whales are the principal marine mammal hunted by Kaktovik residents. Whaling occurs from late August until early October during the westward migration of bowheads off the Beaufort seacoast. Whales are not hunted in spring in Kaktovik because the open leads are too far from shore. Whale hunting is generally done within 16 km of land, but may occur as much as 32 km offshore (Jacobson and Wentworth 1982). Whaling began in Kaktovik in 1964. Between 0 and 5 whales per year ($\bar{X}$ = 1.8) were taken by Kaktovik residents from 1964-1985 (Table 11).

Jacobson and Wentworth (1982) reported that over the past few years, as many as 8 whaling crews with about 5 people each have participated in the hunt. The crews use small (4-7 m) outboard-powered boats, and communicate with each other by citizen band radio. After a crew has struck a whale, the other crews help kill and land it. In the whaling seasons of 1979 and 1980, hunters from the village of Nuiqsut joined Kaktovik whalers because of unfavorable conditions in their own area (Jacobson and Wentworth 1982).

Crews normally hunt as far west as Anderson Point at Camden Bay and as far east as Griffin Point, and may occasionally go as far east as Humphrey Point (Jacobson and Wentworth 1982). The community whaling area identified by Pedersen et al. (1985) includes over 420,000 ha along the coast from Camden Bay to the Kogopak River (Fig 6).

The earliest date that Kaktovik hunters have seen a whale is 21 August. Whale sightings vary from day to day, from none to 15 or 20. Large females and calves are seen during the last stage of migration (Jacobson and Wentworth 1982).

Whale meat (including that from beluga whales) was estimated to be about one third of the total meat harvest (Table 7) in 1962-1982 (Pedersen et al. 1985). Meat and maktak is divided among the captain, crews, and the rest of the village. The captain saves the portion from the navel to the tail for distribution at Thanksgiving, Christmas, and Nalukatuq feasts. One portion goes to the Presbyterian church in Fairbanks, and some families send part of their shares to relatives in Anaktuvuk Pass, Barrow, Inuvik, or other

Table 11. Whales taken by the village of Kaktovik between 1964 and 1985 (source: Jacobson and Wentworth 1982, Table 7).

| Number of crews | Number taken | Year | Approximate length of whale | Sex | Approximate location |
|---|---|---|---|---|---|
| -- | 2 | 1964 | ---- | - | 1.6 km NW Bernard Spit and 1 found dead off Humphrey Pt. |
| -- | 3 | 1973 | 9.1-12.2 m | - | One 1.6 km N Bernard Spit. 2 between Jago Spit and Griffin Point. |
| | | 1974[a] | | | |
| 2 | 2 | 10-24 Sept | ---- | - | ------- |
| 2 | 0 | 1975[b] | ---- | - | ------- |
| 7 | 2 | 1976[c] | | | |
| | | 20 Sept | 13.7 m | M | 3.2 km NE Jago Spit. |
| | | 27 Sept | 9.1 m | -- | Barter Island's Arey Spit, N of Iglukpaluk. |
| 5 | 2 | 1977[d] | | | |
| | | 28 Sept | 16.8 m | M | 3-7 km N Barter Island. |
| | | 1 Oct | 9.1 m | F | 3-7 km N Barter Island. |
| 5 | 2 | 1978[e] | | | |
| | | 21 Sept | 11.1 m | M | Barter Island; washed up at Camden Bay. |
| | | 26 Sept | 13.3 m | M | 16-24 km N Griffin Pt. |
| 7 | 5 | 1979[f] | | | |
| | | 20 Sept | 12.7 m | M | 5-8 km NE Griffin Pt. |
| | | 6 Oct | 10.7 m | F | Shallow water 1 km N-NE Barter Island. |
| | | 8 Oct | 10.3 m | M | ------- |
| | | 10 Oct | 10.8 m | M | ------- |
| | | 11 Oct | 10.8 m | M | Shallow water Arey Island Pt. |
| 5 | 1 | 1980[g] | | | |
| | | 14 Sept | 9.2-10.7 m | M | Pukak. |
| 5 | 3 | 1981 | | | |
| | | 8 Sept | 17.1 m | F | 8-9 km NW Jago Spit. |
| | | 11 Sept | 14.3 m | M | N Tapkaurak Spit. |
| | | 22 Sept | 16.2 m | F | 11 km NE Jago Spit. |
| - | 1 | 1982[h] | --- | - | ------ |
| - | 1 | 1983[h] | --- | - | ------ |
| - | 1 | 1984[h] | --- | - | ------ |
| 8 | 0 | 1985[h] | --- | - | ------ |

[a] Fiscus and Marquette 1975
[b] Marquette 1976
[c] Marquette 1978
[d] Marquette 1979
[e] Braham et al. 1980
[f] Johnson et al. 1981
[g] Marquette et al. 1981
[h] B. Morris, NMFS, pers. comm.

villages. In 1981, over half of the meat and maktak went to places outside Kaktovik (Jacobson and Wentworth 1982).

Whaling is perhaps Kaktovik's most important community activity. Pedersen et al. (1985) reported 67% of households participated in harvesting whales (Table 7), but everyone in the village is involved, according to Jacobson and Wentworth (1982). Whaling emphasizes the cultural values of cooperation and sharing of resources, and passes these values to the younger generation (Jacobson and Wentworth 1982).

Beluga whale. Kaktovik people sometimes catch beluga whales, which are usually taken incidental to the hunt for bowhead whales in the fall. One family took 2 beluga whales from a school swimming near Pukak, in early August 1978. In late August or early September 1980, 6 to 20 beluga whales were taken near Barter Island, and a few belugas were also taken at Griffin Point. No beluga whales were taken by Kaktovik residents between 1981 and 1985 (I. Akootchook, pers. comm.).

Gray whale. Gray whales are observed occasionally. During the fall of 1979, a gray whale was seen close to Barter Island, but apparently no gray whales have been taken by Kaktovik whalers (Jacobson and Wentworth 1982).

Seals. Kaktovik people hunt 3 species of seal; bearded seal, ringed seal, and spotted seal, for oil, meat, and skins. Although relatively few are taken today, seal oil is eaten and is also used for storing and preserving food (Wentworth 1979, as cited by Jacobson and Wentworth 1982). Sealskins are used for boots, slippers, mitts, parka trim, and sometimes as dufflebags or purses for belongings. Bearded seal skins are used as boot soles (Jacobson and Wentworth 1982).

Most seals are hunted by boat from July to September along the coast, both inside and outside the barrier islands, up to 32 km offshore. Hunters may travel on the sea ice by snowmachine searching for seals along open leads (Jacobson and Wentworth 1982).

Pedersen et al. (1985) reported a use area of almost 600,000 ha along the entire ANWR study area coastline up to 30 km offshore, for seal hunting in 1923-1983. According to Jacobson and Wentworth (1982), the most intensely used summer seal hunting area extends from Pokok Bay on the east to Nuvugaq and Simpson Cove on the west. The Canning River delta and the Flaxman Island area are also important. Sea ice hunting extends as far east as Pokok Lagoon and as far west as Brownlow Point, with traditional spring seal hunting camps at Naalagiagvik on Arey Island, and on Tapkaurak Spit, and other coastal sites (Jacobson and Wentworth 1982).

Ringed seals and bearded seals are taken much more commonly than spotted seals. Ringed seals are most numerous and occur year around, but bearded seals are probably hunted more actively. Spotted seals are the least common and are present only during summer months. One Kaktovik resident identified 2 coastal areas (Anderson Point to the Hulahula-Okpilak delta, and Demarcation Bay to the Canadian border) as important spotted seal habitat (Jacobson and Wentworth 1982). Some residents consider spring the most important time for sealing, when days are long and the animals are lying on the ice. But ringed seals shed in May, and hides are not prime until August or September. Seals were formerly hunted for dog food. Relatively few seals are taken today

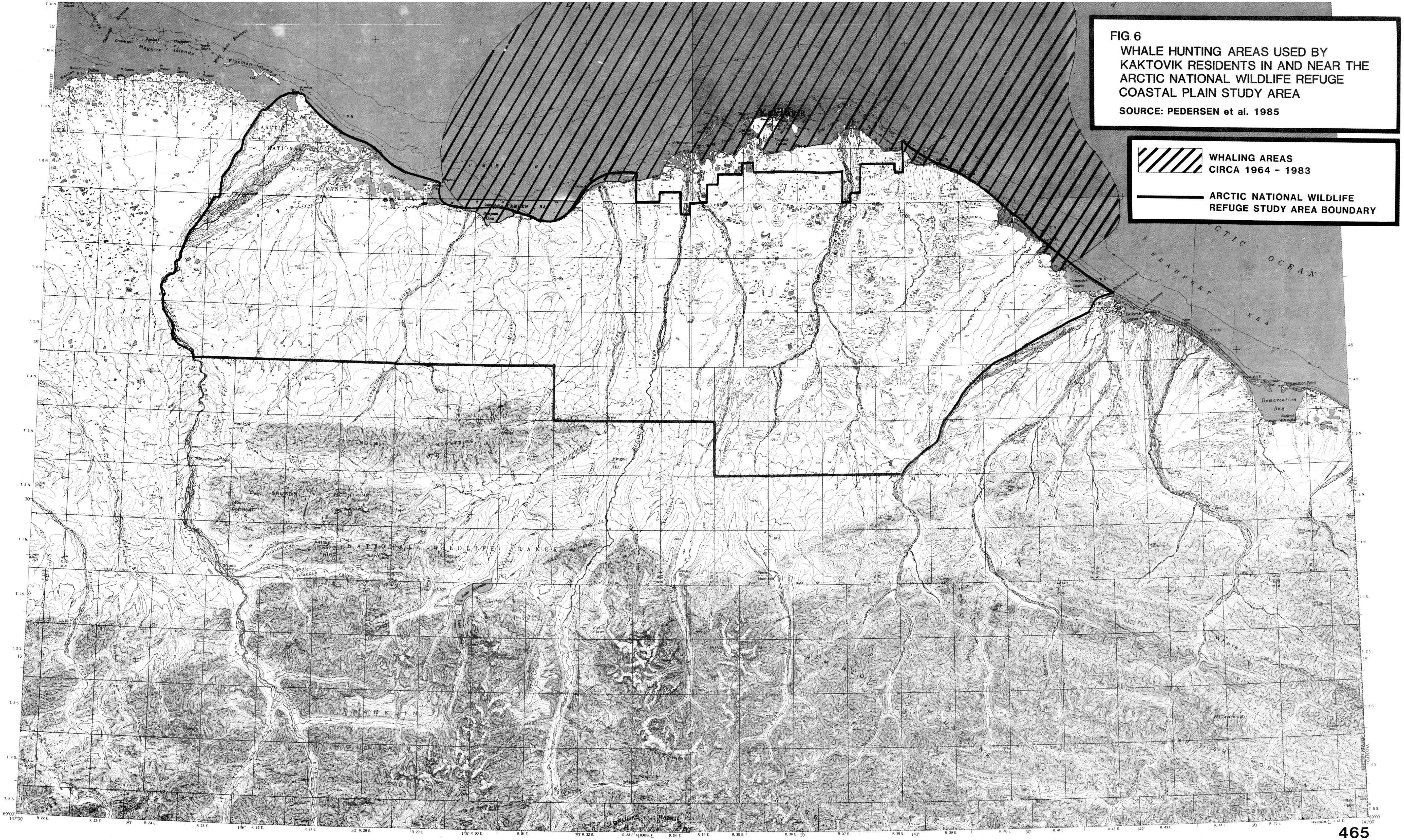


FIG. 6
WHALE HUNTING AREAS USED BY KAKTOVIK RESIDENTS IN AND NEAR THE ARCTIC NATIONAL WILDLIFE REFUGE COASTAL PLAIN STUDY AREA
SOURCE: PEDERSEN et al. 1985

because dog teams have not been commonly used in Kaktovik since the late 1960's. This lessened dependence on seals in not seen as a permanent change, as the price of fuel makes some hunters talk of going back to dog teams (Jacobson and Wentworth 1982).

Walrus. Walrus infrequently occur as far east as Kaktovik (K. Frost, ADF&G, pers. comm.). Over the past 20 years only 5 or 6 walrus have been taken by Kaktovik hunters. In the mid-1950's, the first walrus seen in several years was taken. In July 1978 a young walrus was taken 0.8 km from Barter Island, and in August 1981 a walrus was taken close to Bernard Spit. A few walrus were seen during the fall whaling season in 1975 or 1976 and 1981, but were not harvested (Jacobson and Wentworth 1982). No walrus were taken between 1981 and 1985 (I. Akootchook, pers. comm.).

Polar bear. In recent years, almost all polar bears have been taken in the vicinity of Kaktovik village, occasionally within a few m of a house (Jacobson and Wentworth 1982). In fall and the dark months of winter, polar bears can be frequent visitors to the village, attracted to the Barter Island refuse dump, or to a whale carcass on the beach, and are considered dangerous. Polar bears occasionally also appear during summer months (Jacobson and Wentworth 1982). According to Jacobson and Wentworth (1985) Kaktovik's main polar bear hunting area extends from the Hulahula-Okpilak River delta on the west, to Pokok Lagoon on the east, and bears are often pursued out on the ice up to 16 km offshore. The polar bear hunting area used in 1923-1983, identified by Pedersen et al. (1985), is about 0.6 million ha and encompasses the entire ANWR study area coast up to 35 km offshore.

Polar bear may be killed opportunistically when people are out camping or looking for other game. In 1968, a man camped at Brownlow Point shot a polar bear which approached him. In 1975, a woman shot a polar bear while her family was camped at Griffin Point. Polar bears have occasionally been seen inland several km, sometimes even in the mountains. About 1946, a village elder shot a polar bear in the mountains in Canada, and 3 men unsuccessfully chased a polar bear by dog team, up the Okpilak River several km inland (Jacobson and Wentworth 1982). In November 1977, polar bear tracks were seen along the Hulahula River, about 32 km from the coast. In April 1980, 2 Kaktovik hunters saw a polar bear sow and cub on the northeast edge of the Sadlerochit Mountains near Itkilyariak Creek.

Into the 1940's and 1950's, polar bears were hunted primarily in late April with dog teams. One man hunted bears north of Demarcation Bay, and between Angun Point and the Kongakut River delta from 5-48 km offshore. A Kaktovik woman who grew up at Flaxman Island hunted polar bears with her family on the western part of the island in the fall (Jacobson and Wentworth 1982). Leffingwell (1919, as cited in Jacobson and Wentworth 1982) reported that Eskimos in the vicinity of Flaxman Island shot perhaps a dozen polar bears each year.

Passage of the Marine Mammal Protection Act in December 1972, which made the sale of unproccessed polar bear hides to non-natives illegal, reduced the incentive for people to hunt bears actively. Hides are valuable when made into articles of clothing such as boots, pants, or coats. Polar bear mittens are important cold weather gear.

Although polar bear hunters are interested mainly in the hides, the meat is usually eaten if the bear is fat. According to village elders, "skinny bears will make you sick." Some villagers prefer not to eat polar bear meat, saying it is too rich (Jacobson and Wentworth 1982). The polar bear harvest estimated for the period 1962-1982 (Pedersen et al. 1985) provided less than 3% of the community's annual harvest (Table 7).

Polar bear harvest varies considerably from year to year (Table 12), depending on ice conditions and the number of bears attracted to the village during fall and winter. Schliebe (1985) documented a minimum polar bear harvest of 26 bears by the village of Kaktovik from 1981 to 1984 or a mean of 6.5 bears per year. Pedersen et al (1985) reported an estimated average annual harvest of 4 polar bears for the period 1962-1982. In 1971, 11 polar bears were taken by 1 family alone (Jacobson and Wentworth 1982). Of the surveyed households, 86% reported taking polar bears (Table 7) in the period 1923-1983 (Pedersen et al. 1985).

Table 12. Minimum number of polar bears harvested by Kaktovik residents, 1978-1985.

| Time period | Number of bears | Data source |
|---|---|---|
| 1977-1978 | 5[e] | Jacobson and Wentworth 1982 |
| 1978-1979 | 1[e] | Jacobson and Wentworth 1982 |
| 1980-1981 | 23 | Schliebe 1985 |
| 1981-1982 | 1 | Schliebe 1985 |
| 1982-1983 | 1 | Schliebe 1985 |
| 1983-1984 | 1 | Schliebe 1985 |
| 1984-1985 | 2 | Schliebe per. comm. |
| 1985-1986 | 3 | Schliebe per. comm. |

[e] Estimated number harvested.

## Birds

Waterfowl and ptarmigan are hunted throughout most of the ANWR study area from the Jago River to the Canning River (Fig. 7). The bird hunting area used by Kaktovik residents in 1923-1983, defined by Pedersen et al. (1985), was more than 1 million ha. The average annual contribution provided by birds was estimated to be 3.2% of the village total meat harvest in 1962-1982, but 95% of the households (Table 7) harvested birds sometime between 1923 and 1983 (Pedersen et al. 1985).

Ducks and geese. Waterfowl are hunted primarily in spring, from May through early June. Less intensive hunting continues throughout the summer and into September. Waterfowl hunting is a family activity and extended families usually camp together, for 1 to 2 weeks. According to Jacobson and Wentworth (1982), virtually the entire village goes spring waterfowl hunting.

Soup made from waterfowl is eaten in spring, and some waterfowl are stored for winter months and holiday feasts (Jacobson and Wentworth 1982). Black brant, prized for their freshness and flavor, are the principle birds sought in spring. People also hunt common eider, king eider (Qinalik), snow geese

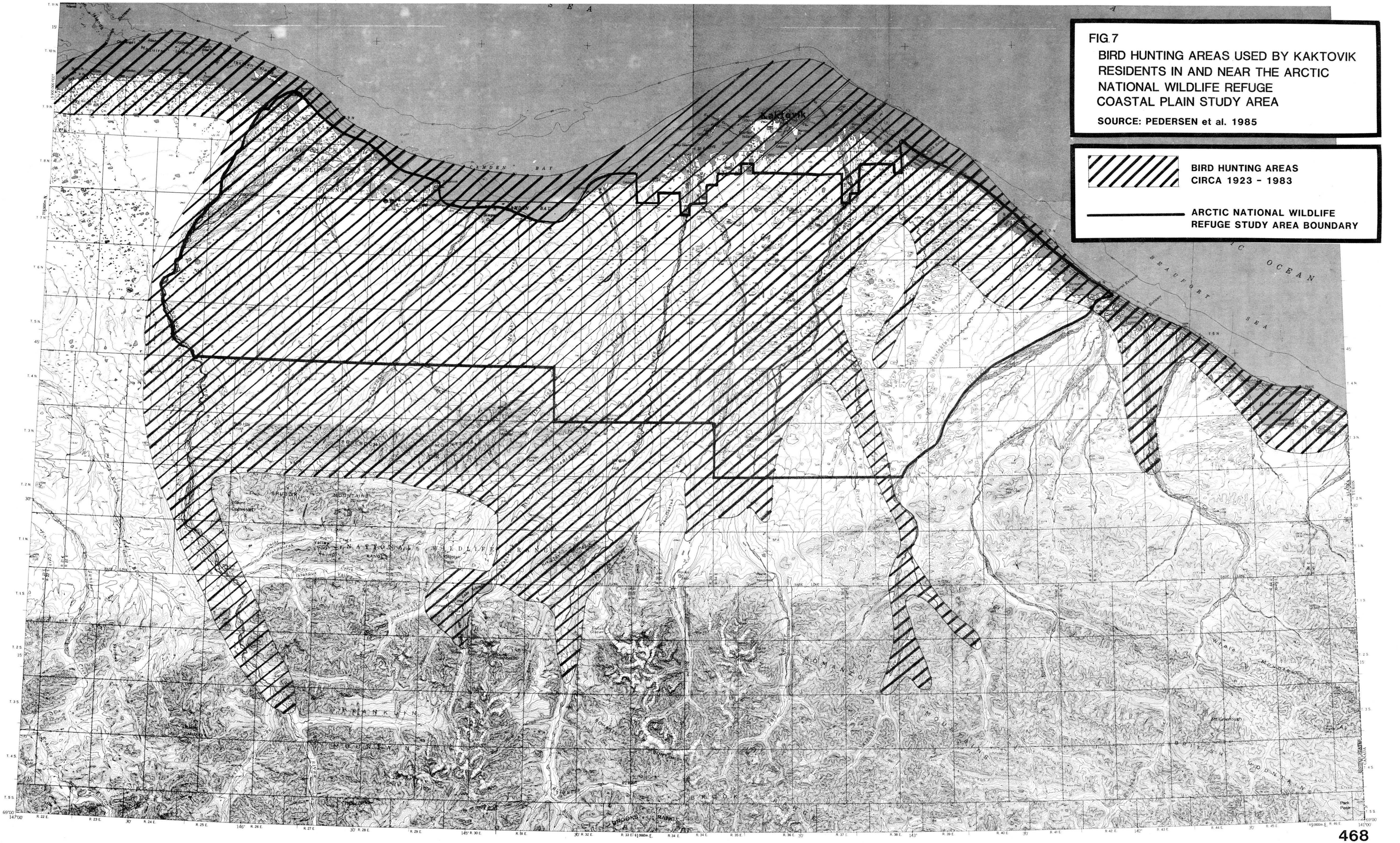


FIG.7
BIRD HUNTING AREAS USED BY KAKTOVIK RESIDENTS IN AND NEAR THE ARCTIC NATIONAL WILDLIFE REFUGE COASTAL PLAIN STUDY AREA
SOURCE: PEDERSEN et al. 1985

(Kanuq), Canada geese, pintail, and oldsquaw. Oldsquaw, the most numerous of the waterfowl, are taken more frequently than any other species, but are not actively hunted (Jacobson and Wentworth 1982).

Jacobson and Wentworth (1982) found that people may hunt ducks and geese along the entire coastline from Flaxman Island to Demarcation Bay. Travel to the more distant areas is usually by boat in July after the ice goes out, and is often in combination with fishing or caribou hunting. A popular place to hunt waterfowl in spring is Collinson Point, where people hunt in a wide area around the spit and coastline. Families also camp at Anderson Point and hunt waterfowl in nearby coastal areas. Konganevik Point and the small bay directly to the south are also good hunting sites for brant. Some people hunt waterfowl in Pokok Bay and Angun Lagoons and on the seaward side of these spits. One person hunts at Beaufort Lagoon from Angun Point to Nuvagapak Lagoon, from Siku Lagoon entrance to the eastern mouth of the Kongakut River, and from Demarcation Bay to the Canadian border. Griffin Point is another popular waterfowl hunting camp where several Kaktovik families go each year. From here, people hunt brant, snow geese, and eiders from Oruktalik Lagoon to Tapkaurak Point and around the narrow spit and coastline to Pokok Lagoon. Flaxman Island, Brownlow Point, and the point southeast are occasionally hunted, and in the fall, 1 family hunts geese in the lake system south of the Tamayariak River mouth. In recent years, the south end of Manning Point spit has been the most commonly used hunting site close to Barter Island. In 1978 and 1979, 3-6 families camped here; 1 family took 35 brant by 5 June, 1978. Naalagiagvik on Arey Island is a popular camping spot if birds pass farther out from the mainland. The lakes southwest of Barter Island are also hunted, and sometimes waterfowl hunting camps for brant and geese are set up along the banks of the Okpilak and Hulahula Rivers, south of the delta. Some people make day trips to the western or southern side of Barter Island, to Bernard Spit, or as far as the lakes south of the Jago River delta when ducks and geese are flying. Waterfowl may be hunted by boat in Arey, Kaktovik, and Jago Lagoons after the sea ice goes out. In 1978, the westward migration of black brant passed over Barter Island between 15 August and 30 August, and some birds were shot from the nearby spits (Jacobson and Wentworth 1982).

Some people collect small numbers of eider eggs and, less commonly, glaucous gull and oldsquaw eggs, each spring, usually from Arey Island or Tapkaurak Spit. Jago Spit used to have many eider duck eggs, before it eroded. The Aichilik River delta, an area not commonly hunted, is the best nesting place for black brant, according to 1 Kaktovik resident. The barrier islands west of Flaxman Island are remembered by older people as having many eider eggs (Jacobson and Wentworth 1982).

Ptarmigan. Although ptarmigan are hunted all year, most are taken in spring when villagers travel inland to the mountains. Hundreds or thousands of birds, primarily willow ptarmigan, concentrate in the willows along the rivers and streams. During spring and summer, many birds, primarily rock ptarmigan, may be taken along the coast (Jacobson and Wentworth 1982). People hunt birds with a .22 caliber rifle, or snare them. In May 1978, a Kaktovik woman caught several willow ptarmigan in snares near Sadlerochit Springs.

In former years, Kaktovik residents depended upon ptarmigan as a reliable source of food when other game was scarce. Ptarmigan feathers were also used as a household necessity for wiping greasy or wet hands. One woman hunted ptarmigan on the eastern side of Flaxman Island, at Brownlow Point, and along the Canning River from the mouth to about 8 km upriver. One Kaktovik man, who grew up at Camden Bay, captured many ptarmigan along the upper Kavik River (Jacobson and Wentworth 1982). A Canadian expedition, stranded at Collinson Point in 1914, survived on ptarmigan which were secured within 24 km of their camp (Leffingwell 1919, as cited by Jacobson and Wentworth 1982).

According to Jacobson and Wentworth (1982), Carter Creek and Marsh Creek, inland for 8 to 16 km, are good areas for hunting ptarmigan. Many ptarmigan are also taken just east of Barter Island at Manning Point. Ptarmigan are hunted on the Sadlerochit River from about 8 km north of Sadlerochit Spring to Fire Creek, on the tributaries of the Sadlerochit, such as Last Creek and Arctic Creek, and on the Kekiktuk River and its tributaries, including Karen Creek. The Canning River is hunted less commonly but is well known as an excellent area for ptarmigan, especially upriver from Ignek Creek. Frequently, a ptarmigan is the first wildlife species a child learns to shoot, when families travel in spring time and teach their children to hunt (Jacobson and Wentworth 1982).

Fish

Many species of fish inhabiting the Beaufort Sea and inland rivers and lakes are taken for subsistence. Fishing was the only harvest activity reported by Pedersen et al. (1985) in which all households where involved between 1923-1983 (Table 7). Pedersen et al. (1985) estimated that fish provided about 20% of the village's subsistence harvest during 1962-1982 (Table 7). Kaktovik's fishing area, delineated by Pederson et al. (1985), lies along the coast from Foggy Island Bay to the Kongakut River delta and Demarcation Bay, and extends up the Canning River and portions of the Katakturuk, Sadlerochit, Okpilak, and Aichilik Rivers in or near the ANWR study area (Fig. 8).

People usually catch fish with gill nets, although rods and reels are sometimes used near the village and at the fish camps. In 1985, 8 families from Kaktovik used 1 to 3 gill nets during the open water season. Although total fishing effort or catch was not determined, the estimated catch per family probably ranged from 300 to 1000 fish, including two-thirds char and one-third Arctic cisco (Envirosphere Co. 1986). Jacobson and Wentworth (1982) found summer fishing activity in July, August, and September was most concentrated off the coast and around the spits of Barter Island, on Bernard spit, and on Arey Island, but included areas from Foggy Island to Demarcation Point. People camp near fishing sites at Iglukpaluk on Barter Island, or on Arey Island, or check nets each day by boat. Griffin Point is another popular summer fishing camp where people may dry large quantities of fish for winter use. From here they fish in Tapkaurak Lagoon, Oruktalik Lagoon, Pokok Lagoon, and on either side of the long and narrow barrier islands which form Angun Lagoon (Jacobson and Wentworth 1982).

Collinson Point spit in Camden Bay, the eastern part of Camden Bay near Anderson Point, and Carter Creek are also good fishing sites (Jacobson and Wentworth 1982). The Inupiaq name for Carter Creek is Iqalugliurak, which means "little river with lots of fish." The best time for netting these fish is in June, after the river opens up (North Slope Borough 1980, as cited in Jacobson and Wentworth 1982). During summer and early fall, the Canning River delta is an important fishing area, particularly the main channel near the mouth to about 16 to 24 km upriver. The larger lakes to the east of the Tamayariak River (between VABM "Walker" and VABM "Noon") are too shallow for


FIG. 8
FISHING AREAS USED BY KAKTOVIK RESIDENTS IN AND NEAR THE ARCTIC NATIONAL WILDLIFE REFUGE COASTAL PLAIN STUDY AREA
SOURCE: PEDERSEN et al. 1985
FISHING AREAS CIRCA 1923 - 1983
ARCTIC NATIONAL WILDLIFE REFUGE STUDY AREA BOUNDARY
CAMDEN BAY
Demarcation Bay

fishing. Brownlow Point at the northern tip of the Canning River delta and the coast to the southeast are other important fishing and camping areas (Jacobson and Wentworth 1982).

Jacobson and Wentworth (1982) found that after freeze-up and throughout the snow season, people travel up rivers where they fish through the ice and camp near the deep pools and open water springs where fish overwinter. Winter fishing may take place as far west as the Canning River and as far east as the Kongakut River. Until the mid-1940's, present-day Kaktovik people also relied extensively on fish in the rivers west of the Canning. In spring and fall, fish are caught through the ice of the Neruokpuk (Peters and Schrader Lakes) and Okpilak Lakes in the mountains using a simple hook and line attached to a willow stick. This common fishing method is referred to as "hooking" (Jacobson and Wentworth 1982).

The Hulahula is the most important winter fishing river to Kaktovik residents. After freeze-up, people camp at First Fish Hole and Second Fish Hole and, when travel conditions permit, many people also go up to <u>Katak</u> or Third Fish Hole, beyond Kolotuk Creek. In 1979, 20 people camped at Second Fish Hole for a week, and caught over 500 char between 23-26 April; 300 of these were caught on 25 April when the river overflowed (Jacobson and Wentworth 1982). The Sadlerochit River, downriver from Sadlerochit Springs, where the water stays open much of the year, and the Okpilak River are less important for snow-season fishing than the Hulahula River. Short nets are used, and 1 woman catches fish from a small rubber boat (Jacobson and Wentworth 1982).

The Canning River drainage provides winter fishing inland from the delta, along braided sections south of the Staines confluence, about 16 km downriver from Shublik Island, and at the warm springs near Ignek and Nanook Creeks. Formerly, Kaktovik people would make fishing trips up the Canning River in the fall and at any time during the snow season, staying several weeks or longer. Trips as far as the Canning are now usually made in the spring when there are long daylight hours for traveling. People travel the coast from Barter Island to the Canning River delta, then follow the river inland, or travel inland along the Sadlerochit or Hulahula Rivers and along the north side of the Sadlerochit mountains, to the Canning. Most people do not make this trip every year because of its distance (Jacobson and Wentworth 1982).

According to Kaktovik people, the Jago River has "no fish whatsoever." There are some smelt in the Jago River delta during the summer, but they are difficult to get because the water is shallow (Jacobson and Wentworth 1982). The Aichilik and Kongakut Rivers are both very good fishing rivers, which were fished often until the mid-1940's, but now are not used very frequently. "First fish hole" on the Aichilik is located at the 304 m contour line just before entering the mountains. A second fish hole, known especially for grayling, is several km further inland near the large western tributary. On the Kongakut River, 1 important fishing area is at the Pungautilik River confluence and another is on the Pagilak tributary. The large bend on the Kongakut was an important winter camping area with many willows for fishing rods as well as firewood. Another winter fishing area was about 6 to 16 km inland from the coast on the east branch of the Kongakut River. In the winter of 1981, a group of Kaktovik people went fishing on the Kongakut River even though no one had fished there for several years. On the coast, people formerly fished in the delta of the Kongakut west branch near <u>Siku</u>, and along the Demarcation Point spit (Jacobson and Wentworth 1982).

Arctic char. Arctic char is the most extensively used fish species. In summer, sea-run char are caught along the coast, around the barrier islands, and up the navigable portions of the river deltas. They are the first fish to appear in the nets after the ice goes out in early July. Char are caught into late August. During the snow season, arctic char are taken by fishing though holes in river ice. These fish are sometimes called "iqalukpiayat" because of their smaller size (Jacobson and Wentworth 1982).

Arctic cisco. Arctic cisco is the most common whitefish species. Cisco appear in the nets about the first of August, usually after the arctic char run peaks. The arctic cisco run is at its peak anywhere from August through early September. They are almost always taken in the ocean, by netting or seining. Arctic cisco tagged by ADF&G near Prudhoe Bay were caught about 275 km west at Griffin Point from 1 month to 1 year later (Jacobson and Wentworth 1982).

Least cisco. Least cisco, are less common than arctic cisco and are taken in the lagoons, river deltas, and particularly the small lakes and streams of the river drainages. The species is distinguished from the arctic cisco by its blackish gray fins instead of white ones, and by its narrower, "skinnier" body. A least cisco tagged at Prudhoe Bay on 25 July 1977 was caught at Griffin Point 20 days later (Jacobson and Wentworth).

Broad whitefish. Broad whitefish, a relatively large species of whitefish, are usually taken in the deeper lakes and channels of the Canning River delta during July through September. Occasionally they are taken in the winter at fishing holes farther inland on the Canning River (Jacobson and Wentworth 1982).

Round whitefish. Round whitefish, similar to but less common than broad whitefish, are found in the same area of the Canning River. Formerly, Kaktovik people caught both broad and round whitefish in the Sagavanirktok River (Jacobson and Wentworth 1982).

Ling cod or burbot. Small numbers of ling cod may be taken inland on the Canning River during the snow season. Formerly, they were taken during fall and winter on the Kuparuk River and other larger rivers, inland at least 16 km from the coast (Jacobson and Wentworth 1982).

Grayling. Grayling is a major subsistence species taken in many rivers and deltas. Late summer, after freeze-up, and spring are the most likely times to catch grayling (Jacobson and Wentworth 1982).

Pink salmon and chum salmon. Pink and chum salmon are occasionally taken in nets in July and August, especially near Barter Island. Pink salmon were taken in large numbers all along the Beaufort seacoast in 1978. This was a very unusual event and some villagers had never seen pink salmon before (Jacobson and Wentworth 1982).

Arctic flounder and fourhorned sculpin. These 2 species sometimes appear in nets during summer ocean fishing. Kaktovik people catch arctic flounder off Manning Point, Arey Spit, and in Kaktovik lagoon between Manning Point and the mainland. Sculpin are usually not eaten because they are too boney (Jacobson and Wentworth 1982).

Lake trout. During the snow season, lake trout are caught in the Neruokpuk Lakes by fishing through the ice with hook and line. Often 63 to 89 cm or more in length, they are the largest fish species taken by Kaktovik people (Jacobson and Wentworth 1982).

Pike. Paigluk, which Kaktovik people believe to be pike, are occasionally taken in the Hulahula River, mainly at First Fish Hole, and in other rivers. This species has not been positively identified. It is described as "sort of an ugly fish", having a large lower jaw, white meat and pink stripes (Jacobson and Wentworth 1982).

Other fish. Arctic cod or tomcod and smelt are small fish that may be caught along the Beaufort seacoast. In summer they are sometimes taken with nets near the spits off Barter Island. In October and November, people fish through the ocean ice at Iglukpaluk on the northwest side of Barter Island and north of Barter Island (Jacobson and Wentworth 1982).

Blackfish are also called "old man fish" by Kaktovik people. They are small fish (up to about 30 cm in length) taken through the ice, in winter and spring, along the Canning, Hulahula, Kongakut, and Aichilik Rivers (Jacobson and Wentworth 1982).

## Other Villages

Other villages located relatively far from the ANWR study area utilize wildlife species which may spend part of their life cycles in or adjacent to the ANWR study area. The Porcupine caribou herd is of particular significance, but some marine mammals, such as beluga whales and polar bears are also used.

### Caribou

Archaeological evidence (Irving and Harrington 1978, as cited by U.S. Department of State 1980) indicates that man may have been using caribou for at least 27,000 years, before the last glaciation in northern Alaska and Canada. Work done at sites occupied up to 1500 years ago near Old Crow, Yukon Territory, documented a subsistence economy centered primarily on the interception of spring and fall migrations of caribou (Morlan 1972 and 1973, Cinq-Mars 1974). The high percentage of caribou bones in faunal remains at the Cadzow Lake site and the Klo-kut site show the importance of caribou and its continuity of use over many years, as accompanying material goods changed from stone axes to bullets.

The Athabaskan people, specifically the Vunta Kutchin (Gwich'in) of the Old Crow area and the Netsit Kutchin (Gwich'in) of the Chandalar area in Alaska, were traditionally nomadic groups whose life cycles basically centered around the hunting of big game animals. The seasonal migration of caribou was the most important natural phenomenon which influenced their way of life (Stager 1974). Caribou were the most important game species and, until the early 1900's, were often hunted using surrounds or enclosures (Balikci 1961, McKennan 1965). Corral areas with long wing fences were constructed, and groups of caribou drifted or were driven into them. Warbelow et al. (1975) recorded the location of many of these surrounds in Alaska and Canada. After the introduction of the rifle to the Kutchin people, the use of surrounds declined, and hunters changed from the group hunting strategies to single hunter strategies. However, 1 surround north of Old Crow was used into the 1950's (Balikci 1961).

Caribou from the Porcupine caribou herd continue to be important to the people in rural villages of Alaska and the Yukon Territory today, despite a general shift during the 1900's from a dependence on subsistence resources to an increased dependence on imported foods (U.S. Department of State 1980). People in Arctic Village, Alaska, which is located near areas often used by the Porcupine caribou herd, are dependent on this caribou resource. Other villages with residents who hunt Porcupine caribou are Venetie, Fort Yukon, and Chalkyitsik in Alaska, and Old Crow, Fort McPherson, Inuvik, Aklavik, Arctic Red River, and Tuktoyaktuk in the Northwest Territories.

Arctic Village, Alaska, is located on the south side of the Brooks Range at 68° north latitude, 145° west longitude in a valley of the East Fork of the Chandalar River about 170 km south of the ANWR study area and 200 km north of Fort Yukon. The village is near the northern limits of the boreal forest. The present population is approximately 125 people (Pederson and Caulfield 1981b). Work done by McKennan (1965) and Hadleigh-West (1963) provided baseline information on lifestyle, culture, and subsistence use of resources of the Kutchin of the present Arctic Village area.

Caulfield (1983) described current subsistence land use of Arctic Village residents, and Lonner and Beard (1982) made a sociocultural assessment of Arctic Village with respect to proposed petroleum exploration in the ANWR. Activities in Arctic Village are still closely tied to the harvest of fish and wildlife resources. An estimated 50% to 90% of all food consumed is derived from local sources. Caribou is the most important source of food, with moose, fish, Dall sheep, waterfowl, and small mammals also important (Lonner and Beard 1982, Caufield 1983). Caribou are often available near Arctic Village from August to April, although changes in migration routes or wintering areas bring few caribou near the village in some years. Fall hunting is usually conducted near the village from hunting camps on Old John Lake. Winter hunting usually includes the use of snowmachines which gives the people an opportunity to hunt farther from the village. When caribou are not available, moose, fish, and Dall sheep may be taken in larger numbers (Pederson and Caulfield 1981b). Estimated annual harvests by Arctic Village residents ranged from 300-1200 caribou per year between 1972 and 1981 (LeBlond 1979, U.S. Department of State 1980, Pedersen and Caulfield 1981a).

Old Crow, Yukon Territory, is located on the north bank of the Porcupine River at 139° west longitude and 67° north latitude. The 1973 population was about 206 including white residents (Stager 1974). Work by Stager (1974) showed that caribou was the most important species of the subsistence resources used by Old Crow people in 1973. The major hunt for caribou is in September when large numbers of caribou pass through the Old Crow flats and cross the Porcupine River heading for wintering areas. At this time they can be taken on land or by riverboat. Most male residents older than 11 years join in the caribou hunt (Berger 1977). Hunting of caribou in winter and spring may also occur, depending on the year (Stager 1974). Between 1963 and 1985 about 300 to 1000 caribou per year were taken by Old Crow residents (Yukon Wildlife

Branch, pers. comm.). In addition to caribou, people harvest fish during the summer, moose, muskrats and waterfowl during spring, and rabbits and ptarmigan when available.

Other villages utilizing caribou from the Porcupine herd are located on the edge of the Porcupine herd's range, and take caribou only in years when animals are available (U.S. Department of State 1980). The estimated annual caribou harvest in Aklavik and Fort McPherson, Canada, has ranged from less than 100 to over 2,000 from 1963 to 1985 (Yukon Wildlife Branch, pers. comm.). Alaskan villages of Venetie, Fort Yukon, and Chalkyitsik harvested about 300-400 caribou in 1980-81 (Pedersen and Caulfield 1981a). Sharing and trading of resources occurs between villages. If caribou are not available in Fort Yukon, people may trade salmon to someone in Arctic Village for caribou. A network of exchange exists and those who are unable to provide subsistence resources for themselves are able to procure it from friends or relatives (Berger 1977). In early 1981, people from Venetie, Fort Yukon, Chalkyitsik, Beaver, and Birch Creek used visits to relatives and friends in Arctic Village as opportunities to take caribou which were within 8 km of the village (R. Caulfield, pers. comm.).

Marine mammals

Communities of the Mackenzie River delta (Inuvik, Aklavik, and Tuktoyaktuk) and Amundsen Gulf (Sachs Harbour, Holman, and Paulatak), are partially dependent on subsistence uses of beluga whales and polar bears. Beluga whales are present in the Beaufort Sea north of the ANWR study area during spring and fall migrations where they generally follow the pack ice edge (Seaman et al. 1981). Beluga whales are harvested in the Mackenzie portion of the Beaufort Sea, when whales enter warmer waters of the bays near the Mackenzie River delta during early July and remain until the middle of August. Whaling for beluga whales near the MacKenzie delta is not regulated, and approximately 120 whales are taken per year (Brackel 1977). Whale products are primarily used locally, although some products such as maktak are occasionally sold. Beluga maktak is often shared with relatives in Kaktovik and other Alaskan and Canadian villages. The importance of beluga whales to the economy and diet of Mackenzie villages may be more a matter of preference than economic necessity. A variation in diet, and the sport and recreation of the hunt, with opportunities for socialization, are all important factors in whaling (Brackel 1977).

Polar bears represent a substantial component of the cultural and economic base of the Inuit people of the Canadian western arctic (Stirling et al. 1975). Some polar bears used by Canadian villages may spend some time in or adjacent to the ANWR study area. Polar bear hides have direct economic value, and in recent years the principal motivation for polar bear hunting has been the sale of hides (Stirling et al. 1975). Fur exports are an important source of cash in the economies of Mackenzie and "Rim" villages. According to Brackel (1977), marine furs (white fox, polar bear, and ringed seal) provided 5% - 19% of the earned income in the Mackenzie and "Rim" economies, respectively. Brackel (1977) also states: "Polar bears warrant special attention because their value and socio-economic importance overshadow other marine furs. Polar bear exports, worth $17,000, make a sizeable contribution to marine fur income in the Mackenzie economy." Polar bears are the least abundant of the marine fur species, but the individual hides have the most valve. The average price per hide received by hunters was $1000 in 1974 (Brackel 1977).

## Recreation, Wilderness and Natural Landmarks

### Recreation

Recreational uses of the ANWR study area are varied and related to wildlife or wilderness values. Recreationists are attracted to the refuge because of its wilderness characteristics, its opportunities to explore remote, untamed areas, and to view wildlife. Solitude and tranquility, considered important components of a wilderness experience (Hendee et al. 1968, Rossman and Ulehla 1977), and pristine arctic and subarctic habitats can also be experienced in ANWR. Lucas (1980) indicated that some visitors to wilderness areas place priority on recreational opportunities, and others desire to find a natural ecosystem.

Use of the refuge by recreationists, particularly hunters, increased rapidly in the early 1970's, and stabilized to a steady increase after 1974 (refuge files). In 1975, Ritchie and Childers (1976) sampled 281 visitors (exclusive of industry, research personnel, Kaktovik residents, and DEW Line site employees) and estimated the total numbers of visitors to be 312-375. Most people visited the refuge between 1 June and 15 September. Warren (1980) estimated the refuge had 434 visitors exclusive of subsistence users in 1977. In 1982, J. Liedberg (pers. comm.) estimated 900-1000 people visited the entire refuge, but no data were collected. Current levels of recreation use are unknown, but fewer recreationists apparently use the coastal plain than other areas of the refuge. Warren (1980) found that 4.1% of hunters and 17.9 to 26.3% of non-hunters visiting the refuge in 1977 spent time in the ANWR study area.

In 1977, 248 (57%) of all visitors to the refuge were hunters (Warren 1980). Most visitors were from Alaska and the contiguous Pacific Coast states, and most were males between the ages of 25 and 45 years old. The average stay was 10.6 days for hunters and 13.4 days for non-hunters. Primary activities included hunting, backpacking/hiking, observing wildlife, and viewing scenery. Over 90% of all visitors surveyed indicated that seeing wildlife was important to their experience (Warren 1980).

Recreational uses of the ANWR study area are difficult to isolate from the remainder of the refuge, especially the contiguous Brooks Range. Many recreational experiences rely on a continuous trip from the mountains, across the coastal plain to the coast, or vice versa. Visitors usually arrive in the study area via commercial air service to Kaktovik or Prudhoe Bay and by aircraft charter from these locations to their destination. Other visitors may arrive by foot, hiking from drop-off points in the Brooks Range or from Arctic Village. Visitors floating rivers begin trips on rivers within the Brooks Range and float north to pick-up points on the coast or on the coastal plain. Some kayak groups float to the coast and then paddle through the coastal lagoons to Barter Island. The river corridors are especially important to most visitors because they serve as navigational aids and provide easy hiking routes across otherwise difficult terrain. No recreational facilities exist in the study area. The abandoned DEW Line sites at Camden Bay and Beaufort Lagoon may occasionally be used by recreationists.

Within the coastal plain study area, backpacking/hiking, and floating rivers are probably the most common forms of recreation (J. Liedberg, pers. comm.). Hiking is good along the coast and along the river courses in the coastal plain, but cross-country hiking is difficult because of wet, tussocky terrain. Most hikers in the study area are enroute to or from the mountains. Boaters utilize rafts or kayaks to navigate the river courses. The more popular floating rivers are the Canning, Hulahula and the Jago. Although hunting is the most common form of recreation throughout the entire refuge, less hunting is done on the coastal plain than in the mountains because Dall sheep, a species commonly sought by hunters, does not occur within the study area. However, 1 hunting guide does operate in the study area, and has applied to the state for an exclusive guide area for caribou and brown bear. Other recreational activities in the ANWR study area include wilderness enjoyment, nature study, photography, fishing, and wildlife observation. These activities may be the major purpose for the trip, but are usually done in conjunction with other recreation such as hunting or backpacking. The residents of Kaktovik occasionally engage in snowmobiling and cross-country skiing (J. Liedberg, pers. comm.).

The number, characteristics, timing, length of stay, activities and demographics of recreationists using the study area need to be quantified. The esthetic values of walking and float trips across the study area also need to be assessed. Information on the number, harvest and other use data for sport and subsistence hunting is also needed. The study of public use on the ANWR, done by Warren (1980) in 1977, should be updated.

## Wilderness Values

The ANWR coastal plain study area has been the subject of at least 2 wilderness studies. The wilderness qualities of the entire ANWR pursuant to the Wilderness Act of 1964 were examined by the U.S. Fish and Wildlife Service (1973). This study concluded that the entire range had outstanding wilderness qualities suitable for inclusion into the National Wilderness Preservation System, with the following exceptions:

1. The abandoned DEW-Line sites at Camden Bay and Beaufort Lagoon, comprising 185 and 170 ha, respectively.

2. The 361 ha military withdrawal, the 57 ha occupied by the village of Kaktovik and the remaining 1,405 ha of Barter Island.

3. A total of 26,525 ha of land in the vicinity of Barter Island selected by the KIC under the ANCSA.

With these exclusions, approximately 3.6 million ha were proposed for wilderness designation in 1973. Congressional action on wilderness designation was delayed, however, pending a decision on possible routing of the Arctic Gas Pipeline across the refuge and Congressional debate on the Section 17(d)(2) provisions of the ANCSA. Extensive public testimony was received from within and outside Alaska about both of these actions, much of which focused on the wilderness quality of the ANWR (U.S. Fish and Wildlife Service 1978).

In 1976, the decision was made to not route the Arctic Gas Pipeline across the wildlife range (Alaska Natural Gas Transportation Act of 1976, PL 94-586). On 2 December 1980, ANILCA Section 303(2) established the Arctic National Wildlife Refuge, expanding it to approximately 7.3 million ha from the 3.6 million ha of the original wildlife range. Most of the original wildlife range was designated as wilderness. Excluded were the exceptions listed above and the ANWR coastal plain study area.

Section 1317 of ANILCA requires that all lands within units of the National Wildlife Refuge System in Alaska not already designated as wilderness be reviewed as to their suitability for preservation, with recommendations going to Congress prior to 2 December 1987. Section 1004 of ANILCA requires a wilderness review of the ANWR study area with no time limit defined. These ANWR wilderness reviews are being conducted as part of the Comprehensive Conservation Planning Process (ANILCA Section 304(g)(1)), which is scheduled for completion in early 1988.

A second wilderness review conducted on the ANWR coastal plain study area (Thayer 1982) similarly concluded that the entire coastal plain, with the exception of the 2 abandoned DEW Line sites, meets the requirements for wilderness classification. The area has also often been described as being _de facto_ wilderness (HR Rep. No. 95-1045, Part I, 95th Congr., 2nd Sess. 151, 1978; HR Rep. No. 96-97, Part I, 96th Congr., 1st Sess. 483 and 487, 1979).

The Wilderness Act of 1964 listed 6 characteristics to be considered in a wilderness evaluation. The following paragraphs describe the wilderness values of the coastal plain study area for each of these 6 characteristics:

1. _Size_: The study area meets the designated size criteria since it exceeds 2000 ha and is of sufficient size to make practical its preservation and use in an unimpaired condition.

2. _Naturalness_: With few exceptions the entire study area is in near pristine condition. Exceptions include the military withdrawal on Barter Island, the village of Kaktovik, and the abandoned DEW Line sites.

Lands selected and conveyed to the Kaktovik Inupiaq Corporation (KIC) and Native allotments on the coastal plain are not eligible since they are in private ownership. Subsurface rights associated with the KIC lands were transferred to the Arctic Slope Regional Corporation in 1983.

Some old tractor tread marks are visible along the coast. On some maps these tracks are incorrectly noted as tractor trails. The tracks are mostly the result of random travel associated with DEW Line construction approximately 25 years ago. Most of these tracks are substantially unnoticeable.

The seismic exploration conducted during the winters of 1983-1984 and 1984-1985 created a network of trails, which, to a degree, detract from the wilderness quality of the area. However, this detraction is minimal, especially to an observer on the ground. More often than not, the signs of these activities are undetectable by a person hiking across the coastal plain, even when the person knows their approximate location and is actively searching for them (Fruge 1985). Botanical studies show that recovery of visual impacts is slowly occurring (Felix et al. 1986), and many of the visual effects of the seismic exploration are expected to eventually disappear.

The ANWR coastal plain study area is the most pristine of any large segment of arctic tundra remaining in the United States. Oil exploration and development are permitted or are occurring on coastal plain areas to the west in Alaska and to the east in the Canadian arctic.

3. Opportunities for solitude: The coastal plain study area is primeval land and offers excellent opportunity for solitude, which is further enhanced by the wilderness status of the land immediately south and east and the Arctic Ocean to the north of the area. There are no roads in the area or designated trails for wilderness travelers, but most travel occurs along river courses. However, even in close proximity to another party, the meandering shape of stream valleys provides adequate opportunity for seclusion.

In traveling by primitive means across the coastal plain, the visitor experiences true solitude and wilderness. Such experience is reminiscent of the hardship, challenge, drama, and peril faced by the early American pioneers, but which is becoming increasingly difficult to experience today. There are relatively few signs of human culture except for archeological sites and artifacts, occasional aircraft, or the vapor trail of a high-flying jet. It is possible, depending upon time of year and route taken, to traverse the entire coastal plain and not see a sign of human existence.

4. Opportunity for primitive and unconfined types of recreation: The characteristics that provide opportunity for solitude, also provide the opportunity for primitive and unconfined recreation, especially hunting, hiking, skiing, photography, wildlife observation, and wilderness enjoyment. Special features of the unit are its openness and feeling of unconfinement.

The close proximity of the Brooks Range to the arctic coast on ANWR presents a unique wilderness situation in the North American arctic, offering the wilderness recreationist the opportunity to experience, in a comparatively concentrated zone, a variety of habitat and terrain types, whether traveling by foot or river. A visitor can, within the span of a few days, go from the alpine zone of ice, snow and rock, to alpine meadows, and arctic tundra valleys. Leaving the mountains, one traverses tussock tundra foothills, braided river floodplains, and rolling tundra plains. Near the arctic coast, one encounters the flat thaw lake plain, and the coastal zone of wetlands, lagoons, barrier islands, and the ocean. This recreational variety is unavailable within such a short distance anywhere else on the Alaskan north slope.

The shallow valleys of the numerous streams that flow across the unit to the Arctic Ocean provide good camping sites. Gravel outcrops on the plain above streams provide camp sites with broad views. The streams in the area are not navigable by conventional power boat and most are not easily navigable by canoe. Rafts or kayaks provide the best crafts for river running.

The Arctic Ocean beach reef system is composed of sand and small gravel. The beach, with the Arctic Ocean to the north and the broad coastal plain to the south, and the general absence of man's work, offers extensive primitive and unconfined camping and wilderness enjoyment opportunities.

In terms of scenic quality, the ANWR coastal plain is expansive and varied. To a person situated midway between the Brooks Range and the ocean, the mountains dominate the southern skyline. Mounts Isto, Chamberlin, and Michelson, the 3 tallest peaks in the Brooks Range, are always snow-clad and are impressive when viewed from the coastal plain, their grays and whites contrasting with the greens and browns of the tundra. To the east and west, one sees the vast expanse of treeless tundra rolling into the distance, creating the illusion of limitless wilderness in both directions. If one is situated in the right place and given the right weather conditions it is also possible to see to the north the coastal lagoons, the ocean, and the permanent pack ice beyond. Because vegetation is mostly very low, only a few cm tall over much of the area, both visitor and wildlife are conspicuous. Animals are easily visible and, because of the relative lack of human presence, are often unwary or even curious when confronted by humans.

5. Ecological, geological, scientific, educational, and historic values: The entire refuge is one of the more primitive and isolated wild land regions left on earth that has been afforded protection as a conservation area. The coastal plain is an integral part of the wilderness ecosystems encompassed by ANWR, as most of the major wildlife species occurring on or near the refuge (caribou, moose, muskox, grizzly bears, wolverines, wolves, polar bears, numerous species of birds) utilize the coastal plain habitats for all or critical portions of their life cycles (i.e., calving, nesting, breeding, staging).

The geologic formations of beach gravel and sand formed by the Arctic Ocean are used as nesting and resting sites for marine and other water birds. Bearded and ringed seals rest on the ocean spits and gravel bars. During early winter, polar bears excavate dens in the snow drifts that form along the coast and inland along rivers. Rivers and streams form deltas with many small ponds and marshes that are used as nesting areas by waterfowl and shorebirds.

Seasonal abundance of wildlife on the coastal plain is high. Many species of migratory birds utilize the ANWR coastal plain for nesting and rearing young. The calving grounds of the Porcupine caribou herd, including core calving areas, are found within the ANWR study area. The coastal plain is the most biologically productive part of the entire ANWR and can be thought of as the center of wildlife activity on the refuge (U.S. Fish and Wildlife Service 1973).

Humans may have been present in the ANWR study area for approximately 50,000 years (U.S. Fish and Wildlife Service 1973). Because of the cold, arid climate, items of cultural or historical significance may be preserved on the coastal plain for long periods. However, because of the geological setting, the possibility of archeological sites dating earlier than 14,000 years ago is not great (Hall 1982). Numerous historic and/or traditional land use sites have been identified, especially along the coast, where archeological and cultural remains have been found. Many of these are of historic or prehistoric study value (Hall 1982) and may contain information valuable to understanding recent human adaptations to the arctic.

The biological diversity and uniqueness of ANWR has been recognized by many scientists. During the 12th Alaska Science Conference in 1961 (Dahlgren 1962), the scientific importance of ANWR was attributed to the relatively undisturbed condition of the area and the ecological diversity represented within such a contracted region. It was stated that the range offered "... an unequaled chance for aquatic ecology", that the area could serve as a control area against which the effects of land-use practices elsewhere in the Alaskan arctic could be measured, and that the area could "... provide topics for an untold number of scientific publications."

In originally recommending the area for preservation, Collins and Sumner (1953) wrote:

> "The region offers science the best opportunity of any place in Alaska, if not in the whole of North America, for studying the processes by which these and other arctic animals maintain their numbers through the natural checks and balances of climate, food supply, and predation.
>
> The whole field of cyclic population fluctuations, so characteristic of the smaller animals in the arctic, can be studied here with no interference by agricultural or other human activities. Such research possibilities are of outstanding importance to various applied sciences such as game, fur and fish management, and human survival techniques.
>
> Ecologists recognize that research in an arctic wilderness study area has special usefulness beyond the confines of the region because the comparative simplicity of environmental factors in the arctic makes them easier to isolate and analyze."

In 1969, the Tundra Biome Section of the International Biological Program (IBP) passed a resolution urging that all or a major portion of ANWR be included in the National Wilderness Preservation System, that scientific research be recognized as a priority use of the range, and that minimal man-induced physical and biological changes be permitted in the area (U.S. Fish and Wildlife Service 1973).

ANWR is the only conservation system in North America that encompasses a complete spectrum of the various arctic ecosystems in an undisturbed condition. The ANWR coastal plain is an integral part of that spectrum. The area presents unique opportunities for scientific study of this undisturbed ecosystem. There are also concurrent educational opportunities inherent in the existence of this pristine area (U.S. Fish and Wildlife Service 1982).

This portion of the arctic coastal plain is the last such area in Alaska that has not been committed to man's development activities. As such, it has extremely high value as a remaining example of the natural coastal arctic ecosystem. Therefore, its ecological, scientific, and educational values are almost incomparable.

6. <u>Possibility of returning to natural conditions</u>: The abandoned DEW Line sites at Camden Bay and Beaufort Lagoon are slowly returning to natural conditions through the processes of beach erosion, thermokarsting, and frost tilling. The FWS is slowly removing some of the human artifacts from these sites (Thayer 1979). Also, a new project proposed by the U.S. Army Corps of Engineers will result in almost complete cleanup of these sites. If all artifacts are removed, these sites may someday assume a near natural condition, though this may take hundreds of years.

The seismic exploration program of the last 2 years has resulted in a grid of seismic trails that are visible from the air. However, at ground level these trails are much less apparent. The majority of the trails are expected to disappear within a few years. Longer lasting scars may persist in isolated areas. Visual effects are expected to disappear over time, though how long it will take for all traces of these activities to disappear is uncertain.

The coastal plain study area in its present state has outstanding wilderness qualities and meets the definition of wilderness contained in the Wilderness Act. In fact, ANWR is regarded by many as epitomizing the values intended to be preserved by formal wilderness designation (S. Rep. No. 96-413, 96th Congr., 1st Sess. 376, 1979).

The wilderness qualities of ANWR have been the subject of a number of articles (Collins and Sumner 1953, Anonymous 1953, 1956, 1957a, 1957b, Sumner 1956, Tall 1959, Douglas 1960, Murie 1962, Dean 1965, Milton 1970, Brower 1971, Laycock 1976, Chadwick 1979, Abbey 1984, Kerasote 1984a and 1984b). In summary, the scenic qualities, the wildlife presence, the excellent opportunities for solitude, the recreational challenges, and the scientific and historic values of the ANWR coastal plain result in an area well qualified for wilderness designation.

## Natural landmarks

Three sites within or immediately adjacent to the study area have been recommended for inclusion in special recognition systems. Bliss and Gustafson (1981) noted that Sadlerochit Mountains and Warm Springs have been nominated for inclusion as a National Natural Landmark site. The goal of the National Natural Landmarks Program, established in 1963, is to inventory and characterize sites that best illustrate the diversity of our nation's natural heritage. The approximate size of the site is 93,313 ha. The Sadlerochit Mountains themselves lie outside of the study area; the Sadlerochit Springs lies within the boundary of the area. This nomination was made because it contains the most northern population of Dall sheep in North America and because of the water aquifer and lush vegetation (Bliss and Gustafson 1981). The area also has several disjunct plant populations and the northernmost balsam poplar stand in North America (Murray 1979).

Two other sites were recommended for inclusion in the National Natural Landmark System. These are the Beaufort Lagoon-Demarcation Bay area and the Jago River system. These 2 sites have also been nominated for inclusion in a statewide Ecological Reserves System. The Beaufort Lagoon site is partially within the study area, and extends 80 km along the coastline from Beaufort Lagoon eastward to Demarcation Bay. It includes a major arctic lagoon and estuary system, a major river delta with perennial aufeis, and a coastline visited by the Porcupine caribou herd, fall migrating waterfowl and shorebirds.

The Jago River drainage, according to Stenmark and Schoeder (1974) contains "a complete array of tundra and floodplain vegetative and animal types typical of the north slope." The complete river drainage from headwaters to mouth is included in the proposal. Much of this drainage lies within the ANWR study area.

## Literature Cited

Anderson, R.M. 1919. Report on the natural history collections of the expedition in the Stefansson-Anderson arctic expedition: preliminary report. Anthropological Pap. Amer. Mus. of Natur. Hist., Vol. 14, Part 1. New York.

Alaska Consultants, Inc. 1983. Background for planning. City of Kaktovik. Unpub. Rep. North Slope Borough. Barrow, Ak.

Alaska Consultants, Inc., and Stephen Braund & Associates. 1984. Subsistence study of Alaska whaling villages. Unpub. Rep. U.S. Dept. of Inter. Anchorage, Ak.

Abbey, E. 1984. The last pork chop. Outside (2):51-86.

Anonymous. 1953. Arctic wilderness preserve. The Living Wilderness. 18(46):28-30.

Anonymous. 1956. Alaska with O.J. Murie. The Living Wilderness. 21(58):28-30

Anonymous. 1957a. Arctic Wildlife Range. The Living Wilderness. 22(62):30-31.

Anonymous. 1957b. Future of Brooks Range wildlife. The Living Wilderness. 22(62):31.

Arctic Environmental Information and Data Center. 1982. Sociocultural assessment of proposed Arctic National Wildlife Refuge Oil and Gas exploration. Final Report. Univ. Alaska, Anchorage. 194pp.

Balikci, A. 1961. Vunta Kutchin social change, a study of the people of Old Crow, Yukon Territory. Northern Coord. & Res. Centre, Dep. of N. Affairs and Natl. Resour. NCRC-63-3. 161pp.

Berger, T.R. 1977. Northern frontier, northern homeland; the report of the MacKenzie valley pipeline inquiry, Volume 1. Minist. of Supply Serv., Queens Printer, Ottawa, Canada. 213pp.

Bliss, L.C., and K.M. Gustafson. 1981. Proposed ecological natural landmarks in the Brooks Range, Alaska. Prep. for Div. of Natural Landmarks, Heritage Conserv. and Recreation Service. Dep. of Inter. 175pp.

Brackel, W.D. 1977. The socio-economic importance of wildlife resource utilization in the southern Beaufort Sea. Bearfort Sea Project, Technical Rep. No. 32, Dep. Fish. and Environ., Victoria, British Columbia. 91pp.

Braham, H., B. Krogman, M. Nerini, D. Rugh, W. Marquette, and J. Johnson. 1980. Research on bowhead whales, June-Dec. 1978. In. Rep. to Int. Whaling Comm., 1980 SC/31/Doc. 51. pp. 405-413.

Brower, A.K. 1979. Beaufort lease sale public testimony. in Arctic Coastal Zone Management newsletter. June. North Slope Borough, Barrow, Alaska. 20pp.

Brower, K. 1971. Earth and the great weather -- the Brooks Range. McCall Publ. Co., New York. 188pp.

Caulfield, R.A. 1983. Subsistence land use in upper Yukon-Porcupine communities, Alaska. Div. of Subsistence, Alaska Dep. of Fish and Game, Fairbanks. 231pp.

Chadwick, D. 1979. Alaska's Arctic National Wildlife Range -- our wildest wilderness. Nat. Geogr. Mag. 156(6):13-26.

Cinq-Mars, J. 1974. Preliminary archaeological study Mackenzie corridor, second report. Environmental-Social Committee Northern Pipelines, Task Force on Northern Oil Dev., Rept. No. 74-11, Canada. 29pp.

Coffing, M., and S. Pedersen. 1985. Caribou hunting: Land use dimensions, harvest level and, selected aspects of the hunt during regulatory year 1983-84 in Kaktovik, Alaska. Tech. Pap. No. 120. Div. of Subsistence, Alaska Dep. of Fish and Game, Fairbanks. 38pp.

Collins, G., and L. Sumner. 1953. Northeast arctic -- the last great wilderness. Sierra Club Bull. 38(8):13-26.

Collinson, Capt. R. 1855. Royal Navy journal of H.M.S. Enterprise, 1850-1855. Proc. of the Enterprise. R. Geogr. Soc. J. 25:194-206.

Cooperative Extension Service. 1974. Alaska's game is good food. Univ. of Alaska, Publ. 126, Chart 1, p. 11.

Dahlgren, G., Jr., ed. 1962. Arctic National Wildlife Range symposium. Proc. 12th Ak. Sci. Conf. 12:31-72.

Dean, F.C. 1965. Wildnerness management and oil exploration in the Arctic National Wildlife Range. Alaska Cons. Soc. News Bull. 6(2):12-13.

Dease, P.W., and T. Simpson. 1837. Account of the recent arctic discoveries by Messrs. Dease and Simpson, with maps. R. Geogr. Soc. J. 8:213-225.

Douglas, W.D. 1960. My wilderness. Doubleday, New York. 206pp.

Envirosphere Co. 1986. Endicott Environmental Monitoring Program, Draft Report. Rep. for U.S. Army Corps of Engineers, Alaska District., Anchorage, Ak.

Felix, N.A., T. Jorgenson, M. Raynolds, R. Lipkin, D. Blank, and B. Lance. 1986. Effects of winter seismic trails on visual resources, vegetation and permafrost on the coastal plain of the Arctic National Wildlife Refuge. Pages __ in G.W. Garner and P.E. Reynolds, eds. 1986 update report, baseline study of the fish, wildlife and their habitats. U.S. Fish and Wildlife Service, Anchorage, Ak. __pp.

Fiscus, C.H., and W.M. Marquette. 1975. National Marine Fisheries Service field studies relating to the bowhead whale harvest in Alaska, 1974. Northwest Fish. Cent., NMFS, Seattle. 21pp.

Ford, J.A. 1959. Eskimo prehistory in the vicinity of Point Barrow, Alaska. Anthro. Lab of Am. Mus. of Nat. Hist., Vol. 47. New York.

Franklin, Sir J. 1828. Narrative of the second expedition to the shores of the polar sea in the years 1825-1827. J. Murray, London.

Frugé, D.J. 1985. Trip report, backpack trip, Peters Lake to mouth of Sadlerochit River, August 1985. Memorandum to Refuge Manager, Arctic National Wildlife Refuge, U.S. Fish and Wildlife Service, Fairbanks, Ak. 19pp.

Giddings, J.L., Jr. 1952. The arctic woodland culture of the Kobuk River. Monogr. of the Univ. of Pa. Mus., Philadelphia.

Giddings, J.L., Jr. 1954. The tenuous Beaufort Sea archaeology. in Proc. 5th Alaskan Sci. Conf. Fairbanks, Ak.

Gordon, B.C. 1971. Recent archaeological investigations on the arctic Yukon coast. Pages 67-86 in R.A. Smith and J.W. Smith, eds. Early man and environments in NW North America. Univ. of Calgary Arch. Assn., Calgary, Alberta.

Gubser, N. 1965. The Nunamint Eskimos: hunters of caribou. Yale Univ. Press, New Haven. 363pp.

Hadleigh-West, F. 1963. The Netsi-Kutchin: An essay in human ecology. PhD. Thesis, La. State Univ., Baton Rouge. 419pp.

Hall, E.S., Jr. 1981. Cultural resource site potential. In D. Libbey and E.S. Hall, Jr. Cultural resources in the mid-Beaufort Sea region. Rep. for the North Slope Borough's Coastal Zone Management Plan, Barrow, Ak. 1-86p.

Hall, E.S., Jr. 1982. Preliminary archaelogical and historical resource reconnassance of the coastal plain of the Arctic National Wildlife Refuge, Alaska Tech. Rep. No. 1. Edwin Hall and Associates, Brockport, New York. 162pp.

Hendee, J.C., W.R. Catton, L.D. Marlow, and C.F. Brockman. 1968. Wilderness users in the Pacfic Northwest - their characteristics, values and management preferences. Oreg. Res. Pap. PNW-61. 92pp.

Hurwitz, R. 1977. Report to Congress on subsistence foods and physical and mental health. Yukon-Kuskokwim Health Corp. Bethel, Ak. 6pp.

Irving, W. n.d. An archaeological reconnaissance of the lower Colville River and delta region. Unpub. Rep. Off. of Naval Res.

Irving, W.N., and C.R. Harrington.. 1978. Upper pleistocene radiocarbon-dated arctifacts from the northern Yukon. Sci. 179:335-340.

Jacobson, M., and C. Wentworth. 1982. Kaktovik subsistence: land use values through time in the Arctic National Wildlife Refuge area. U.S. Fish and Wildlife Service Northern Alaska Ecological Service. Fairbanks, Ak. 142pp.

Jenness, D. 1914. Archaeological notes on eskimo ruins at Barter Island on the arctic coast of Alaska, excavated. Manuscript No. 779. Ottawa: Nat. Mus. of Can.

Jenness, D. 1928. Archaeological investigations in the Bering Strait, 1926. Ann. Report to Nat. Mus. of Canada for 1926. Nat. Mus. of Can. Bull. No. 50:71-81.

Johnson, J.H., H.W. Braham, B.D. Korgman, W.M. Marquette, R.M. Sonntag, and D.J. Rugh. 1981. Bowhead whale research: June 1979 to June 1980. NMFS, Marine Mammals Laboratory, Seattle. in Report to International Whaling Commission 1981, SC/32/PS 10.

Kaveolook, H. 1977. Kaktovik on Barter Island: A brief history of Kaktovik and its schools. North Slope Borough School District. Education hearings, First Inuit Circumpolar Conference. Barrow, Alaska. 1977. 22pp.

Kerasote, T. 1984a. Across arctic mountains, Part. I. Sports Afield 193(2):76-114

Kerasote, T. 1984b. Across arctic mountains, Part II. Sports Afield. 193(3):58-144.

Kruse, J., J. Kleinfeld, and R. Travis. 1981. Energy development and the north slope Inupiat: quantitative analysis of social and economic change. Univ. Alaska Inst. Social and Econ. Res. Rep. No. 50 Man in the Arctic program. Mono. No. 2, Anchorage. 53p.

Laycock, G. 1976. Our last arctic wilderness -- a gift denied? Audubon. 78(4):80-102

LeBlond, N.R. 1979. Porcupine caribou herd. Canadian Arctic Res. Comm., Res. Monog. 3: Yukon Series. 156pp.

Leffingwell, E.D. 1919. The Canning River region, northern Alaska. U.S. Geological Survey Prof. Pap. 109. Washington, D.C. 242pp.

LeResche, R.E. 1974. Caribou: survey - inventory proq. rep. 1972. Vol. IV Alaska Dep. of Fish and Game, Fairbanks, Ak.

Libbey, D. 1981. Cultural resource site identification. in Cultural resources in the Mid-Beaufort Sea region. A Report for the North Slope Borough's Coastal Zone Management Plan, North Slope Borough, Barrow. 86pp.

Libbey, D. 1982. Kaktovik area cultural resource survey. Unpub. Rep. for North Slope Borough and State Office of History and Archaeology, Anchorage, Ak. 124pp.

Lonner, T.D., and S.W. Beard. 1982. Part II Arctic Village. Pages 94-179 in Arctic Environmental Information and Data Center. Sociocultural assessment of proposed Arctic National Wildlife Refuge oil and gas exploration final report. Univ. Alaska, Anchorage. 194pp.

Lucas, R.C. 1980. Use patterns and visitor characteristics, attitudes and preferences in nine wilderness and other roadless areas. U.S. Forest Service, Res. Pap., Intermountain For. and Range Exper. Station.

MacNeish, R.S. 1956. The engigstciak site on the Yukon arctic coast. Univ. of Alaska Anthropology Pap. 4:91-111.

Marquette, W.M. 1976. Bowhead whale field studies in Alaska, 1975. Pages 9-17. in Marine Fish. Rev. Vol. 38, No. 8, August.

Marquette, W.M. 1978. The 1976 catch of bowhead whales, Balaena mysticetus, by Alaska Eskimos. Pages 18-27 in Marine Fish. Rev., Vol. 40, No. 11. November.

Marquette, W.M. 1979. The 1977 catch of the bowhead whales by Alaskan Eskimos. NMFS. Marine Mannal Laboraty Seattle, Pages 281-289. in Rep. to Inter. Whaling Comm. 1979. SC/30/Doc. 35.

Marquette, W.M., M.K. Nerini, H.W. Braham, and R.V. Miller. 1981. Bowhead studies, Autumn 1980 - Spring 1981: harvest, biology, and distribution. NMFS Marine Mammal Lab., Seattle, June SC/33/PS 5. 27pp.

Mathiassen, T. 1930. Archaeological collections from the western Eskimos. Rep. 5th Theele Expedition 1921-24, Vol. 10. Copenhagen

McGhee, R. 1974. Beluga hunters: an archaeological reconstruction of the history and culture of the Mackenzie delta Kittegararyumiut. Newfoundland Social and Econ. Studies No. 13, Inst. of Social and Econ. Res., Memorial Univ. of Newfoundland.

McKennan, R.A. 1965. The Chandalar Kutchin. Arctic Inst. of North Am. res. Monog. 3: Yukon Series. 156pp.

Milan, F.A. 1979. A broad view of health and nutrition as they relate to subsistence and changing life styles: an example from arctic coastal Alaska. Pages 108-118 in Proceedings of Seminar Series: The subsistence lifestyle in Alaska now and in the future. School of Agric. and Land Resources Manage., Univ. Alaska, Fairbanks.

Milton, J.P. 1970. Nameless valleys, shining mountains. Walker and Co., New York. 195pp.

Morlan, R.E. 1972. The Cadzow Lake site: a multi-component historic Kutchin camp. National Mus. of Man, Ottawa, Canada. Arch. Surv. Can. Pap. No. 3. 91pp.

Morlan, R.E. 1973. The later prehistory of the middle Porcupine drainage, N. Yukon territory. National Mus. of Man, Ottawa, Canada. 583pp.

Murie, O.J. 1962. Wilderness philosophy, science and the Arctic National Wildlife Range. Proc. 12th Alaska Sci. Conf. 12:58-69

Murray, D.F. 1979. Balsam popular in arctic Alaska. Canadian J. Anthropology. :29-32.

Nielson, J.M. 1977a. Beaufort Sea study. historic and subsistence site inventory. North Slope Borough, Barrow, Ak. 113pp.

Nielson, J.M. 1977b. Kaktovik Alaska: an overview of relocations. North Slope Borough, Barrow, Ak. 26pp.

Nobmann, E.D. 1978. Nutritional considerations in rural Alaska: implications of different sources. Pages 96-107 in Proceedings of seminar series: the subsistence lifestyle in Alaska now and in the future. School of Agric. and Land Resour. Manage., Univ. of Alaska, Fairbanks.

North Slope Borough. 1980. Qiniqtuagaksrat Utuqqanaat Inuuniagninisiqun. The traditional land use inventory for the mid-Beaufort Sea. Commission on History and Culture. Vol. 1. 209pp.

Okakok, L. 1981. Puiguitkaat: The 1978 elders conference. Gary Keane, ed. North Slope Borough Comm. on History and Culture, Barrow, Ak. 653pp.

Pedersen, S. 1979. Regional subsistence land use North Slope Borough Alaska. Cooperative Park Studies Unit, Univ. of Alaska, Fairbanks and Environmental Protection, North Slope Borough, Barrow. Occas. Pap. No. 21, June. 30pp.

Pedersen, S., and R.A. Caufield. 1981a. Porcupine caribou harvest estimates of Alaskan communities in game management units 25 and 26, 1986-81 reporting years. Unpub. memo. to Porcupine Caribou Technical Committee. A Division of Subsistence, Alaska Dept. of Fish and Game, Fairbanks, Ak.

Pedersen, S., and R.A. Caulfield. 1981b. Some elements of subsistence land and resource use within the range of the Porcupine caribou herd in Alaksa. Interm Report. ADF&G Subsistence Division, Fairbanks.

Pedersen, S., and M. Coffing. 1984. Caribou hunting: land use dimensions and recent harvest patterns in Kaktovik, northeast Alaska. Tech. Pap. No. 92. Div. of Subsistence, Alaska Dep. of Fish and Game, Fairbanks. 75pp.

Pedersen, S., M. Coffing, and J. Thompson. 1985. Subusistence land use and place names maps for Kaktovik, Alaska. Tech. Pap. No. 109. Div. of Subsistence, Alaska Dep. of Fish and Game, Juneau.

Reed, J.C. 1958. Exploration of Naval Petroleum Reserve No. 4 and adjacent areas, northern Alaska. 1944-53. Part 1, History of the exploration. U.S. Geol. Sur. Prof. Pap. 301. 192pp.

Reynolds, H.V. 1976. Caribou: survey - inventory. Prog. Rep. Vol. 6 Alaska Dep. Fish and Game, Fairbanks, Ak.

Reynolds, H.V. 1977. Caribou: Survey - inventory. Prog. Rep. Vol. 6 Alaska Dep. Fish and Game, Fairbanks, Ak.

Reynolds, H.V. 1978. Caribou: Survey - inventory. Prog. Rep. Vol. 8. Alaska Dep. Fish and Game, Fairbanks, Ak.

Ricciardelli, A.F. 1953. The causes which have led to the abandonment of the north slope of Alaska. M.A. Thesis, Univ. Pennsylvania.

Ricciardelli, A.F. 1954. Archaeological survey of Kongakut - Firth River area. in W.G. Carnes, eds. Preliminary geographic survey of the Kongakut - Firth River area. Unpub. Rep. National Park Service.

Ritchie, R.J., and R.A. Childers. 1976. Recreation, aesthetics and the use of the Arctic National Wildlife Range and adjacent areas, northeastern Alaska. Preliminary Rep. Arctic Gas Biol. Rep. Ser. 207pp.

Rossman, B.B., and Z.J. Ulehla. 1977. Psychological reward values associated with wilderness use. Environ. and Behav., Vol. 9(1):41-66

Schneider, W., and D. Libbey. 1979. Historic context of life on the north slope. Pages 37-46. in NPR-A Work Group 1 and North Slope Borough. Native livelihood and dependence: a study of land use values through time. Field Study 1 of 105c Land Use Study.

Seaman, G.A., G.F. Tande, D.L. Clausen, and L.L. Tresky. 1981. Mid-Beaufort coastal habitat evaluation study: Colville River to Kuparak River. Alaska Dep. of Fish and Game. 199pp.

Solecki, R.S. 1951. Archaeology and ecology of the arctic slope of Alaska. Pages 469-95. in Annual Rep. of the board of regents of the Smithsonian Instit. for 1950, Washington, D.C.

Solecki, R.S., B. Salwen, and J. Jacobson. 1973. Archaeological reconnaissances north of the Brooks Range in northeastern Alaska. Occas. Pap. No. 1, Dep. of Archaeology. Univ. of Calgary, Alberta.

Spencer, D.L., C. Naske, and J. Carnahan. 1979. National Wildlife Refuges of Alaska - A historical prespective, Part I. U.S. Fish and Wildlife Service, Anchorage, Ak. 183pp.

Stager, J.K. 1974. Old Crow, Yukon Territory and the proposed northern gas pipeline. Environmental-Social Program, Northern Pipelines, Task Force on N. Oil Dev. Rep. No. 74-21. 233pp.

Stefansson, V. 1914. Prehistoric and present commerce among the arctic coast eskimo. Geol. Surv. of Can., Mus. Bull. No. 6, Ottawa.

Stefansson, V. 1919. The Stefansson arctic expedition: preliminary ethonological report. Anthropological Papers of the Am. Mus. of Nat. Hist., Vol. 14, Pt. 1.

Stenmark, R.J., and T.H. Schoeder. 1974. Recreation and preservation opportunities - arctic region resources inventory. Joint Federal-State Land Use Planning Comm., Res. Planning Team. 83pp.

Stirling, I., D. Andriashek, P. Latour, and W. Calvert. 1975. Distribution and abundance of polar bears in the eastern Beaufort Sea. Beaufort Sea Project, Tech. Rep. 2, Instit. of Ocean Sci., Sidney, British Columbia. 59pp.

Stoker, S.W. 1983. Subsistence harvest estimates and faunal resource potential at Whaling Village in Northwestern Alaska. In Alaska Consultants Inc. and Stephen Braund and Associates 1984. Subsistence study of Alaska whaling villages, Unpub. Rept. U.S. Dept. of Inter., Anchorage, Ak.

Sumner, L. 1956. Your stake in Alaska's wildlife and wilderness. Sierra Club Bull. 41(10):54-71.

Tall, B. 1959. Our last wilderness. Sci. Newsletter. 76(9):154-155.

Thayer, A.S. 1979. Memorandum in response to 12 October 1979 memo, solid waste disposal. ANWR files, Fairbanks, Ak. 2pp.

Thayer, A.S. 1982. Wilderness evaluation of 1002(c) area. Memo. to Refuge Manager, Arctic National Wildlife Refuge, U.S. Fish and Wildlife Service, Fairbanks, Ak. 3pp.

U.S. Bureau of Indian Affairs. 1936. Reindeer program records. Alaska Reindeer Service. Univ. Alaska Archives, Fairbanks, Ak.

U.S. Bureau of the Census. 1950. Census of the population. U.S. Dep. of Comm., Washington, D.C., U.S. Gov. Printing Off.

U.S. Department of the Navy. 1977. Final environmental impact statement continuing exloration and evaluation of Naval Petroleum Reserve No. 4. Washington, D.C. 829pp.

U.S. Department of State. 1980. Draft environmental impact statement for the agreement between the U.S. and Canada for the conservation of migratory caribou. 105pp.

U.S. Fish and Wildlife Service. 1973. Arctic wilderness study report. Unpubl. Rep., on file Arctic National Wildlife Refuge, U.S. Fish and Wildlife Service, Fairbanks, Ak. 94pp.

U.S. Fish and Wildlife Service. 1978. Draft environmental impact statement, proposed Arctic Wilderness, Alaska. Unpubl. Rep., on file Arctic National Wildlife Refuge, U.S. Fish and Wildlife Service, Washington, D.C. 69pp.

U.S. Fish and Wildlife Service. 1982. Initial report, baseline study of the fish, wildlife and their habitats, Arctic National Wildlife Refuge coastal plain resource assessment. U.S. Fish and Wildlife Service, Anchorage, Ak. 507pp.

Warbelow, C., D. Roseneau, and P. Stern. 1975. The Kutchin caribou fences of northeastern Alaska and the northern Yukon. in Arctic Gas Report. Series, Vol. 32. Renewable Resources Consulting Services Ltd. 129pp.

Warren, G.A. 1980. Activities, attitudes and management preferences of visitors of the Arctic NWR, Alaska. M.S. Thesis, Univ. of Idaho, Moscow. 51pp.

Wentworth, C. 1979. A Kaktovik synopsis. Pages 89-105 in Native livelihood and dependence: a study of land use values through time. National Petroleum Reserve in Alaska, 105c Land Use Study, Field Study 1, U.S. Dep. of Inter., Anchorage, Ak.

Whistler C. 1916. Harpoons and darts in the Stefansson collection. Anthropological Pap. of the Amer. Mus. of Nat. Hist. 14(2).

Whitten, K.R. 1980. Caribou: Survey - inventory. Prog. Rep. Vol. 10. Alaska Dep. of Fish and Game, Fairbanks, Ak.

Wilson, C.J. n.d. Report of archaeological survey of the Arctic National Wildlife Refuge. Unpub. Rep. on files at Arctic National Wildlife Refuge, U.S. Fish and Wildlife Servie, Fairbanks, Alaska.

Wolfe, R.J., and L.J. Ellanna. 1983. Resource use and socioeconomic systems: case studies of fishing and hunting in Alaskan communities. Div. of Subsistence, Alaska Dep. of Fish and Game, Juneau, Ak.

Worl, R. 1979. Values of subsistence to north slope Inupiat culture. Pages 17-26. in Native livelihood and dependence: a study of land use value through time. National Petroleum Reserve in Alaska; 105c Land Use Study, Field Study 1, U.S. Dep. Inter., Anchorage, Ak.

Worl, R.F. and P.O. McMillan. 1982. Part I. Kaktovik pages 11-93 in Arctic Environmental information and Data Center. Sociocultural Assessment of proposed Arctic National Wildlife Refuge oil and gas exploration final report. Univ. Alaska, Anchorage. 194pp.

Chapter 8

# IMPACTS OF FURTHER EXPLORATION, DEVELOPMENT AND PRODUCTION OF OIL AND GAS RESOURCES

Section 1002 (c) (D) of ANILCA requires the baseline study to address the impacts of exploration and development of petroleum resources upon the fish and wildlife resources of the coastal plain study area. The Initial Baseline Report (U.S. Fish and Wildlife Service 1982) addressed impacts of geophysical exploration separately from impacts of further exploration, development, and production of oil and gas. Additional geophysical exploration will likely be an integral part of any further exploration activity that Congress may authorize; however, experience with winter geophysical exploration on the Arctic National Wildlife Refuge (ANWR) and elsewhere on Alaska's north slope has shown that impacts to surface resources are minor, especially when compared to potential effects from development and production. Consequently the discussion of geophysical exploration effects has been integrated into this chapter in the Final Baseline Report.

This chapter is a compilation of current information on the impacts of exploration and development of petroleum resources in arctic areas and an analysis of how such activities may affect surface resources of the study area if further exploration, development and production are authorized by Congress. This report discusses impacts of petroleum exploration and development at the generic level, and does not address cumulative impacts. Predictions of petroleum reserves, their locations, means of extraction, and site specific cumulative effects to surface resources are discussed at length in the Report to Congress required by 1002 (h) ANILCA. The Report to Congress also discussed various mitigation measures designed to reduce or eliminate adverse effects of further oil and gas activities on the ANWR coastal plain. The Secreatry's recommendations contain additional measures that may be required to insure that adverse effects are minimized or avoided. Therefore, this Chapter makes no attempt to include types of mitigation that might be used. Instead, it provides a general discussion of the types of effects that may occur as the result of standard industry practices.

Examples of petroleum exploration, development, production, and transportation are found in nearby oil fields on the north slope of Alaska (Fig. 1). Currently in production are the Prudhoe Bay, Kuparuk River, and Milne Point units. East and north of the Prudhoe Bay, is the Endicott unit which will begin production in 1987. Point Thomson, Mikkelson Bay, and the Colville River delta are currently being explored. Point Thomson is along the coast just west of the ANWR study area. The Mikkelson Bay unit is between Prudhoe Bay and Point Thomson. The Colville River delta is west of Prudhoe Bay. The National Petroleum Reserve-Alaska (NPRA), extends from the Colville River west to the Chukchi Sea, and has been explored under the direction of the U.S. Geological Survey (USGS) and the Bureau of Land Management (BLM). Tracts which have been leased or are scheduled for lease in NPRA or elsewhere (both onshore and offshore) are indicated in Fig. 1. Oil and gas exploration is also occuring off the MacKenzie River delta in Canada. General discussions of oil development scenarios have been presented by U.S. Geological Survey (1979), Bureau of Land Management (1983), and in Chapter IV of the Section 1002 (h) Report to Congress. They are repeated here in part to provide an understanding of the types of effects that may occur.

A transportation system for oil and gas is required in the production phase of oil development. The oil from Prudhoe Bay and associated fields is transported through a combination of pipeline and tanker ships. Oil produced from ANWR would probably be transported through above-ground pipelines to Pump Station No. 1 of the Trans-Alaska Pipeline System (TAPS), and then follow the route of current Prudhoe Bay oil. Shutdown, abandonment, and rehabilitation would follow the end of production; this phase has not yet occurred on the north slope.

A discussion of oil and gas development on federal lands in Alaska is contained in Hanley et al. (1980). While development on a National Wildlife Refuge may come under different regulations than on other federal, state or private lands, the general scenario for development would be similar (Hanley et al. 1980).

Impacts which may occur are related to the intensity of field development, such as spacing and number of well pads, size of the field, amount and kind of support services required, and the type of petroleum transportation system used. Several publications have included discussions of potential impacts of petroleum development (U.S. Dept. of Interior 1976, U.S. Geological Survey 1979, Bureau of Land Management 1981, Starr et al. 1981, Bureau of Land Management 1983).

This chapter is arranged in 3 main sections. The first section discusses impacts of the seismic exploration program conducted during 1984 and 1985 on ANWR. The second section analyzes potential impacts of further exploration for petroleum resources on the coastal plain of ANWR, including the drilling of exploratory wells. The third section analyzes potential impacts of development, production, and transportation of petroleum resources. Each section is preceeded by a general presentation of the types of petroleum related activities involved. The discussion of potential impacts on ANWR's coastal plain resources is presented in the order in which they appear in Chapters 3 through 7 of this document. Again, these analyses are generic; no attempt has been made to develop analyze cumulative impacts as the Report to Congress addresses this aspect of the resource assessment.

## Surface and Seismic Exploration

Section 1002(a) of ANILCA authorized oil and gas exploration on the ANWR study area in a manner that avoided significant adverse effects to the fish and wildlife and other resources. The U.S. Fish and Wildlife Service (USFWS) published an environmental impact statement in February 1983, and final regulations governing exploration on the study area were published in the Federal Register on 19 April 1983 (48 FR 16838-16872), and codified in 50 CFR 37.

Surface and subsurface geological exploration includes stratigraphy, structure, paleontology, and geochemistry, and is generally the first step to exploring previously unexplored areas. It can yield important information about the rocks likely to be present in the subsurface. In the study area, where bedrock is not exposed, data are gathered from rocks exposed in adjacent areas (ie: the Brooks Range and its foothills) and extrapolated to the study area. Data acquired by surface geological studies include (1) determining the order and age of the stratigraphic sequence, (2) measuring the thickness of

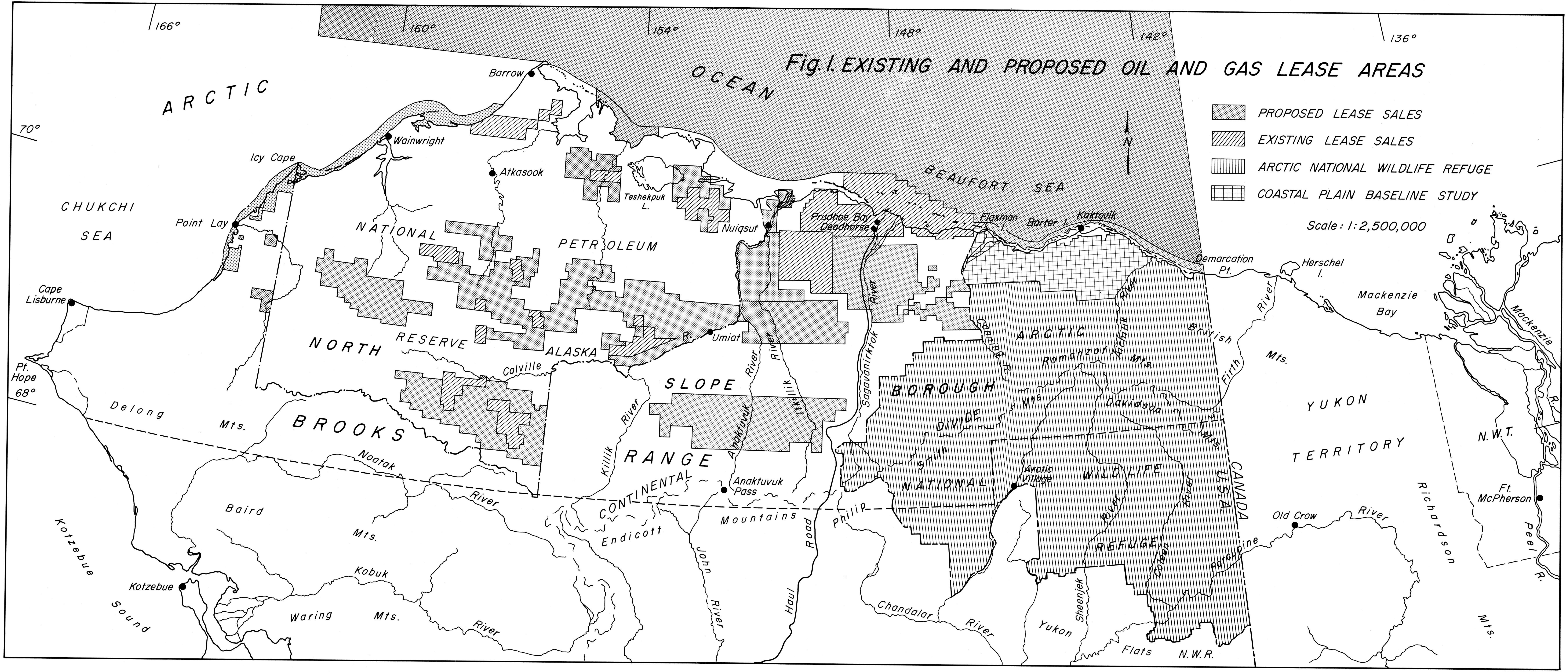


Fig. I. EXISTING AND PROPOSED OIL AND GAS LEASE AREAS various stratigraphic units, (3) making sedimentologic studies to determine depositional environments, which are necessary to extrapolate the stratigraphic sequence into the subsurface, (4) sampling different rock units for reservoir, geochemical, and paleontologic studies, and (5) determining the structural style and timing of the deformation.

Surface exploration crews from 13 different companies visited the ANWR study area during the summers of 1983-1985. Access was by helicopter. The work involved field observations, surface measurements, mapping, and collecting rock samples. Samples were analyzed for age and geochemistry (hydrocarbon-generation potential), and porosity and permeability (potential-reservoir characteristics). The USFWS monitored all activities, and no significant adverse effects to fish or wildlife or their habitats were observed.

Subsurface geologic structure is not always accurately indicated by surface outcrops. In such cases, geophysical exploration is used. Three commonly used methods are seismic, gravity, and magnetic surveys. Gravity and magnetic surveys provide regional information on the general thickness or presence of sedimentary rocks, and in some cases on the presence and extent of large structures or faults. Gravity surveys measure small differences in the earth's gravitational field caused by differences in density of various types of rocks. Small portable instruments called gravimeters take measurements along traverses across an area with stations spaced from less than 0.8 km to 5.0 km apart. Magnetic surveys supplement gravity surveys, using relatively small airborne or portable ground instruments called magnetometers that measure subject variations in the earth's crust.

A helicopter-supported gravity survey was conducted on the ANWR study area in late summer 1983. The permittee collected approximately 1,300 gravity readings at ground level along a 1.6-3.2 km grid covering the entire study area. The survey was restricted by spatial closures when snow geese were staging on the ANWR coastal plain, and no significant adverse effects to fish and wildlife resources were documented.

Seismic surveys gather subsurface geological information by recording impulses from an artificially generated shock wave. The procedure consists of creating shock waves and recording, as a function of time, the resultant seismic energy as it arrives at groups of vibration detectors (seismometers or geophones) on the surface. These arrays of geophones are connected to a recorder truck that receives and records the reflected seismic energy. The 2 most commonly used methods of generating shock waves are explosives or vibrator. When using dynamite 2-45 kg of explosive charges are detonated at the bottom of a 7-60 m hole (shothole) drilled by a truck-mounted drill. The vibrator method (Vibroseis, a registered trademark of CONOCO) uses 3 or 4 large trucks or tractors, each equipped with a vibrator pad mounted between the front and back wheels, and 4 or 5 support vehicles. The vibrator pads (about 1.2m$^2$) are lowered to the ground and vibrations are triggered electronically from the recorder truck. After the information is recorded, the trucks are moved forward a short distance and the process repeated.

Winter seismic exploration occurred in the study area from January through May in 1984 and 1985. A total of 2000 km of seismic line arranged in an approximately 10 x 19 km grid were completed during the 2 year program (Fig. 2). The shothole technique was used for most of the 1984 program (Plate 1);

Vibroseis was used for coastal tie lines. The entire 1985 program used Vibroseis. The 2 techniques required different types and numbers of vehicles as shown in Table 1.

Table 1. Vehicles used in 1984 and 1985 for seismic surveys on the study area.

| 1984 Shothole Crew | | 1985 Vibrator Crew | |
|---|---|---|---|
| 8 | Drills on FN-110 tracked vehicles (2.8 psi) | 5 | Tracked vibrator units (4.5 psi) |
| 1 | Preload vehicle-FN110 (2.8 psi) | 1 | Chieftain tracked vibrator tender (3.5 psi) |
| 1 | Chieftain tracked recording vehicle (3.5 psi) | 1 | Chieftain tracked recording vehicle (3.5 psi) |
| 4 | Geophone carriers-FN110 (2.8 psi) | 4 | Geophone carriers-FN110 (2.8 psi) |
| | | 1 | Drill on FN-110 tracked vehicle (2.8 psi) |
| 9 | Bombardiers (1.3 psi) | 8 | Bombardiers (1.3 psi) |
| 1 | Camp FN-110 with crane (2.8 psi) | 1 | Camp FN-110 with crane (2.8 psi) |
| 6 | Caterpillar D-7 tractors (10.5 psi) | 6 | Caterpillar D-7 tractors (10.5 psi) |
| 14 | Camp sleighs (6.0 psi) [2 strings of 5, 1 string of 4] | 12 | Camp sleighs (6.0 psi) [3 strings of 4] |
| 3 | 6000 gallon fuel sleighs (6.0 psi) | 4 | 6000 gallon fuel sleighs (6.0 psi) |
| 1 | Dynamite magazine (8.0 psi) | 1 | Sleigh-mounted survival unit for remote deployment (on 1 crew) |
| 1 | Magazine for detonators (less than 1.0 psi) | | |

For both Vibroseis and shothole operations, crews laid out geophones in a line ahead of the seismic crew, using bombardiers and a snow machine. The Nodwell geophone carriers made several passes on each line to lay out and pick up the geophone cables used for data collection. A Chieftain recording vehicle carried the electronic equipment needed to record seismic data.

In the 1984 program, 8 truck-mounted drills were used to drill shotholes (18 m deep) at 67 m intervals on approximately 800 km of the seismic lines, and at 101 m intervals on 160 km of line (Plate 2). A Nodwell preload vehicle filled each shothole with explosives. The shooter bombardier then travelled to each hole and a radio signal sent by the recorder was used to set off the explosives. Multiple passes of vehicles left straight trails on either side of the shotholes, with total trail width ranging from 10 m to 80 m and averaging 31 m.

In 1985, 5 tracked vibrators made single trails parallel to each other along the seismic line, creating a total trail approximately 41 m wide with a range from 20 m to 110 m (Plate 3). The 5 vibrators made 8 sweeps (vibrations) per 33.5 m interval or 12 sweeps per interval when only 4 vibrators were operating. For each sweep, each vehicle stopped in formation, the vibration pad (2.4 x 1.0 m) was lowered to the ground, and most of the vehicle's weight was raised off the tracks onto the pad. A radio signal sent by the recorder initiated the vibrations. A Chieftain tracked vibrator tender was used to repair vibrators and to transport fuel from camp to the vibrators.

Ski-mounted camps pulled by Caterpillar D-7 tractors (cat-trains) usually moved daily to stay ahead of the crews (Plates 4 and 5). These camp moves occasionally followed the seismic line, but often followed separate routes

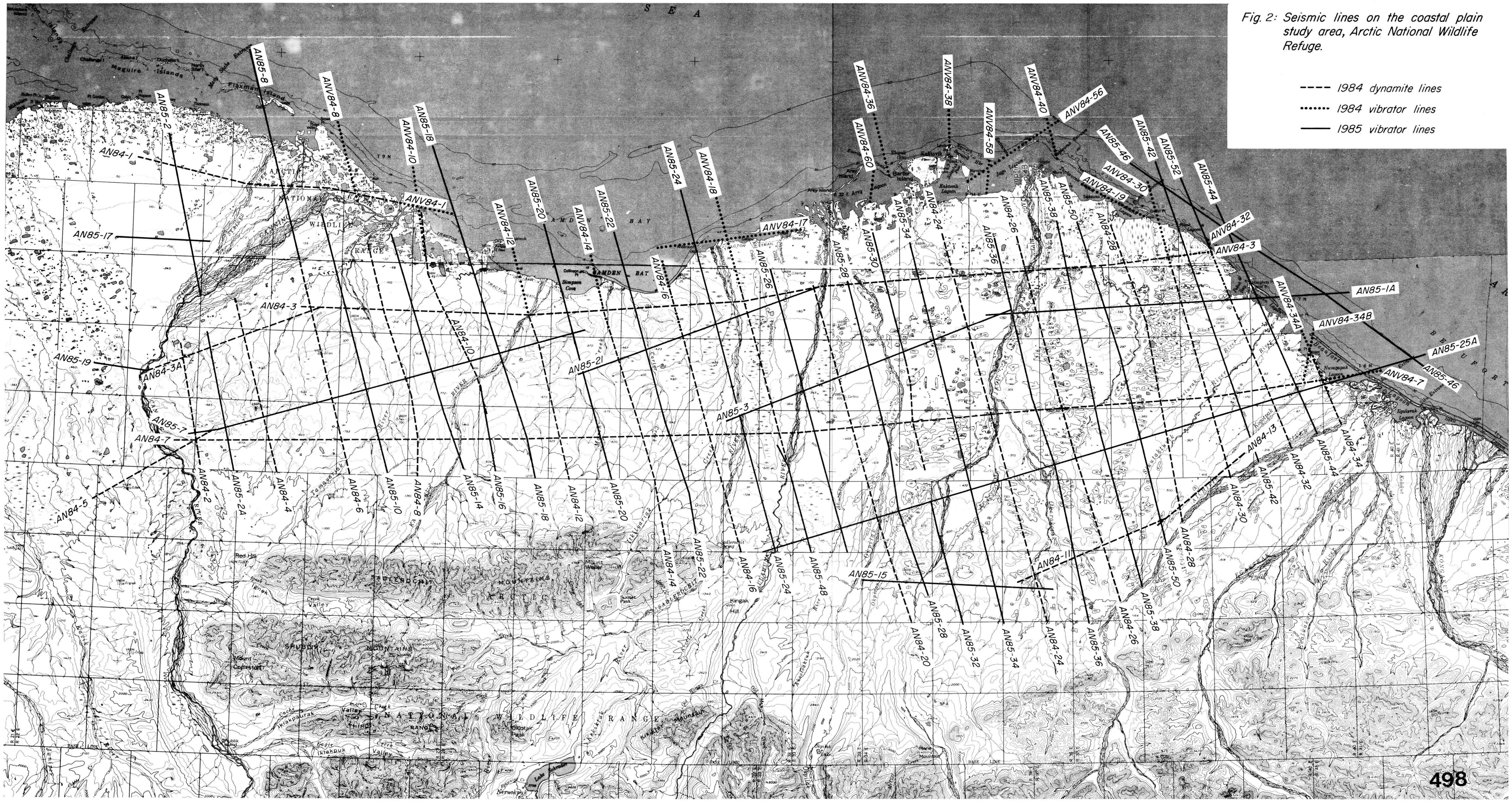


Fig. 2: Seismic lines on the coastal plain study area, Arctic National Wildlife Refuge.

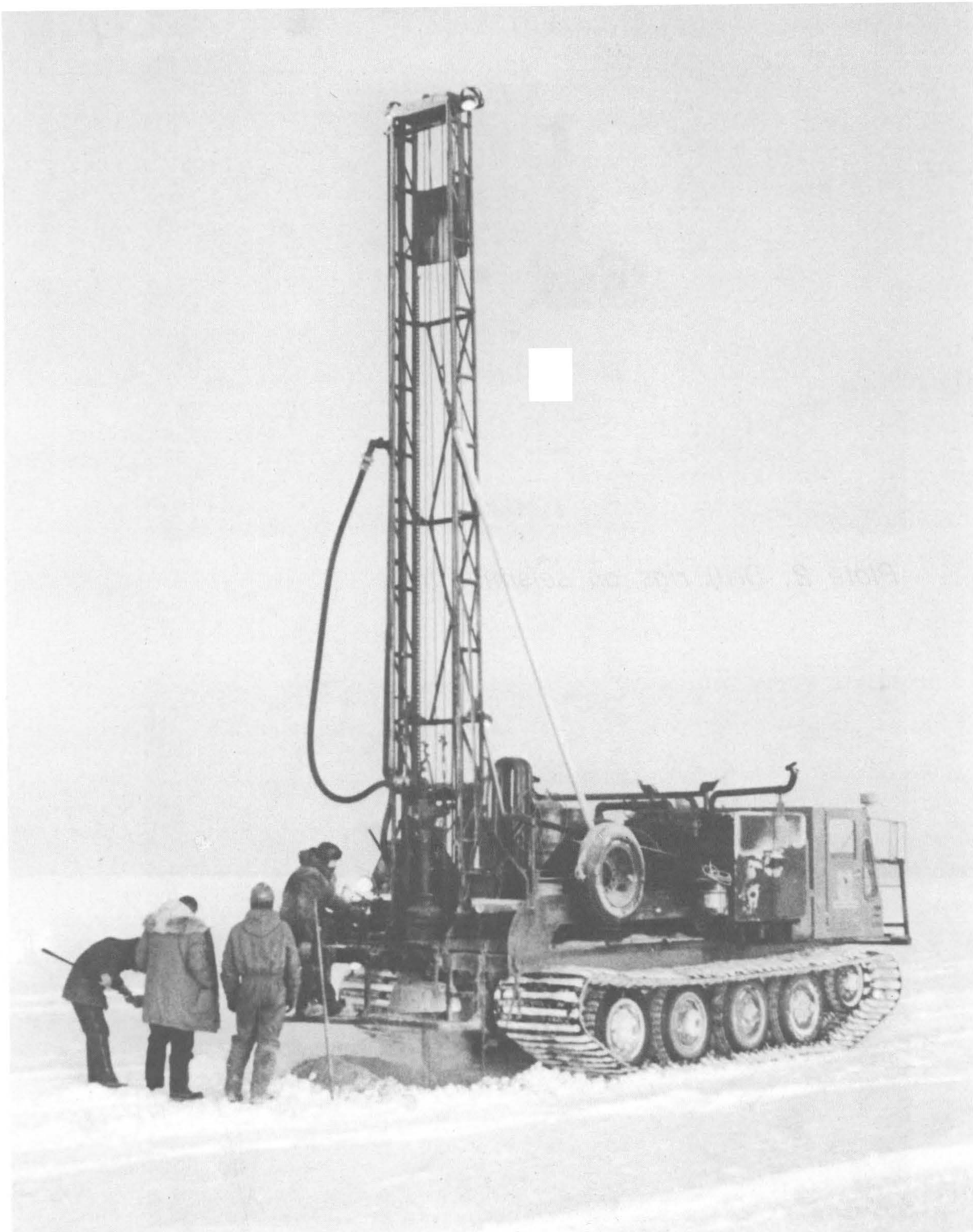

*Plate 1. Mobile drill rig drilling shothole in which to place dynamite.*

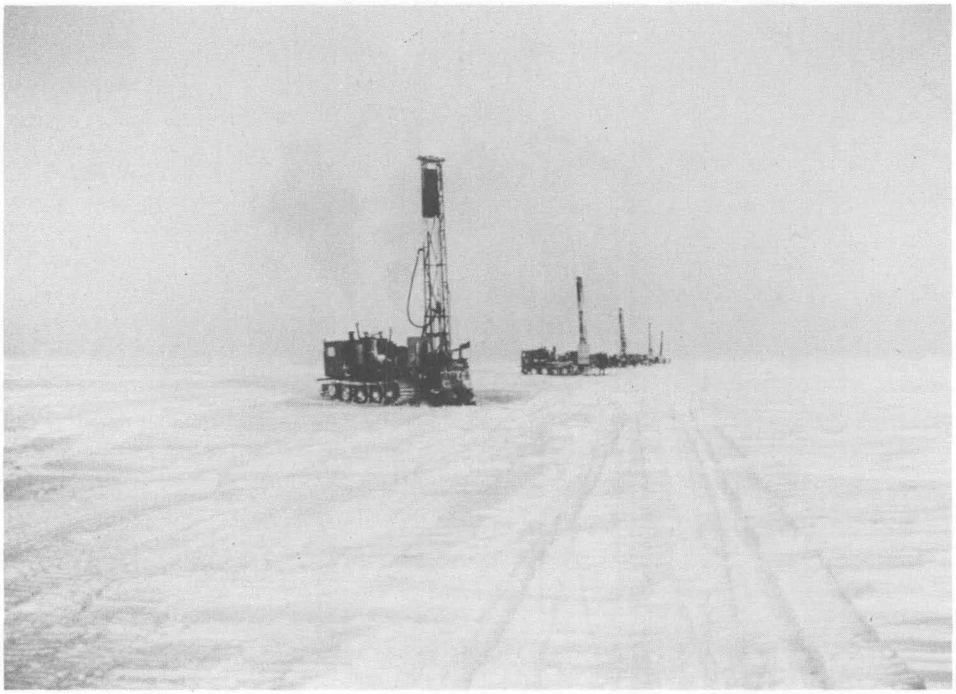

*Plate 2. Drill rigs on seismic line.*

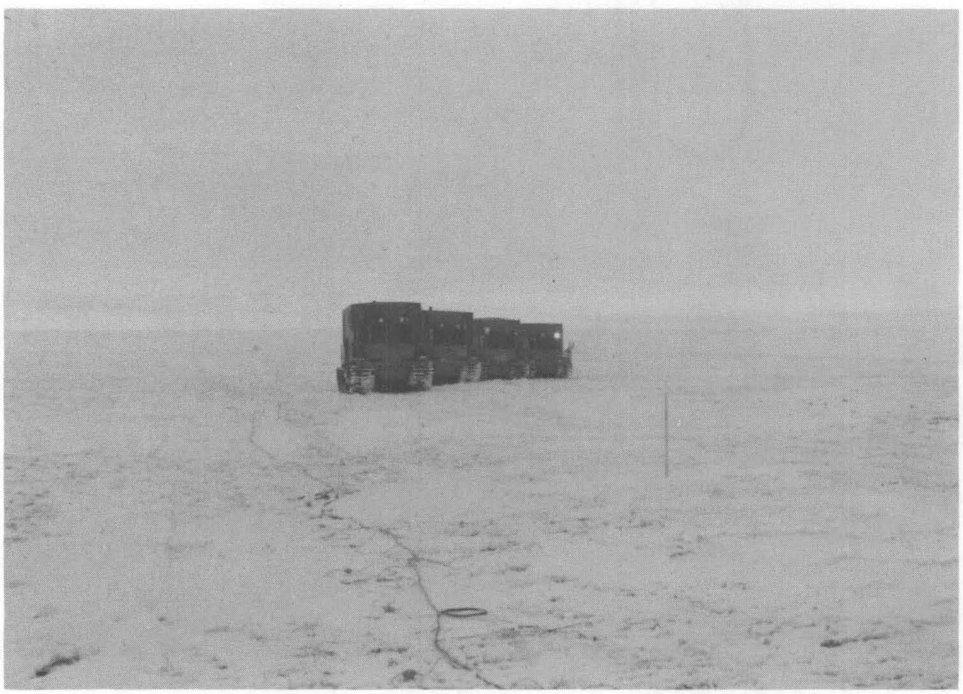

*Plate 3. Tracked vibrators proceeding along seismic line in parallel.*

through areas of deeper snow and around areas of sensitive vegetation types to minimize surface disturbance. Resupply of fuel, and explosives in 1984, were transported overland from the coast in ski-mounted tanks and magazines pulled by D-7 Caterpillar tractors. Other supplies and personnel were flown in by a turbine Beaver or Twin Otter, which landed on a small lake or tundra airstrip.

## Impacts to Vegetation and Surface Stability

The following descriptions of disturbance due to winter seismic exploration are based on studies and observations of by USFWS personnel (Felix and Jorgenson 1985, and Felix et al. 1986a, b, c).

### Vehicle Trails

Winter seismic exploration left a series of visible trails across the tundra, which included seismic lines, camp moves, and single vehicle trails (Plate 6). Statistically significant decreases in plant cover, changes in nutrient levels, increases in active layer thickness, and track depression occurred in the first 2 summers following seismic exploration. These impacts are detailed below by vegetation type.

The most severe impacts occurred on narrow trails with multiple vehicle passes, usually camp moves or supply routes (Plate 7). Diffuse traffic patterns, where vehicles made parallel tracks next to each other, caused less severe damage to the tundra. The visibility and vegetation damage on vibrator seismic lines (1985) was slightly higher than on drill trails, because of the greater weight of the vehicles. However, the diffuse traffic pattern of the vibrator lines minimized this disturbance. Turning vehicles also created more disturbance than vehicles travelling in a straight line. During turns, vehicle tracks dug deeply into the vegetation mat, compressing and killing vegetation, and exposing soil in some areas (Plate 8). Vehicles turns were more frequent on shothole lines than on vibrator lines, since the drills turned to position themselves at each shothole.

Cat-trains generally caused more damage than the vehicles used on seismic lines. However, routing camp moves was more flexible than that of seismic lines and cat-trains often detoured around sensitive areas to minimize disturbance.

Concentrated vehicle use occurred around campsites. The most disturbed campsites were surrounded by vehicle trails radiating in all directions (Plate 9). To minimize these impacts, campsites were located in drifted drainages when possible, and a single route was marked between camps and the seismic line.

An average snow depth of 15 cm was required before vehicles were permitted on the tundra. This depth prevented vehicle tracks from digging directly into the vegetative mat in most cases. However, in areas of high micro-relief, exposed microsites remained even when the average snow depth was well above 15 cm. Vegetation studies showed that snow depths above 25 cm were more effective in controlling the amount of disturbance resulting from vehicle traffic. Snow depths well over 40 cm would be necessary to completely prevent visible disturbance.

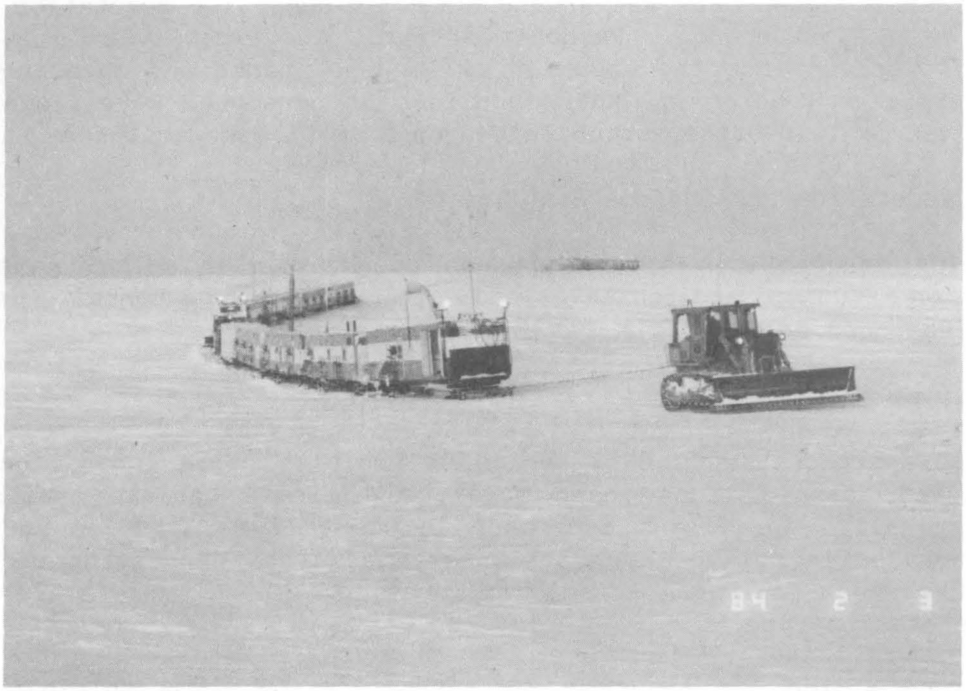


*Plate 4. Caterpillar D-7 tractor pulling sled-mounted camp trailers (cat-train). The mobile camp usually moved daily to stay near the seismic crews.*

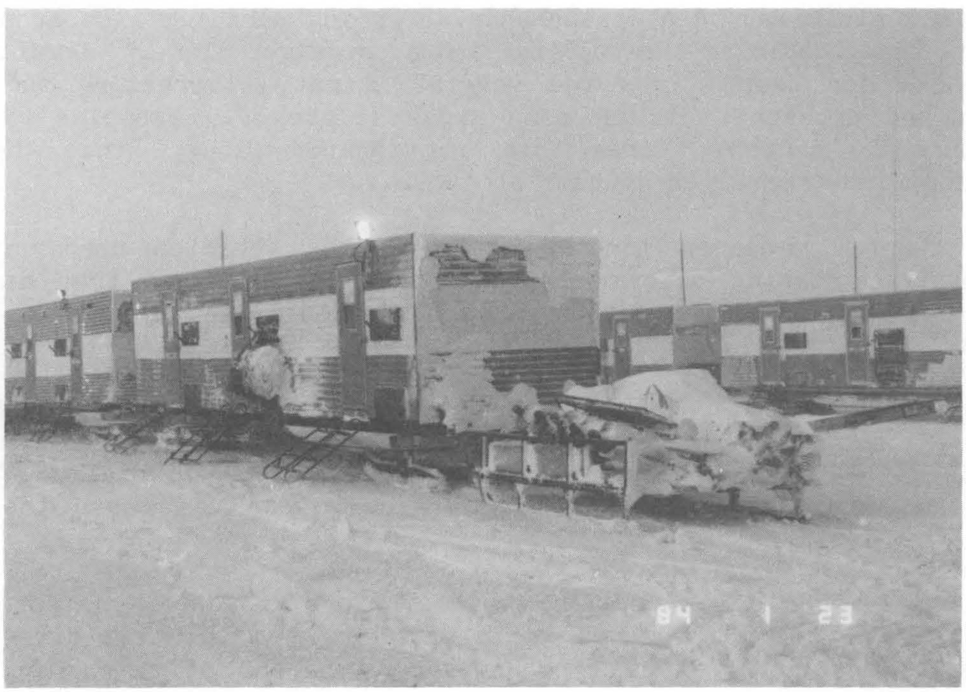


*Plate 5. Trailers in parallel lines at campsite. Trailers were set up in close proximity for crew safety during whiteouts.*

Plate 6. Seismic line through wet and moist sedge tundra, photographed the following summer. Vehicles travelled on either side of the center survey line; single vehicle trails can be seen on the edges of the line.

*Plate 7. Disturbance due to multiple vehicle passes along a narrow trail in an area of high micro-relief.*

*Plate 8. Disturbance caused by a sharp turn made by a tracked vehicle.*

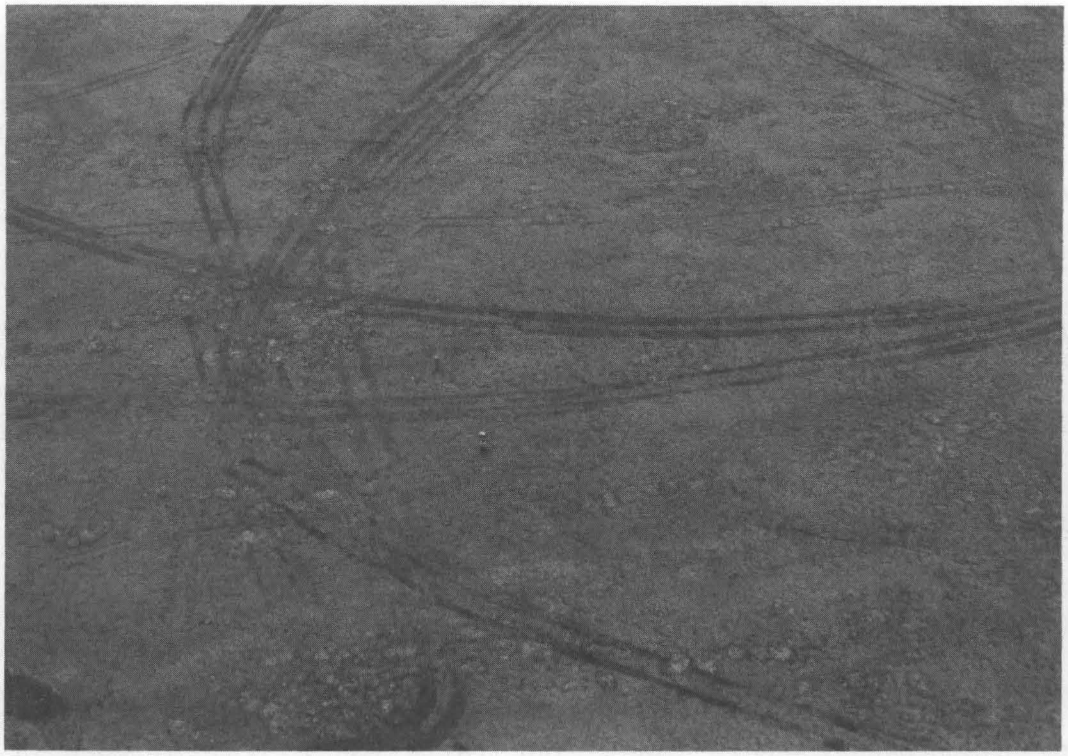

*Plate 9. Trails around campsite in moist sedge, prostrate shrub tundra. Decreased standing dead, and increased moisture and soil exposure give the tracks a dark appearance.*

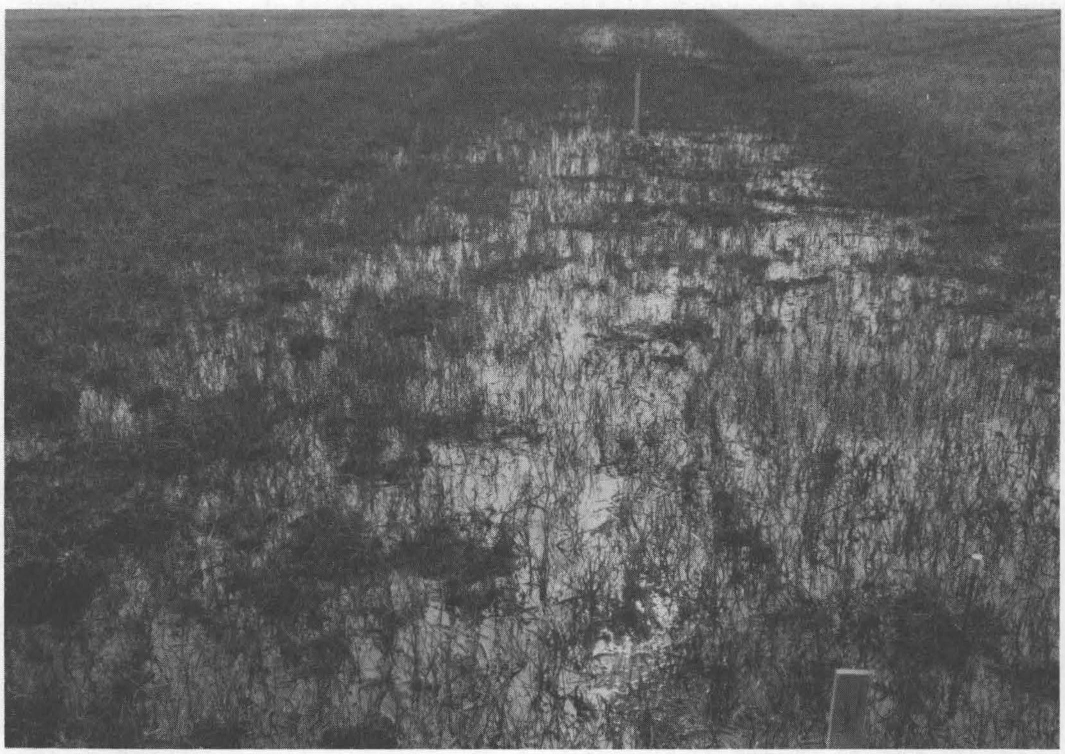

*Plate 10. Narrow supply trail through wet sedge tundra. All the standing dead was knocked down, mosses were compressed, and track depression occurred, resulting in standing water on the trail.*

Vehicle trails showed slight recovery during the second growing season after disturbance. Aerial visibility of some trails decreased due to the drying and weathering of exposed peat and soil to a lighter color, an increase in the amount of standing dead, and (more rarely) to regrowth of vegetation. Slight increases in plant cover were evident disturbed plots in the second season after disturbance. Bare patches changed little in appearance, but some recolonization occurred, mainly by vegetative propagation from adjacent plants.

Wet Sedge and Moist Sedge, Prostrate Shrub Tundra. Wet sedge tundra includes sedge or grass dominated communities, usually on poorly drained, seasonally flooded sites, such as low-centered polygons. This vegetation type is typically dominated by the sedges *Carex aquatilis* and *Eriophorum angustifolium* (Appendix I, Table 1). Moist sedge, prostrate shrub tundra is found on better drained sites, and is often dominated by cottongrass (*Eriophorum angustifolium*) and willow (*Salix planifolia* ssp. *pulchra*).

Disturbance in these vegetation types ranged from knocking down standing dead leaves to compression of the moss mat and obvious track depression. Even single vehicle passes compressed the gray-brown standing dead leaves to the ground surface, creating green trails that were more visible than single vehicle trails in other vegetation types. During the second growing season following disturbance, sedge plants on trails had 1/3 the number of dead leaves found on plants in the control areas. Two more growing seasons are expected to produce a full complement of standing dead leaves per plant, resulting in reduced trail visibility.

Ground cover of sedges changed little on disturbed plots in the first year, and increased to above control levels on a few plots in the second year after disturbance. Leaf mass and number of live leaves per plant increased on 2-year-old wet sedge sites, but nitrogen and phosphorus concentrations decreased compared to control plots. Many researchers have reported similar increases in sedge cover on old trails (usually more heavily disturbed) in comparable vegetation types (Chapin and Chapin 1980, Everett et al. 1985). Challinor and Gersper (1975) and Chapin and Shaver (1981) both found increases in nutrient concentrations on trails, contrary to USFWS data.

Mosses were the most sensitive life form in areas of wet and moist sedge tundra, with statistically significant decreases in moss cover ranging from 30-50%. Other studies have also shown that in wet vegetation types, mosses are vulnerable to compression and abrasion in the winter, whereas the graminoid component of the vegetation is protected because the roots are in frozen soil (Hernandez 1973a, Lawson et al. 1978). As a result of compression, standing water was sometimes apparent on the trails that was not visible in adjacent areas (Plate 10). Trails with standing water were easily visible from both the air and the ground, and Abele et al. (1984) found that they were slower to recover than trails without standing water. Standing water on trails was not observed in 1985, which was a dry year.

Willow cover was decreased on many moist sedge, prostrate shrub tundra sites. An increase in shoot length was apparent on several plots in the second year after disturbance. Measurements of twig mass and length were greater and leaf nitrogen concentration was higher on a 2-year-old disturbed plot when compared to a nearby control.

Disturbance in wet sedge and moist sedge, prostrate shrub tundra areas did not create much bare ground or exposed soil. The edges of the small bare patches were being recolonized by vegetative shoots of sedge and willow species that were common in the adjacent vegetation. Seedlings were absent or rare on all moist sedge, prostrate shrub plots, but accounted for 20% of all recolonizing shoots on 1 wet sedge site. Mosses were also recolonizing this wet sedge site, but were rarely present as recolonizers in other vegetation types.

Statistically significant increases in thaw depth (up to 16 cm) were found at many disturbed wet and moist sedge sites. Increased thaw depths even occurred at low levels of disturbance where knocking down standing dead leaves was the main disturbance. Such disturbance causes increased surface absorption of sunlight, and, thus, warming of soils (Babb and Bliss 1974, Haag and Bliss 1974). Warming the soil causes an increase in thaw depth, thawing ground previously permanently frozen. If the permafrost is ice-rich, thawing will cause loss of ice volume, and consequent subsidence. Subsidence, combined with compression of vegetation, led to measurable track depression on several narrow trails through moist sedge, prostrate shrub tundra and wet sedge tundra. This depression, ranging from 5 to 12 cm, was observed more frequently in moist sedge, prostrate shrub tundra than any other vegetation type.

Abele et al. (1984) reported recovery of track depression on vehicle trails in wet sedge tundra. In the most rapid case, a 15 cm depression caused by multiple passes of light tracked vehicles in late summer rebounded to natural levels within 10 years. Recovery on wider rolligon trails and on trails with standing water occurred at a slower rate. A slight decrease in surface depression was evident on all trails studied by Abele et al. (1984) in the first year after disturbance. In contrast, no recovery of surface depression was found in the study area in the second summer after winter seismic exploration. Long-lasting track depressions have been reported in tussock tundra usually on trails with large decreases in plant cover (How and Hernandez 1975, Lawson et al. 1978, Everett et al. 1985). No studies have been conducted in moist sedge, prostrate shrub tundra similar to that found in the study area.

Moist Sedge/Barren Tundra Complex. These moist, well-drained graminoid, shrub communities have over 30% cover of hummocks or frost scars (Appendix I, Table 1). Disturbance resulted in scuffing of these fragile mound tops and statistically significant reductions in cover of prostrate shrubs, mosses, and lichens occurred. Trails in this vegetation type were often barely perceptible because of the large amount of natural disturbance (frost scars) adjacent to the trails. Trail visibility increased with the level of disturbance. Visibility decreased in the second year due not to recovery of vegetative cover, but rather to the fact that exposed soil dried out and weathered to a less contrasting color.

The prostrate shrub, *Dryas integrifolia* was impacted the most, with up to 80% decreases in *Dryas* cover. Other researchers have noted the vulnerability of prostrate shrubs, and their slow rate of recovery (Barrett and Schulten 1975). However, several of the USFWS 2-year-old study plots this vegatation type showed slight increases in *D. integrifolia* cover, and long-term recovery of *Dryas* cover has been reported (Reynolds 1982, Everett et al. 1985).

Deciduous shrubs (including the willows Salix phlebophylla and Salix reticulata) showed statistically significant decreases in cover. Some resprouting of Salix phlebophylla was evident on second year trails. Mosses and lichens, which were commonly growing on frost scar areas, had large decreases in cover (up to 90% decrease in crustose lichen cover), and showed no sign of recovery.

Disturbance caused more exposure of peat and mineral soil (up to 12%) in moist sedge/barren tundra complex than in most other vegetation types. Small patches of bare soil were common due to disruption of hummocks and frost boils. At the most disturbed sites nearly all the higher microsites were disrupted. Some graminoid species (particularly Arctagrostis latifolia and Carex bigelowii) and a few forb species, which commonly colonized the natural frost scar disturbance, were found in the patches of bare soil created by winter traffic. Frost action and needle ice formation are common in this vegetation type, and they disrupt the soil surface making plant establishment difficult.

Thaw depths were highly variable, corresponding with the amount of frost scar activity in any given area. Average increases in thaw depth in the most disturbed sites were 6-10 cm, with no measurable compression or subsidence.

Moist Sedge Tussock, Dwarf Shrub Tundra. Tussock tundra is found on well-drained sites, including gentle slopes and high-centered polygons, and is dominated by the tussock-forming cottongrass Eriophorum vaginatum (Appendix I, Table 1). Disturbance in this vegetation type ranged from lightly scuffed tussocks to broken tussocks (Plate 11). Trails were visible as brown tracks the first year (Plate 12), and changed to less visible gray trails as the litter and exposed peat weathered and dried. Resprouting of Eriophorum vaginatum from damaged tussocks also lessened trail visibility.

Ericaceous shrubs (Ledum palustre ssp. decumbens and Vaccinium vitis-idaea) and dwarf birch (Betula nana) were sensitive to disturbance, with lower cover values on most disturbed plots. Other researchers have reported similar sensitivity, particularly to winter disturbance, when the shrubs are brittle (Lambert 1972, Hernandez 1973a, Chapin and Shaver 1981). Moss and lichen cover decreased on all disturbed sites. Disturbance commonly caused small patches of exposed peat due to disruption of tussocks and hummocks.

Shoot weights and nitrogen concentrations of tussock cottongrass, diamond-leaved willow, and dwarf birch (B. nana) were higher on some disturbed sites than on corresponding control sites, corroborating Chapin and Shaver's (1981) findings. Tillers were commonly observed recolonizing the edges of crushed tussocks. Tussock cottongrass seedlings were completely absent, in marked contrast to other studies of disturbance in tussock tundra (Chapin and Chapin 1980, Gartner et al. 1983). However, this lack of seedlings agrees with the lack of germinable buried seed found in selected study plots (Felix and Jorgenson 1985), and the evidence of a decrease in tussock tundra seedbank size with increasing latitude (Ebersole 1985). Vegetative shoots of lingonberry (Vaccinium vitis-idaea) and some mosses (Aulacomnium spp., Pohlia spp., Polytrichum spp.) were occasional colonizers of bare patches. Lingonberry has been found to vigorously recolonize small bare patches in tussock tundra by resprouting from buried roots (Ebersole 1985), though more severe damage has led to reductions in cover which persisted for decades

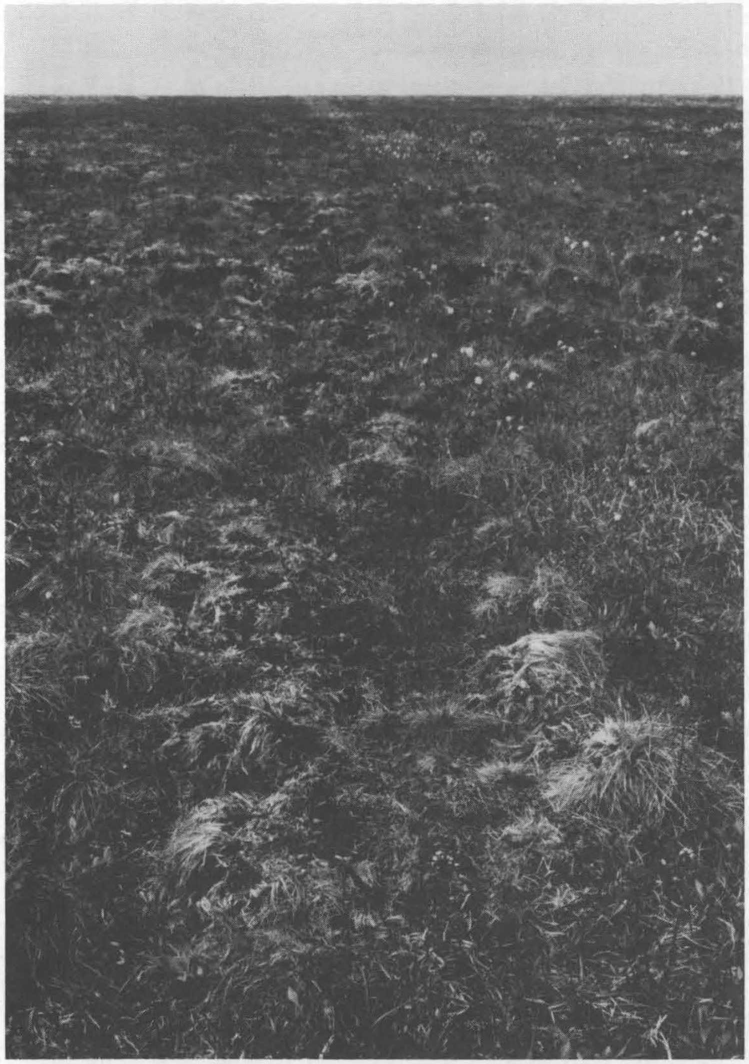

*Plate 11. Crushed and broken tussocks along a cat-train track.*

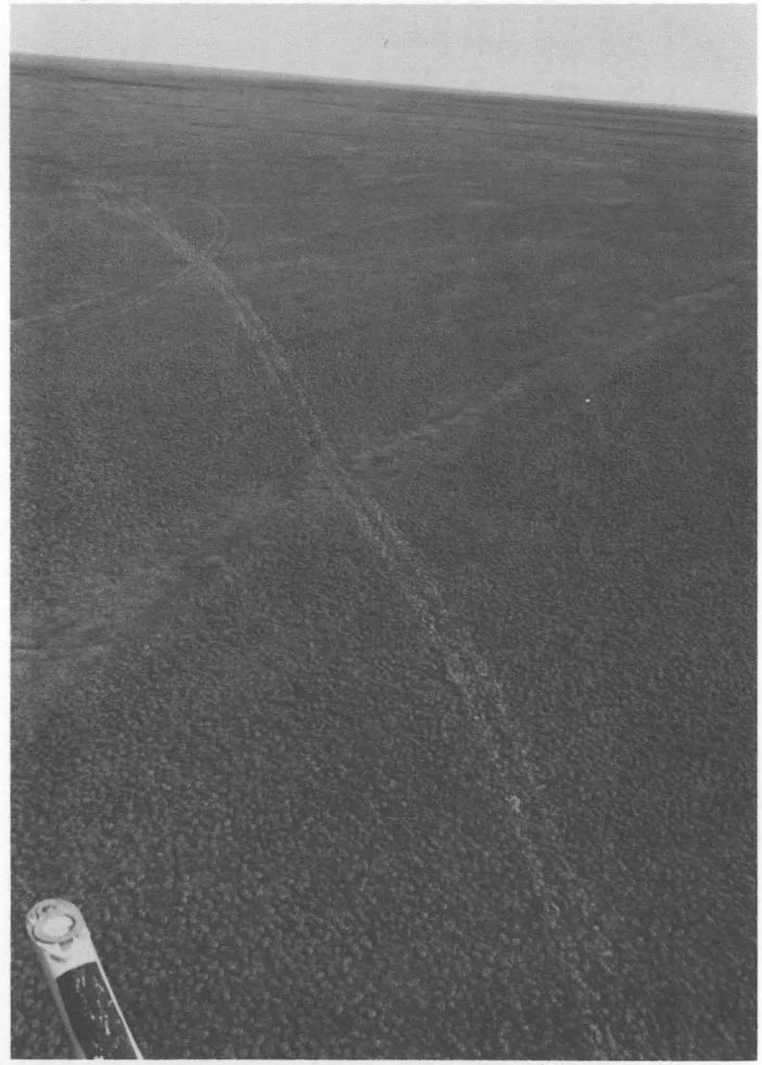

*Plate 12. Narrow camp move trail across tussock tundra. Scuffed and crushed tussocks appear lighter than undisturbed tussocks.*

(Hernandez 1973a, Chapin and Shaver 1981, Ebersole 1985).

Significant increases in thaw depth (from 3 to 9 cm) were measured at some of the tussock tundra plots. Based on reports of comparable disturbed sites, these changes are expected to persist for several years. Increases in thaw depth due to winter disturbance of tussock tundra were found 3 years later on the Mackenzie River Delta (Hernandez 1973a), and 4 years later in the NPR-A Envirosphere 1985. Chapin and Shaver (1981) found increases in soil temperature at 2 7-year-old sites where winter disturbance had partially removed the vegetative mat. At the most disturbed sites in the study area, narrow trails appeared as shallow ruts where tussocks had been crushed, vegetation compressed, and some thaw settlement had possibly occurred. However, thaw settlement was not measurable at any of the USFWS sites, since control elevations were difficult to establish due to highly variable tussock micro-relief.

Moist Dwarf Shrub, Sedge Tussock Tundra. Non-riparian shrub-rich tundra is found on palsas and high-centered polygons in the study area, and is characterized by dwarf birch (Betula nana) (Appendix I, Table 1). Disturbance in this vegetation type resulted in breakage of the low shrub canopy, creating trails that were visible from both air and ground. As mentioned above, dwarf birch and ericaceous shrubs are especially vulnerable to disturbance. Recovery from severe disturbance is very slow; Ebersole (1985) reported decreased cover of Betula nana, Ledum palustre and Vaccinium vitis-idaea still evident on 30-year-old trails at Oumalik, Alaska. In less severely damaged sites, resprouting from broken stems and roots was common.

Graminoids were the most important recolonizers of bare patches in this vegetation type, with the grasses Arctagrostis latifolia and Hierochloe alpina accounting for about 1/4 of the recolonizing shoots. Thaw depths in shrub tundra varied, but a few trails had statistically significant increases of 2 to 5 cm, with no evident thaw settlement.

Dry Prostrate Shrub, Forb Tundra. These dry alkaline sites, dominated by arctic avens (Dryas integrifolia) are found on ridges, bluffs and river terraces, and are often called Dryas terraces (Appendix I, Table 1). Dryas terrace was the least resistant to disturbance of any of the vegetation types, and trails were usually visible or easily visible from the air. This was the only vegetation type in which a trail was more visible in the second year after disturbance than in the first year. Increased visibility resulted from the loss of the moss mat, which, though dead, had remained in place during the first summer following disturbance.

Decreases in the cover of arctic avens (ranging from 20-96%), prostrate willow, horsetails, and mosses were found on disturbed plots (Plate 13). These plots had the highest percentage of unvegetated ground of all vegetation types. Recolonization was mostly by resprouting of prostrate shrubs and horsetails from buried roots and stems. Relatively high rates of recolonization suggest that while the surface stems and leaves were easily removed, some buried stems and roots were less seriously affected. Further recovery of these sites may be slow due to soil disruption by winds or needle ice which makes plant establishment difficult. Slow recolonization of Dryas on exposed, xeric sites has been reported (Barrett and Schulten 1975, Everett et al. 1985), and cleat marks were still visible in the Dryas mat on 1 20-year-old trail in the study area. However, Everett et al. (1985) reported

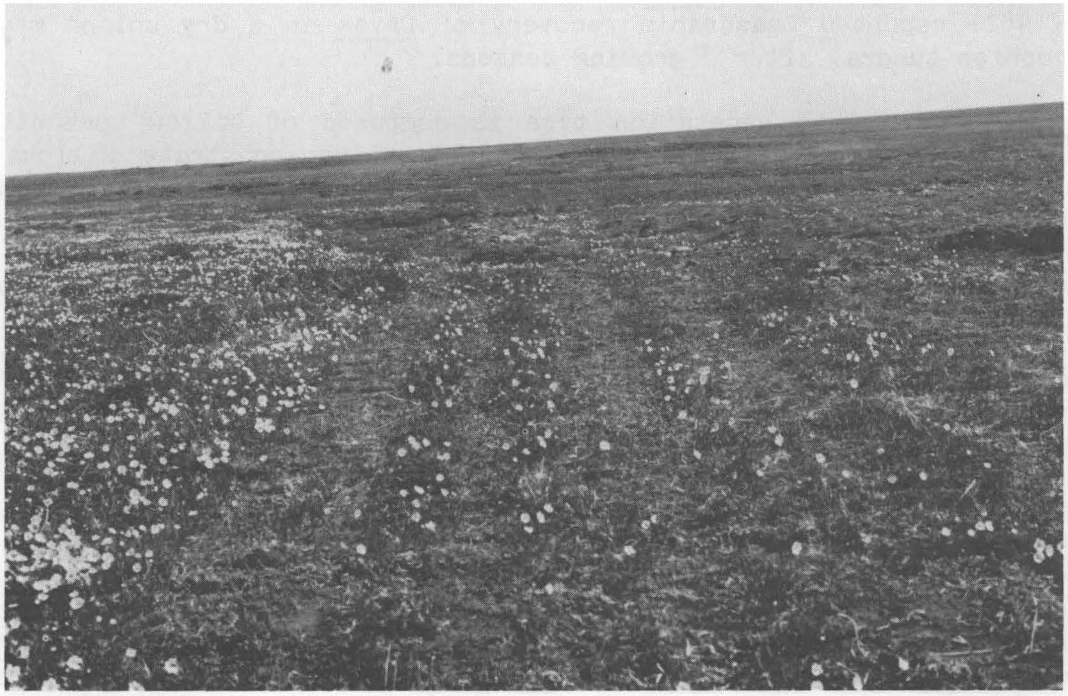

*Plate 13. Trail through dry prostrate shrub, forb tundra. Profusely flowering arctic avens (Dryas integrifolia) is absent on tracks.*

*Plate 14. Narrow camp move trail through low riparian willow, resulting in over 60 % reduction in shrub canopy cover.*

successful recolonization by Dryas at 1 disturbed site after 20 years, and Reynolds (1982) reported measurable recovery of Dryas in a dry upland meadow (mat and cushion tundra) after 2 growing seasons.

Riparian Shrubland. This vegetation type is composed of willow communities found on gravel bars and floodplains. Heights of non-prostrate willows in this type ranged from 5-50 cm, and spacing varied from scattered to continuous closed cover. Riparian shrubland occurs in narrow strips without sufficient area to be recorded by satellite imagery; consequently, there is no corresponding vegetation type in the Landsat classification system (Appendix I, Table 1).

Winter traffic through riparian shrub breaks willow branches, reducing the height of the willow canopy, and creating a visible trail (Plate 14). Damage to the moss and forb understory occurred on some trails, but little soil was exposed.

There was no measurable recovery of cover values on 2-year-old riparian plots, though an increase in shoot length on willows in some disturbed areas was observed. Bare patches were being slowly recolonized by vegetative propagation of prostrate shrubs (Salix reticulata and Arctostaphylos rubra), and legumes (Astralagus umbellatus and Oxytropis spp.). Seedlings were also important recolonizers, constituting up to 20% of all recolonizing shoots. Almost all of these seedlings were legumes, either Oxytropis spp. or Astralagus umbellatus.

Thaw depths were measured on few riparian or Dryas terrace plots because rocks and gravel often blocked the thaw probe before frozen ground was reached. Thaw depths in these habitats normally exceed 1 m (Walker et al. 1982) and therefore, increased thaw depth due to disturbance is not expected to be a problem. There was no measurable subsidence or compression on any of these plots.

Slope Erosion

No evidence of slope erosion was found on seismic line or camp move trails. Vehicles were routed around steep slopes whenever possible. Damage to slopes occurred mainly on river banks where tractors spun their tracks while pulling the camp sleds out of snow-drifted river bottoms. The resulting patches of exposed peat and mineral soil were usually small and localized, on well-vegetated slopes of less than 20%, and slope erosion is not expected to be a problem. One 30% slope on the north fork of the Sikrelurak River had more extensive damage. The gravelly soils at this site are expected to be stable, but the site will be monitored for any evidence of erosion.

Shotholes and Craters

A small pile of tailings (2 m in diameter) remained around each shothole. Shotholes were generally visible from the air and on the ground, and were highly visible from the air in a few locations. On a few trails, shotholes were the only disturbances visible in the second year after disturbance. Shotholes appeared to be blending into the surrounding vegetation by the second year in many locations. The outside edges (0.5 m) of the tailings piles were often less than 5 cm deep and plants were growing through the thin portion of the piles at most shotholes.

Occasionally the dynamite explosion blew out pieces of tundra surrounding a shothole, creating craters 1-5 m in diameter and 0.5 m deep. Large chunks of earth, some with complete vegetative mats, surrounded the craters. By late July of the first season, these craters had filled with water, making small ponds. The craters remained dry in 1985 due to the dry year. Recovery of these sites is expected to be quite slow since the vegetative mat was completely removed and mineral soil was often exposed.

Fuel Spills

Diesel fuel spills were evident at some campsites. These spills completely killed vegetation over areas ranging from 1-6 m in diameter. The largest spill observed was estimated to be 200-450 liter, and killed vegetation in a wet sedge community over an area 6 m in diameter. A few sprouts of cotton grass (Eriophorum spp.) were evident around the edges of this spill in the second year following exploration. Lawson et al. (1978) reported little recovery of vegetation on diesel spills after 30 years.

Oil drips were noted at campsites and along the line during the winter. At campsites drips were limited by use of absorbent pads and drip pans. Oilspills observed in the summer were small and localized. In some areas, oil residue covered the ground surface but plants were only partially killed.

Garbage

Garbage, especially absorbent pads, was found at campsites the first season after exploration. Most of the garbage was white paper which blended in with the snow during the winter, but was highly visible on the green tundra the following season. A helicopter cleanup program was required in 1984. In 1985, orange absorbent pads were used so that they were visible on the snow, and crews were more conscientious about trash pickup. Little trash was found on the tundra during a reconnaissance of trails in 1985.

Impacts to Wildlife and Fish

Birds

Winter seismic operations had minimal impact on birds. Only 7 birds species spend the winter in the study area: gyrfalcons, rock and willow ptarmigan, snowy owls, ravens, red polls, and American dippers (see Chapter 4). Ravens were reportedly attracted to garbage sleds on the cat trains and ptarmigan were reportedly attracted to vegetation exposed by tracked vehicles (N. Felix, pers. comm.). No significant adverse impact to birds were observed during the seismic exploration program. Trails left by seismic trains had altered vegetation and topography (micro-relief) which resulted in increased thaw depths, depressions, and additional flooded habitat. Depending on the location and habitat such alterations may have had positive or negative impacts on terrestrial birds.

## Mammals

### Caribou

Porcupine Caribou Herd (PH). Historical records indicate that large numbers of caribou, presumably the Porcupine caribou herd (PH), may have wintered on the arctic coastal plain and foothills during the late 1800's (Skoog 1968). Results from numerous surveys conducted over the past 15 years indicate that a majority of the PH currently uses winter ranges south of the continental divide in Alaska, and a variety of areas in Canada.

Relatively small numbers of PH caribou (app. 1-2,000) occasionally winter in the Schrader Lake area located immediately south of the study area (Whitten et al. 1985b). There has been no documentation over the past 15 years of PH caribou within the study area during the winter season.

Large numbers of PH caribou usually begin to enter the study area in mid-to-late May (Roseneau and Curatolo 1976, Whitten et al. 1984, 1985a, 1986). The earliest known entry by the PH was reported to have occurred on 6 May (Olson 1958). A majority of the PH usually vacates the study area by late July (Roseneau et al. 1974, Roseneau and Curatolo 1976, Whitten et al. 1984, 1985, 1986). In certain years residual groups remain in the study area throughout the summer (Roseneau and Stern 1974). During the 1983-1985 seismic exploration program no direct contact with the PH was observed.

Central Arctic Herd (CAH). Relatively low numbers of small scattered groups of caribou have been documented wintering within the study area from the Canning River to approximately the Sadlerochit River (Roseneau et al. 1974, Roseneau and Curatolo 1976). Radio telemetry studies indicate that these caribou are associated with the CAH which ranges primarily west of the ANWR. Currently the number of caribou that winter within the study area does not exceed 1,000 individuals (Whitten, Alaska Dep. of Fish and Game, pers. comm.).

The reactions of caribou to winter seismic exploration activities conducted in the study area during 1984-1985 were not specifically studied. Reports from monitors accompanying these seismic operations however, indicate that very few caribou were observed (ANWR files). It is likely that caribou were locally displaced from areas of exploration activity for relatively brief periods. In a study on Banks Island, Russell (1977) reported that all caribou groups encountered by seismic vehicles at less than 0.8 km reacted by moving (usually walking) away at right angles. At distance greater than 1.2 km, Russell (1977) found that caribou remained in the area and were generally non-reactive to the activity. Urquhart (1973) found that the distance at which caribou would react to seismic operations varied according to terrain. In rolling country seismic vehicles were able to approach nearer to caribou than on flat area. However, the intensity of reaction by caribou in rolling terrain was greater, possibly due to the "surprise" of a moving object suddenly appearing over a rise (Urquhart 1973, as cited in Carruthers 1976). Russell (1977) reported that caribou reoccupied habitat within 0.8 km of a seismic line within 2 to 4 days after the disturbance ceased.

Muskox

Responses of muskoxen to vehicular traffic associated with winter seismic exploration activities in the ANWR were documented in 1984 and 1985 as part of the ANWR baseline study (Reynolds and LaPlant 1985, Reynolds 1986a). Aerial and ground observations of muskoxen were made while seismic exploration programs were being conducted. Radio-collared muskoxen were relocated 11 times in 1984 and 6 times in 1985 between late January and early May. Aerial observations of other muskoxen were also obtained during overflights of the coastal plain. Field monitors traveling with seismic trains provided locations of muskoxen near seismic trains as well as responses of herds to seismic vehicles.

Muskox reaction to ground seismic vehicles varied (Table 2). The most common response was to form a loose aggregation or walk away from the vehicle. Animals grouped and then ran on 4 of 10 occasions when 1 or more moving vehicles were within 1 km, however, 1 herd showed no response to a bombardier approaching within a 0.2 km. Two herds responded by grouping and running when vehicles were over 3.0 km away (Reynolds & LaPlant 1985).

Table 2. Muskox response to seismic vehicles in the Arctic National Wildlife Refuge, January-May 1984 and 1985.

| | Number of muskox herd observations | | | | | |
|---|---|---|---|---|---|---|
| Distance from muskox (km) | Response category: Group and run | Group and stand | Form loose group or walk away | Look up or rise | None seen | Type of vehicle |
| 1 | | | 1 | 3 | | 1 parked Bombardier (engine running) |
| 1-2 | | | 1 | | | |
| 2 | | | | | | |
| 1 | 2 | 1 | 1 | 1 | 1 | 1 moving Bombardier |
| 1-2 | 1 | 4 | 1 | 1 | 1 | |
| 2 | | | 2 | 1 | 1 | |
| 1 | 2 | 1 | 1 | | | 2-7 moving Bombardiers tractors and/or tracked vehicles |
| 1-2 | 1 | | 2 | | | |
| 2 | 1 | 1 | 3 | | 2 | |
| Totals | 7 | 7 | 12 | 3 | 8 | |

Distances moved by radio-collared muskoxen in the Tamayariak area in 1984, during times when seismic vehicles were working within 5 km of herds, were within the range of movements observed before and after seismic exploration commenced (Table 3). But distances moved by radio-collared muskoxen in the Okerokovik area appear to be greater during times when seismic vehicles were within 5 km of herds, compared with distances moved before and after seismic vehicles were present in the area (Table 3). Maximum movement observed occurred when a herd moved 17 km from the Niguanak River to hills southwest of the Okerokovik River on 19-28 March (Reynolds and LaPlant 1985). Although seismic vehicles were in the area on 27 March, it is not known if the herds encountered and/or were disturbed by the activity.

Table 3. Movements of radio-collared muskoxen prior to, during, and after seismic survey activities occurred in the Arctic National Wildlife Refuge, January-May 1984.

| Time period relation to seismic activities | Number of herd observations | Distance moved (km/day)[a] range | mean ± S.D. | Geographic area |
|---|---|---|---|---|
| Prior to activities | 13 | 0.1 - 1.9 | 0.6 ± 0.5 | |
| After activities | 19 | 0.0 - 1.9 | 0.5 ± 0.5 | Tamayariak |
| During activities | 7 | 0.0 - 1.4 | 0.6 ± 0.6 | |
| Prior to activities | 9 | 0.0 - 0.8 | 0.3 ± 0.28 | |
| After activities | 7 | 0.1 - 0.8 | 0.6 ± 0.25 | Okerokovik |
| During activities | 3 | 0.3 - 1.8 | 0.9 ± 0.65 | |

[a] excluding single day movements

In 1984 and 1985, general distribution of muskoxen was similar before, during and after seismic survey were completed (Fig. 3) and did not differ from winter-precalving distributions in 1982-1985 (Chapter 5, Fig. 28). Muskoxen apparently were not displaced from areas of traditional use. All muskoxen observed were within or near use areas documented in 1982-1985 (Chapter 5, Fig. 25).

Information from movements of radio-collared animals in 1984 also showed that muskoxen did not move long distances in response to seismic surveys. Observed movements possibly caused by a negative response to the presence of seismic vehicles did not exceed 5.0 km. Two herds, observed on 2 consecutive days before and after animals ran from approaching vehicles, moved 4.5 km and 3.0 km in about 24 hours (Reynolds and LaPlant 1985). Year round average daily movements of 9 radio-collared muskoxen recorded in 1982 ranged from 0.0 to 6.7 km/day (Reynolds et. al 1983), and Jingfors (1982) reported daily group movement rates ranging from 0.66 km/day to 9.9 km/day for a muskox herd on the Sadlerochit River in summer. Data from a satellite-collared muskoxen in the eastern part of the study area showed that muskoxen apparently reduce their daily movements in winter, probably as an energy conserving mechanism (Reynolds 1986b). Muskoxen remained within a small area from mid-December until early June (Chapter 5. Fig 31). Daily movements during these times generally did not exceed 1.0 km/day, although 1 movement of about 5.0 km in 48 h was documented.

Muskox herds encountered seismic crews infrequently in 1984 and 1985. Although the seismic program covered several areas of high muskox use, activities were present within each area for only a few days. Movements away from lines were apparently of relatively short duration and herd or population size did not appear to be affected (Reynolds and LaPlant 1985, Reynolds 1986a). Even if disruptions in normal movements and activity patterns occurred, effects on the population were probably not substantial, because of the transitory nature of the program. Productivity, determined by the number of

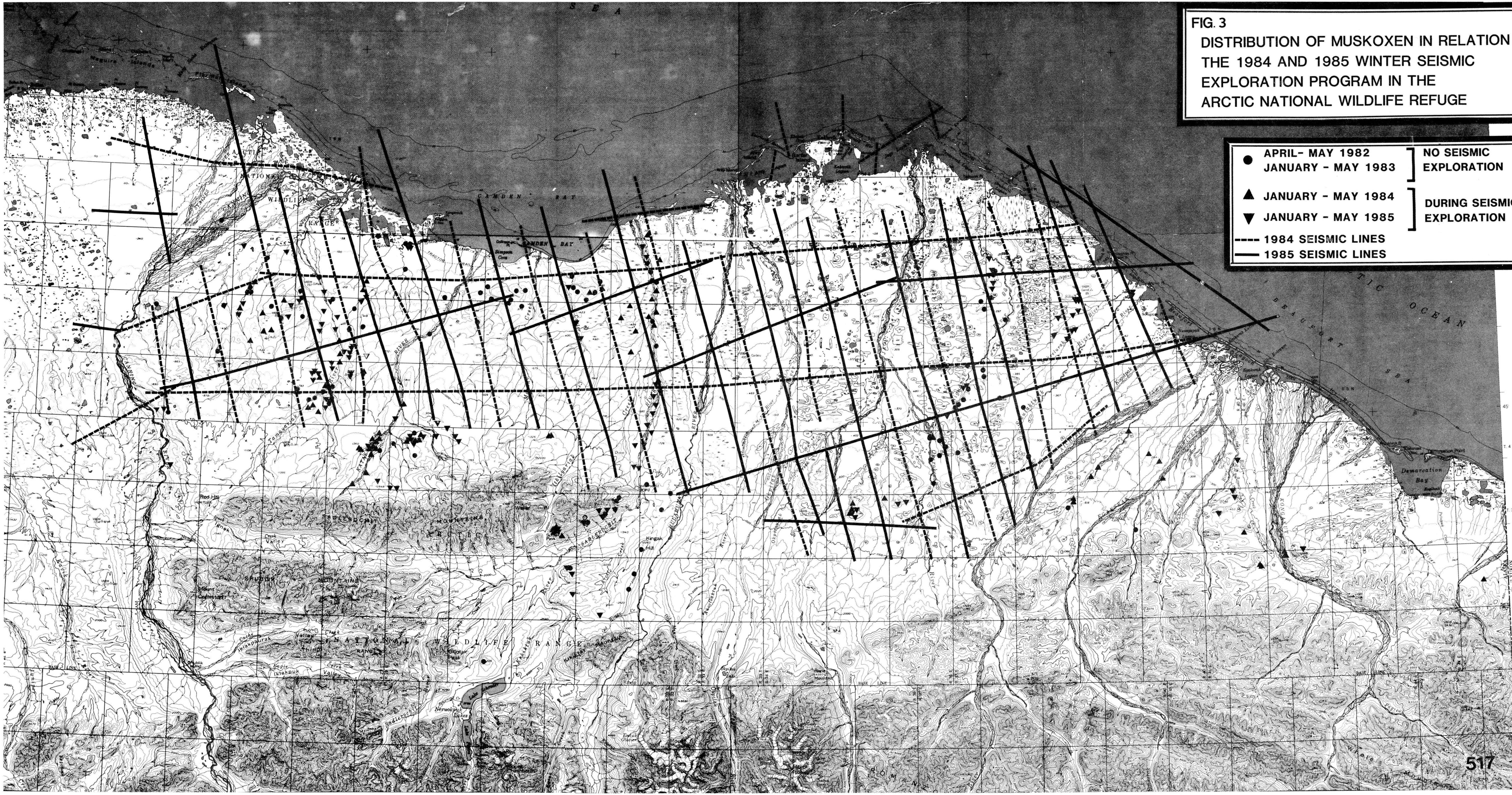


FIG. 3
DISTRIBUTION OF MUSKOXEN IN RELATION TO THE 1984 AND 1985 WINTER SEISMIC EXPLORATION PROGRAM IN THE ARCTIC NATIONAL WILDLIFE REFUGE

calves born to cows older than 3 years, was 0.75 calves per cow in 1984 and 1985 compared with 0.66 calves per cow in 1983 and 0.63 calves per cow in 1982 (Reynolds et al. 1986).

Results of this study were similar to studies in Canada which found that animals responded to vehicles by forming defensive groups and running, or gradually moving away from the vicinity of a seismic line (Urquhart 1973, Beak Consultants Ltd. 1976, Russell 1977). Jingfors and Lassen (1984) found that during a seismic survey being conducted in summer, muskoxen gradually and temporarily avoided the area immediately around a seismic line, perhaps due to the presence of helicopter overflights. Miller and Gunn (1979) indicated that experimental helicopter overflights (N=351) during July and August in 1976-1977 did not cause animals to leave their normal ranges.

Moose

Moose were not present in the study area during the winter, and were not directly impacted by activities from the 1984 and 1985 seismic surveys.

Polar Bears

Polar bears may be present in the study area during denning, which begins during late October to early November. At this critical period in the polar bears' life cycle (Lentfer 1974), pregnant females travel to the coastal areas where denning habitat may be found on the fast ice, offshore islands, or on the mainland up to 48km inland. Cubs are born in midwinter, and the sow and cubs break out of the dens in March and April (Lentfer and Hensel 1980). During the ANWR seismic surveys, seismic crews were informed about the location of known polar bear dens and instructed to stay at least 1.6 km from dens. Two polar bear dens were known during each year of the seismic surveys. In January or early February 1985, a female polar bear abandoned its den near the mouth of the Canning River. It had been radio-collared during the spring of 1984, tracked to a den site in December 1984 and observed alone on the ice pack about 80 km north of Barrow in early February 1985. The bear was young and thought to be pregnant with its first litter. Disturbance from vehicular traffic associated with seismic exploration on ANWR may have caused it to abandon its den and cubs if any had been born. Vehicles had passed within 0.2 -0.8 km of the den. Other known polar bears denning within the study area were apparently not disturbed by winter seismic activities.

During the winter, most non-denning bears remain offshore, and during the summer nearly all bears are far offshore at the edge of the ice pack. Impacts to non-denning bears during the 2 seismic seasons were negligible.

Other Marine Mammals

Whales and seals were probably not affected by the terrestrial seismic program conducted in the ANWR study area during the winter in 1984 and 1985.

Brown Bears

The seismic exploration program was conducted during winter when bears are in dens. Only 7 of 199 documented dens occurred within the ANWR study area. Operating stipulations for the seismic program allowed no approach to within 1.6 km of a known bear den. No dens were disrupted and the seismic program had no affect on brown bears in the ANWR study area.

## Wolves and Foxes

Impacts of winter seismic activities on canids include habitat destruction, harassment, attraction to artifical food sources (garbage and handouts), human-carnivore interactions (property destruction, personnel bitten, disease transmission), killing nuisance animals, and displacement of prey species. Conclusions as to levels and types of impacts have been drawn from observations of USFWS monitors and reports of seismic crew personnel. Wolves are uncommon on the coastal plain during winter. Wolves tend to avoid disturbance and seismic crews are usually not in one location long enough for a wolf to become habituated to the disturbance. No wolves were observed by the seismic crews on ANWR although tracks were found on several occasions.

Sightings of arctic fox were common during the seismic work. Although foxes were sometimes reported near camp sites, no reports of foxes becoming dependant upon camps were received. Urquhart (1973) reported arctic foxes following camps as they moved on Banks Island, N.W.T. This phenomenon was attributed to the availability of garbage, food, handouts, etc. Instances of arctic foxes following camps was not observed on ANWR. Garbage was burned daily and food was stored in trailers.

Elevated land forms such as river banks, sand dunes, and pingos are used by foxes for den sites. These land forms are often utilized by humans for observation points, campsites, and travel routes (Brooke et al. 1971, Weeden and Klein 1971, Klein 1972). These activities may result in destruction of den sites as was documented in sand dunes on the Sagavanirtok River where burial pits for waste storage were made (Brooks et al. 1971, Weeden and Klein 1971). No destruction of dens was reported on ANWR, although seismic lines in several places passed within several m of a few dens (M. Jorgenson, U.S. Fish and Wildlife Service, pers. comm).

Red foxes could be affected by the same activities as arctic fox, although as they are generally not as common on the coastal plain. Red foxes were sighted on several occasions but no problems were reported. One red fox was reported showing strong avoidance behavior of the seismic crew and associated equipment (G. Weiler, U.S. Fish and Wildlife Service, pers. comm.).

Foxes and wolves have been known to disrupt operations by chewing through wires and cables connecting geophones (Brooks et al. 1971, Klein 1973, Urquhart 1973). Problems of this nature were not reported on ANWR.

## Wolverines

Little is known about current wolverine populations inhabiting the ANWR study area, and the impact of seismic exploration activities on them are unknown. Thus far, there have been no published observations of impacts of seismic exploration elsewhere in the Alaskan arctic on wolverines. Wolverines are wary animals and are not vulnerable to problems related to human feeding. It is not known if seismic activities could pose a serious disturbance to maternal denning activity of wolverines.

## Small Mammals

Effects of the ANWR seismic program on small mammals were not studied, but were probably limited to direct mortalities of lemmings crushed under vechiles and loss of trails and runways used by lemmings. Arctic ground squirrels hibernate in winter and were probably not affected by the seismic exploration program.

## Fish

Effects of winter seismic activities in the ANWR study area on fisheries were not determined. Known fish overwintering areas were identified to seismic crews and avoided.

## Impacts to Human Culture and Lifestyle

### Archaeology and Human History

During the 1983-1984 seismic program conducted on the ANWR coastal plain, seismic areas were given maps identifing locations of archaeology and historical sited identified by Hall (1982) and Libbey (1982). USFWS monitors accompanying seismic crews did not report any damage to standing structures during the 1983-1984 program. Hall (1982) stated that probably little or no damage to sites without standing structure would occur if ground was frozen and snow covered.

### Subsistence

Impacts of the 1983-1984 seismic program on the subsistence economic system of the village of Kaktovik were not documented. Although no study was done to determine if impacts had occurred, effects on the community were apparently relatively minor. Kaktovik was not used as a staging area for people or equipment. Crews were housed in portable cat trains which had little or no contact with the village. No known employment resulted from the program. Crew 1195 provided tours of the cattrain to school children when the crew was working near Kaktovik.

### Recreation, Wilderness, and Natural Landmarks

There have been no specific studies on impacts of seismic exploration activities on recreationists using the coastal plain of ANWR. Neither are such studies available from other areas. The 1983-1984 and 1984-1985 winter seismic activities appear to have had minimal impact on recreation. A very limited amount of cross-country skiing occurs during the spring. However, it is not known whether these visitors' experiences were negatively affected by the exploratory activities. One group of recreational backpackers that crossed the coastal plain during late June 1985 reported seeing numerous signs of the seismic exploration. Their reaction to these trails and debris was negative. The group also observed helicopter activity each day of their trip which they found objectionable.

Retention of wilderness characteristics of the study area was an important consideration during conduct of the seismic exploration during the winters of 1983-1984 and 1984-1985. Although the USFWS was under no legal obligation (Eastin 1984), it was recognized that protection of esthetic quality and wilderness characteristics was important. Some impacts which may have been acceptable in terms of fish and wildlife habitat loss or population level declines were considered unacceptable for protection of wilderness values and characteristics necessary to qualify for future wilderness designation. Many field monitor actions were designed to prevent such impacts.

Surface disturbance resulting from seismic exploration during winters 1983-1984 and 1984-1985 resulted in a grid of seismic trails that are highly visible from the air. Though these trails are much less visible from the ground, many are nonetheless detectable. Felix and Jorgenson (1985) found that impacts resulting from the winter 1983-1984 exploration included destruction of plant cover and breakage or compaction of the organic mat. This increased thaw depths in places, with some subsidence or track depression. However, slope erosion is not expected to occur on the refuge as a result of the seismic exploration. This high level disturbance was relatively limited and localized.

The seismic trails detract from the wilderness quality of the coastal plain study area. However, this detraction is not significant, at the current extent of trails and the overall levels of disturbance. Permanent scars on the land are not expected. If they occur they will be extremely limited. Other types of impacts to wilderness qualities included refuse and debris left behind by the seismic crews. Cleanup operations removed most of this material, though some residual small items remain scattered across the coastal plain. Frugé (1985) found that the seismic activity of 1983 through 1985 did not significantly detract from the area's wilderness quality, though the evidence of the seismic program was observed in places. The present level of impacts from seismic exploration has not substantially affected the wilderness quality of the coastal plain.

## Further Exploration

Further exploration on the coastal plain study area of ANWR would include additional surface and seismic exploration with impacts expected to be similar to those previously described. Local variations could occur due to grid density of unit seismic programs. In addition to these exploration activities, exploratory wells would be drilled. The following analysis focuses on additional impacts on fish and wildlife resources that can be anticipated from exploratory well drilling.

### Exploratory Drilling

Exploratory drilling on the north slope is typically conducted during the winter due to environmental and logistical considerations. If drilling operations, including construction, drilling and testing, can be completed in approximately 170 days or less, the well can probably be completed in a single winter season. A winter operation involves the mobilization of construction crews and equipment, followed by the mobilization of the drilling rig. After the rig and support equipment are assembled, drilling begins, and continues until total depth is reached. Following drilling, testing, and suspension or abandonment of the well, the rig, support equipment, and camp are demobilized and the pad is rehabilitated.

Construction equipment is hauled cross-country by low ground-pressure vehicles to the exploratory well site. Once the equipment and crew arrive on site, construction of ice roads, ice airstrips, and the drilling pad commences. The drilling pad can be constructed of ice or of excavated material from the reserve pit.

The drilling pad is large enough to hold the rig, camp, and support equipment, and provides storage for drilling supplies (drillpipe, casing, drilling mud, cement, etc.). A typical pad is about 180 m by 210 m and covers approximately 4 ha of ground surface. A reserve pit, usually excavated next to the drilling pad, receives cuttings and drilling muds, and contains potential fluid surges. The pit is lined with an impermeable material and is designed to confine the frozen mixture of drilling fluids and cuttings to the permafrost. The excavated material from the pit is placed over the frozen mixture.

The construction and drilling camps contain sleeping and eating accommodations, communication equipment, power generator units, storage space, and offices. A construction camp contains facilities for 50-75 people and the drilling camp for 50-60 people. The actual number of people varies with the type of activity.

The drilling pad is usually connected to the airstrip and the camp water source by ice roads. Initially, a source of water sufficient for ice road and airstrip construction, and camp and drilling uses must be located. After the water source is selected, ice roads are constructed by applying a layer of water over snow cover along the desired route with water trucks. This process is repeated until an ice layer of sufficient thickness (approximately 15 cm) is created. This should be considered a minimum requirement and the ice road may require more water for periodic maintenance. A 1.6 km ice road generally requires about 1.5 acre-foot of water. Ice airstrips are usually placed on nearby lakes if they are of sufficient size; otherwise, the airstrip is constructed on level tundra similar in manner to an ice road except with a minimum ice thickness of 30 cm. The airstrip is 1,500-1,800 m long and about 45 m wide to accommodate Hercules C-130 and Boeing 737 jet-sized aircraft.

Drilling operations begin with augering a hole for the conductor casing (typically 15-30 m) and then the drilling rig is placed on the pad. To prevent differential settling during drilling, the rig is placed on pilings or timbers. The conductor casing is run and cemented in place and the well is spudded. The drilling begins and the hole is drilled to a competent geologic formation. The surface casing is run into the hole and cemented with a special arctic cement. This casing passes through the entire permafrost zone and provides a anchor for blowout-prevention equipment until the next casing string is set. Drilling continues to the next casing point where the well is logged and intermediate casing is run and cemented. This procedure is followed until the target zone is reached and tested. After the final testing and logging, the well is abandoned by placing several cement plugs in the well bore and casing.

Usually demobilization of the drilling rig and camp starts immediately after the abandonment of the well. Within several weeks, the equipment and most of the debris have been removed or the equipment secured for movement to the next well site. A final-cleanup crew returns to the site in the summer to pick up any remaining debris or garbage, and if a pad was constructed, to check on the rehabilitation.

For wells which can not be completed in a single winter season, 2 options exist: (1) year-round drilling or (2) interrupted drilling during 2 or more winter seasons. Year-round exploration drilling uses the same facilities as the winter method, but the pad, roads, and airstrip must be constructed with gravel instead of ice. In many instances, exploration drillings can not operate year round on pads made from ice, insulation, and timbers. Therefore, a source of construction material must be available.

Multi-winter drilling is similar to single-winter drilling, except that the drilling pad is constructed with enough gravel (usually about 27,000$m^3$) or other thaw-stable material to provide a stable and suitable surface on which to store the drilling equipment and camp during the summer, and the well is arctic packed and suspended. At the beginning of the second or subsequent winter drilling seasons, the roads, airstrip, and drilling pad are rebuilt with ice and the drilling proceeds.

## Impacts to Vegetation and Surface Stability

### Vehicle Trails

The potential impact of trails caused by further geophysical exploration in the study area would vary depending on the number and type of vehicles used, the seismic technique employed, and the vegetation and terrain types traversed. Winter exploration, using either the drilled shothole or the Vibroseis technique, would result in additional impacts as detailed above in the discussion of the 1984 and 1985 winter seismic exploration programs. A more closely spaced network of visible trails, with decreased vegetative cover, changes in nutrient composition, compression of the vegetative mat, destruction of micro-relief, increased soil exposure, increased thaw depths, and some areas of track depression would be expected. Close monitoring of the 1984 and 1985 seismic operations was an important factor in decreasing disturbance. USFWS monitors maintained diffuse traffic patterns, routed cat-trains through less sensitive areas, and minimized travel on steep slopes, snow-free areas, or sensitive vegetation types. Impacts would be more severe than those experienced up to now if seismic operations were permitted without monitoring or if vehicles were permitted to travel on the tundra before a minimum average snow fall of 15 cm had accumulated.

Severe impacts would occur if seismic exploration or other vehicle uses were allowed to occur during the summer (this is no longer a standard industry practice and is not permitted by the State of Alaska). Even single passes of vehicles during the summer have caused permanent vegetation and surface form changes that were easily visible 30 years later (Lawson et al. 1978). Many studies have reported severe decreases in plant cover, subsidence of vehicle tracks and long-term species composition changes on summer trails (Bliss and Wein 1972, How and Hernandez 1975, Chapin and Shaver 1981, Ebersole 1985, Everett et al. 1985). Retention of the vegetative cover is critical in preventing long-term impacts due to disturbance. The depth of thaw increases if the vegetation is removed exposing the organic layer, and becomes even deeper if the organic layer is removed and mineral soil is exposed (Hernandez 1973a). Increased thaw depths can lead to subsidence and, in extreme cases, to slumping and erosional gullies.

Off-road vehicle travel may also occur around exploratory wells. Winter traffic with similar vehicles and number of passes as occurred during seismic exploration would cause impacts similar to those discussed above, as long as slopes, snow-free areas and sensitive vegetation types were avoided. Repeated passes of vehicles with high ground pressure or heavy loads would result in severe vegetation damage if ice roads are not used.

Rolligons may be used to transport equipment to exploratory wells during the winter if ice roads are not built. CATCO Rolligons commonly used in the Prudhoe Bay oil field carry up to 13,000 kg and have variable ground pressure which can be regulated from 3 to 15 psi by the vehicle operator (J. Larsen, Alaska Dep. of Natural Resources, pers. comm.). The average operating range of 4 to 5 psi is similar to the ground pressure of many of the seismic vehicles used in the study area (Table 1), however the smooth tires are less damaging to the vegetation mat than the tracks of seismic vehicles. Rolligons operating with higher ground pressures, or making multiple passes over one route could cause compression of vegetation, increased thaw depth, and possible subsidence due to melting of permafrost.

Snow Roads

Temporary roads are needed to haul drill rigs, equipment, supplies, personnel, and frequently gravel to exploratory well sites from nearby airstrips, existing roads, or the ocean. When drilling is limited to the winter season, snow and ice roads can be used to avoid the impacts associated with gravel cover and mining. Snow roads are built of either compacted or processed snow and are normally constructed by repeated passes of a Caterpillar tractor pulling a snow drag or roller. Snow roads do not provide as much protection as ice roads and their use for heavy traffic has largely been discontinued.

Snow roads can protect the surface from a limited amount of traffic when properly constructed and sufficiently deep to cover the higher microsites. A snow road or pad was used by Alyeska for constructing an 8 km segment of the pipeline over tussock tundra in the foothills region and varied from 30 to 60 cm in thickness (Johnson and Collins 1980). Traffic on the pad consisted of light and heavy drills, trucks, cranes, loaders, side boom tractors, and other standard pipeline construction equipment. The only impacts to vegetation occurred late in the winter when tussock tops were damaged by vehicle tracks.

When the snow road is not sufficiently deep to adequately protect the higher micro-relief features or has heavy traffic, serious damage to the surface can occur. A compacted snow road used to move drilling rigs and supplies near the Mackenzie Delta resulted in almost total removal of the vegetation, nearly complete exposure of peat, and thaw depth increases in the worst sections (Hernandez 1973). In areas of thicker snow cover, damage was limited to scuffing the tops of hummocks. Wet graminoid communities were less susceptible to damage than moist plant communities.

The construction of snow roads to adequately protect the surface in the study area is made more difficult by the terrain conditions. Natural snow cover by itself is inadequate and must be augmented by trapping snow, manufacturing snow from a water source or hauling it from large snowbank deposits. Much of the terrain in the study area has features of high micro-relief, such as high-centered polygons or hummocks, which would be difficult to adequately protect. In some areas in the foothills, steep grades may make snow roads impractical. In addition, the amount of compaction of the surface caused by heavy traffic on snow roads is not well known and is a cause of concern, particularly for moist sedge, dwarf shrub tundra. The heavy, concentrated traffic of cat-trains during seismic exploration has caused serious track depression in a few locations in the study area (Felix et al. 1986a).

Ice Roads and Airstrips

Ice roads are generally used where compacted snow cannot carry the volume and weight of traffic. An ice-capped snow road is nearly identical to an ice road, but first requires construction of a compacted snow road to establish a firm sub-base. Present construction practice for ice roads is to accumulate the minimum 15 cm of snow needed for off-road traffic as required by federal and state permit stipulations before watering begins. The snow is first leveled and compacted with a drag or roller pulled by a Rolligon or a Caterpillar tractor. Water is then sprinkled or hosed onto the surface to develop a layer of ice. Once a layer of ice has developed and the surface is fairly impervious, larger amounts of water can be applied to fill the depressions. The Alaska Department of Natural Resources requires ice roads to be a minimum of 15 cm thick and ice-capped snow roads to be 30 cm thick.

The impacts of ice roads and airstrips on vegetation have not been well documented, although it is generally thought that the effects are few if roads are properly constructed. Ice roads generally melt about two weeks later than the adjacent tundra leaving a brown strip early in the summer. The effects of this delay on plant phenology have not been studied. Ice roads in wet and moist sedge tundra persist as green trails for several years due to the knocking down of light-colored, standing dead leaves. High microsites in tussock tundra or hummocky vegetation types will be scuffed if the ice is not sufficiently thick (Adam 1981). Some damage to higher microsites may also occur during construction when snow is being spread or compacted to form a uniform base.

When an ice road is used for heavy traffic, such as gravel hauling, the impacts may be greater. Serious compaction of the tundra surface resulted on an ice road used to haul over a million cubic meters of gravel for the artificial island constructed for the Mukluk well (K. Bulchis, U.S. Fish and Wildlife Service, pers. comm.). Moist sedge, prostrate shrub tundra in the study area may be particularly sensitive to such compaction, since multiple passes of seismic vehicles in this habitat caused obvious surface compression. Everett (1981) documented a significant increase in the depth of thaw along the Inigok ice road in NPRA, and cautioned against using ice roads widely until more is known about long-term recovery. Another impact associated with ice roads may be the deposition of gravel along the road during gravel hauling operations.

On state lands, ice roads are not permitted to be built along the same right-of-way in succeeding years as a precaution against compounding the effects on vegetation. However, no studies have been conducted to determine the impacts of single year versus multiple year ice roads.

The limitations of using ice roads and pads in the study area are similar to those mentioned for snow roads. In addition, water will be in short supply since few lakes in the study area are deep enough to supply water during the winter.

Gravel Roads and Airstrips

Gravel roads and airstrips may be used for year-round exploratory drilling operations. They have been used for exploratory wells in northern Alaska at NPRA and Kavik. Currently, exploratory wells on state lands are usually drilled during the winter when ice roads can be used. At one recent year-round operation, ice roads were used for access in the winter and helicopters were used in the summer.

Vegetation will be lost as a result of gravel cover on roads and airstrips. Larger areas will be affected by the erosion and sedimentation, impoundments, gravel spray, dust, snowdrifts, and thermokarst associated with roads on the tundra. A full discussion of these impacts is included in the section on development.

Well Pads

A level, durable work surface (approximately 1 ha in size) is needed for the drill rig and logistical support activities at an exploratory well. Well pads can be constructed of various materials depending on the duration of the drilling program, costs, and available materials. Ice pads have been used for wells drilled in one season, and in some cases a small gravel pad directly under the drill rig has been added for stability and in case drilling cannot be completed. Gravel pads or gravel-timber-foam pads are used for multi-season wells. Gravel-timber-foam pads, consisting of gravel or mixed material (often from the reserve pit excavation), covered with insulation and protected by timbers, are used to minimize gravel requirements.

Gravel pads produce long-lasting vegetation changes as described for gravel roads and airstrips. Gravel-timber-foam pads create less impact due to the need for less gravel and more successful rehabilitation can be expected since a thinner layer of materials is placed over the natural surface. Ice pads cause the least vegetation disturbance, as described for ice roads and airstrips.

Gravel Mines

Gravel mines would be required during further exploration if facilities with gravel bases are constructed. A typical exploratory well (1.3 ha) with a pad built completely of gravel would require approximately 30,000 $m^3$ (Hanley et al. 1980). The use of timber and insulation would reduce the need for gravel, and the use of material excavated from the reserve pit with timber and insulation would eliminate the need for any gravel mining.

The most likely source for small amounts of gravel would be from scraping the gravel deposits on a river floodplain. This type of excavation was commonly carried out in the winter in the NPRA to get gravel for exploratory wells. Shallow scraping at a rate of 3000 $m^3$/ha (0.3 m depth) was conducted with little impact to vegetation (Woodward-Clyde 1980). A full gravel pad would require scraping 4 ha, and any roads or airstrips would require additional area. Although most small shallow scrape mines are restricted to unvegetated areas, the impacts could include the loss of a small amount of riparian vegetation. Gravel mining in upland areas would result in vegetation losses in the area of the mine, the area covered by overburden, and any area affected by erosion. Such mines would result in long-lasting visual and vegetational impacts.

Fuel Spills

During an exploratory program, most spills are likely to be refined petroleum products such as diesel fuel, though some crude oil spills from drilling are possible. Based on past experience, many small (less than 10 m diameter) fuel spills would be expected to occur in a seismic exploration program (Felix and Jorgenson 1985). Spills of much greater magnitude would be expected to occur during exploratory drilling, since large amounts of fuel are used. Diesel spills are more damaging than crude oil, generally killing all plants on contact and remaining toxic for decades (Walker et al. 1978, Lawson et al. 1978, Mackay et al. 1980). Small leaks of crankcase oil, antifreeze, and hydraulic fluid from vehicles are also expected. The effects of fuel spills on vegetation and soils are treated more fully in the section on development.

Drilling Muds and Reserve Pits

Drilling muds and cuttings are disposed of either by reinjection into the well or in excavated reserve pits. Reinjection of drilling muds into a well is a recently developed method which largely eliminates the need for excavated pits, and therefore decreases the possible impacts of reserve pit fluids on the vegetation of the surrounding area.

Exploratory wells have typically used excavated pits to contain drilling muds. Although properly constructed and filled pits in NPRA had relatively little impact on the surrounding area (J. Mellor, pers. comm.), fluids from some pits did leach up to 30 m. Because most of the NPRA wells were drilled in 1 season, the pit could be backfilled before spring, freezing the muds in place. Improper location, construction, or closure can lead to future leaching and breaching of reserve pits (French and Smith 1980). Open pits from multiple season wells often fill with snow or spring run-off, and fluids may overflow or leach onto the surrounding tundra. Further discussion of the impacts of drilling muds on vegetation is included in the section on development.

## Impacts to Wildlife and Fish

### Birds

Further seismic exploration or exploratory wells will be conducted in the winter when few bird species are present (Chapter 4). Habital loss or alteration may result from exploratory wells. Such impacts are discussed in the section of further development. Winter activities such as ice roads, airstrip pads, and offroad vehicular traffic could disrupt rodent tunneling and have locally negative impacts on Lemmings and voles through reduced winter survival (Schmidt 1971 as cited by Bury 1978). If significant this could result in localized reductions in prey for owls, jaegers, and hawks. Gyrfalcons, although not common nesters on the coastal plain, may be disturbed from eyrie site by aircraft or vehicles. Dippers winter in the only open water available near Sadlerochit and Shubelik springs. Reductions in water flow at the springs, or any other activity that would cause the open water to ice-over, would probably extirpate dippers from the particular spring/stream system. The dippers that winter at Sadlerochit Springs are the northern most population known in Alaska.

### Mammals

#### Caribou

The impacts of an expanded winter seismic programs within the study area will be dependent on the location, intensity and duration of such operations as well as the current status and distribution of caribou using the area. If winter seismic activities are of low density and remain mobile (such as the 1984-1985 programs) and caribou distributions remain similar, the expected reaction would be local displacement of caribou from areas of activity for relatively brief periods. If activities intensify or are of longer duration, more prolonged displacement of wintering caribou would occur. The consequences of such displacement are not known. Seismic exploration activities west of the Sadlerochit River would potentially affect caribou of the CAH traditionally wintering there. Assuming that any further seismic exploration programs would be limited to when there is adequate snow and ground frost conditions (November to early May), and that distributions and range use patterns of the PH remain similar to those described earlier, such operations will have minimal direct contact with the PH.

Effects of exploratory drilling on caribou also depend on the number, location, duration, and season of operation of exploratory wells. The potential for impacts to a majority of the PH would be greatly reduced if drilling operations were restricted to the winter period when most of the herd is not in the study area. Winter drilling operations west of the Sadlerochit River could affect CAH caribou which traditionally winter in this area. Reactions of caribou are expected to be greatest during periods of activity (mobilization, drilling, and demobilization) at drill sites. The most prevalent reaction will likely be an avoidance of the immediate vicinity around the drill site. The distance of avoidance will vary due to a number of factors such as: noise levels, wind speed/direction, topography, moving visual stimuli (vehicles and humans), scent, and the size and composition of caribou groups encountering drill sites (Kelsall 1968, Bergerud 1974a, Jakimchuk 1980, Horejsi 1981). Because caribou tend to be less sensitive to disturbances during the winter as opposed to during the calving and post-calving season, and occur in sparse, scattered groups, reactions to isolated drilling operations are expected to be relatively mild (Gilliam and Lent 1982, Bergerud 1974a, Davis and Valkenburg 1979, Calef et al. 1976). The influence of winter exploratory drilling on caribou will depend primarily on the number and spacing of drill sites that would be in simultaneous operation during a given time period, although the number of drill sites active at one time is expected to be low. The location of transportation facilities (ice roads and air strips) and the level of traffic (aircraft and surface vehicles) will also influence the degree of impact to wintering caribou. Caribou may be impacted if roads and airfields used for support of drilling sites also provide access for hunters to previously inaccessible areas. Increased harvest of caribou could occur under such circumstances. Gravel roads and airfields would have a prolonged influence due to their permanent nature. The reactions of caribou to moving vehicles and human activity related to exploration activity will be considerably stronger if caribou associate such disturbance with the negative influence related to hunting (Klein 1980).

If drilling is not be completed within a single winter season, and continues beyond spring breakup (early May), potential adverse effects to caribou could increase substantially. During calving, post-calving, and insect seasons (late May to mid-August), caribou are more vulnerable to disturbance. Drilling activity within traditional "core" calving grounds of the PH during calving and post-calving could have major negative influences on large portions of the population. Year-round exploratory drilling activities in the western portion of the study area could effect that portion of the CAH which use the area, and in certain years may influence portions of the PH as well. The extent of impact would depend on the number of drill sites remaining active and the level of disturbance associated with each site. Displacement of at least 2 km from the drill site could be expected and some cow/calf groups may be displaced even further (Wright and Fancy 1980). Disturbance from aircraft associated with support functions would also adversely affect the herds.

Direct loss of habitat would occur if drilling is conducted from all-season gravel pads and if access were via gravel roads. Although the amount of habitat lost in relation to that amount which remains unaltered may be small for any particular drill site, the loss of vegetation will be very long term, and cumulative. Loss of vegetative habitat will be reduced if drilling is accomplished using ice pads and ice roads.

Overall, winter seismic exploration and exploratory drilling activity at select sites in the ANWR study area would probably not result in major, direct impacts to caribou, provided that these activities occur at low intensity, are widely spaced, and are conducted as temporary operations with no permanent roads, airfields or structures.

Muskoxen

Several aspects of muskox biology contribute to their vulnerability to potential impacts of continuing petroleum exploration on the ANWR coastal plain. Muskoxen are 1 of the few species present year round on the coastal plain. The animals are relatively sedentary and have a high fidelity to specific geographic areas (Jingfors 1984, Reynolds et al. 1986). However, muskoxen may have seasonal differences in movement and activity patterns. Data from satellite collared cow muskox showed decline in daily activity in winter (Reynolds 1986b). This muskox also moved less in winter, remaining in a relatively small area from March until May (Chapter 5, Fig. 31). This decrease in movement and activity is hypothesized to be an adaptive mechanism for the conservation of energy in winter (H. Thing, Denmark Game Biology Station, pers. comm.). White et. al (1984) suggest that muskoxen have evolved an intrinsically lower energy expenditure and food requirements in winter compared to other ruminants and found that voluntary food intake and maintenance energy requirement of young captive muskoxen were lower in winter than summer. Disturbances to muskoxen in winter which cause the animals to be more active (e.g: running into defensive formations or even rising from rest frequently) or which result in animals making long distance movements to avoid noise or other stimuli, would increase energetic costs during a time period when the animals must conserve energy.

Accessibility into new areas with the use of snow machines, trucks, tracked vehicles and aircraft will increase as petroleum exploration continues. Such access may increase the potential of muskoxen being harassed or illegally killed. The behavioral adaptation of grouping together into defensive formations when threatened (Hone 1934, Tener 1965, Gray 1973 and 1984) also contributes to the vulnerability of muskoxen.

Effects of additional winter seismic surveys on ANWR muskoxen would be similar to those observed during preliminary seismic work conducted during the winters of 1983-1984 and 1984-1985. No major dispersals from areas of current muskox distribution or effects on population size, are anticipated. Impacts would be on a temporary local scale.

Unlike seismic surveys which are only present for a few days in each area, drilling exploratory wells will concentrate activities at a given location for several months, possibly throughout the summer and into a second winter season.

Effects of aircraft overflights were documented in 1982-1985 during the ANWR baseline study (Reynolds 1986c). Muskoxen ran and grouped more frequently in response to helicopter overflights than to fixed-wing overflights. Seasonal differences in muskox response to fixed-wing overflights were also apparent. Animals were less responsive during summer, rut, and fall and more responsive during winter, pre-calving and calving. Flight altitude affected the animals' response to fixed-wing aircraft. Increasing altitude of the aircraft was related with fewer animals running, grouping, and becoming alert. Over 40% of herds observed showed no observable response to fixed-winged aircraft at elevations above 150 m. But over 35% of all herds showed some response to aircraft overflights, at flight altitudes of 300-610 m or higher (Reynolds 1986c). Bull groups (including single bulls) showed different response patterns to fixed-wing overflights than did mixed sex herds (including cow groups). Bulls grouped less frequently, probably as a result of agonistic behavior prior to and during the rut and showed no observable response more frequently than did mixed-sex herds (Reynolds 1986c). Responses to fixed-wing aircraft appeared to decline between 1982 and 1985 indicating that long term habituation by some muskoxen to fixed-wing aircraft overflights may have occurred. A decline in all response categories and a corresponding increase in no observable response were observed over all 4 years.

Miller and Gunn (1979) found an inverse relationship between response level and the altitude of helicopter flights over muskoxen in July and August. Less than 45% of all individual response samples (eg. maximum response of an individual) showed an observable response to helicopter overflights. Of these, almost 70% ran into defensive formations when overflights were at 50 - 100 m above the ground. At flight altitudes of 200-400 m, the percentage running into defensive formations declined to about 30%. They also concluded that muskox cows and calves were usually more responsive than other sex/age classes, that solitary bulls and bull groups tended to be more responsive than individual bulls in mixed-sex groups and that muskoxen may respond more to people on the ground than helicopter overflights. Some short term habituation may have occurred during helicopter overflights (Miller and Gunn 1980), but tolerances apparently vary among individuals or herds (Miller and Gunn 1984). Jingfors and Lassen (1984) observed 11 overflights of helicopters during summer seismic activities in northeast Greenland. Two herds ran from the disturbance, 3 herds grouped into defensive formations, and 6 herds showed no response. Aircraft traffic will be highest during construction phases, which may peak between January and May. Muskoxen were observed to be most responsive to aircraft overflights during the pre-calving period from mid-March to mid-April (Reynolds 1986c), a time when active/resting ratios may reach a yearly low as animals attempt to conserve energy reserves (Reynolds 1986b). High volumes of aircraft traffic as well as other activities associated with construction and drilling may cause animals to increase their activity and local movements.

Direct habitat loss will result from construction of exploratory wells when well pads, airstrips, and connecting roads are built and the land surface is covered with gravel or other material. Actual loss from these sources will be slight in comparison to the amount of habitat available. Gravel mining for construction will create greater impact if gravel is removed from areas of high muskox use on the Canning River, forks of the Tamayariak River, the Katakturuk River, the Sadlerochit River, the Okerokovik River and the Niguanak River. The effects of gravel removal on muskox habitat is difficult to predict without knowing the location and magnitude of gravel removal operations.

Noise, human presence and surface vehicles associated with construction activities at well pads, gravel sites, water sources and airstrips, may displace muskox in areas of frequent use. The magnitude of disturbance that will result in displacement is not known.

Most construction activities will probably occur in winter. Increases in muskox activity and movements may result in increased mortality for some individuals if energy expenditures exceed critical limits (Reynolds 1986b). Effects on the entire population probably would be limited.

When actual drilling begins, activities will be confined to relatively small areas at and adjacent to well pads. Displacement of individuals and increases in movements or activity patterns will probably be the same or less than that which may occur during construction of exploratory wells. Magnitude of the impacts will depend on the location and extent of drilling activities. Because activities associated with continuing petroleum exploration will be confined to relatively small areas and will occur over relatively short time periods, overall effects will probably be limited to local areas.

Moose

Moose are not commonly present in the study area in winter and are present relatively small numbers in summer (Chapter 5). Continued seismic exploration and exploratory drilling are not likely to impact ANWR moose populations, although displacement of individuals from areas of activity may occur.

Polar Bears

Polar bears may be present in the study area during denning, which begins during late October to early November. Pregnant females travel to coastal areas to den on fast ice, offshore islands or on the mainland up to 48 km inland. Cubs, born in midwinter, emerge from the den with the snow in March or April (Lentfer and Hensel 1980).

Potential, sources of disturbances to denning polar bears from continued exploration of the ANWR study area would include noise from seismic activities, and the drilling, of exploratory wells.

Responses of denning female polar bears to disturbance vary. Belikov (1976) found several bears deserted newly formed dens in October and November due to the presence of scientific investigators and thought that impact during the denning period was significant. In early March 1986, a female and an extremely small cub were sighted northeast of Prudhoe Bay, indicating an early exit from the maternal den (Lentfer 1974b). A female with 2 cubs was apparently disturbed by a seismic charge which caused the group to leave their den and travel north (Moore and Quimby 1975). Belikov (1976) reported observing female polar bears with cubs in dens without apparent disturbance, and a female with 2 cubs at a den in Prudhoe Bay were observed by oil company personnel for several weeks (Lentfer 1974).

Disturbance to denning female polar bears may result in 2 possible negative impacts. If the pregnant female was disturbed while searching for a den, she may retreat to the pack ice to den, where a less stable substrate and less snow may reduce denning success and productivity. Disturbance of females with cubs in dens may cause neglect or abandonment of the cubs, leading to their death and lower recruitment to the population (Lentfer and Hensel 1980).

Undisturbed denning habitat is important for polar bears. Denning habitats include areas which accumulate drifting snow, such as rivers, lake banks, and coastal bluffs. The percentage of potential habitat actually used is not known.

Other Marine Mammals

Seals and whales may not be affected by continued seismic exploration and the drilling of exploratory wells, unless a major fuel spill into the ocean occurs. Most activities would take place in winter, although year round drilling on the coast may cause displacement of animals in a local area.

Brown Bears

Further exploration, including the drilling of exploratory wells, has the potential of affecting the brown bear population that uses the coastal plain of ANWR. Brown bears are normally found in remote areas not readily accessible by man. As these remote areas became more accessible, brown bear populations usually decline. As Jonkel (1970) observed, these declines are not the result of brown bears leaving the area, but rather the extermination of bears from the newly accessible areas. If further exploratory activities are primarily confined to winter operations and no access modes (roads and airstrips) are installed on the coastal plain, brown bear populations will be little affected by further exploration.

Another potential effect exploratory drilling is the generation of garbage at well sites. Brown bears are highly adaptive in their food habits and readily learn to use food avialable at garbage dumps (Kucera 1970). The attraction of bears to garbage areas in several National Parks is well documented (Craighead and Craighead 1971, Cole 1971, Marsh 1972, Mundy and Flook 1973). This attraction can increase intraspecfic strife (Jonkel 1970) and result in higher mortality, especially for cubs. The behavior of bears that become conditioned to humans and human odors can change and become dangerous to humans (Craighead and Craighead 1971). These bears are routinely killed to avoid this danger to humans. If the recommendation of Milke (1977) are following in an exploratory drilling program (re. incinerated garbage, enclosed containers, and frequent removal of processed garbage), brown bears will probably not be attracted to well sites.

Wolves and Foxes

Seismic activity, if conducted as previously, should have similar impacts as described for the 1984-1985 program with the exception of additional habitat destruction. Habitat destruction would primarily affect foxes through destruction of den sites. Intensive seismic activity in a restricted area increases the potential for damage and/or destruction of den site locations, and will have the greatest effect in areas where the availability of den sites are limited. Data on the availability of fox den sites on ANWR are lacking.

Arctic fox populations fluctuate in cycles which are closely related to cycles in numbers of microtines (Dementyeff 1958, Tchirkova 1958, Chesemore 1967, 1975, Wrigley and Hatch 1976), the principal prey items in most areas. During Hatch periods following crashes in prey populations, foxes wander over large areas searching for food. Outbreaks of disease are common. In arctic Alaska rabies is endemic in arctic fox populations and epizootic outbreaks are well documented (D. Ritter, Northern Regional Laboratory, pers. comm.). If seismic activity were to occur during such a period, human-fox interactions would be expected at seismic camps and the potential for transmission of disease from foxes to human would increase proportionally.

Exploratory wells have a greater potential for impacts on canids as structures are semi-permanent and require support activities such as staging areas, roads between supply areas and wells, and airstrips. Structures and activity in 1 place for any length of time allows animals to become habituated to human presence. Once habituation occurs, human-animal interactions increase. Urquhart (1973) and Follmann et al. (1980) found the main attraction of staging areas and camps to be availability of food in the form of garbage, sewage, handouts, and food stored under trailers. Improper handling of food material and band feeding by workers and truckers caused "serious" problems during the construction of the Trans Alaska pipeline (TAPS) (Klein and Hemming 1976, Milke 1977, Klein 1979). Virtually all construction camps and pump stations north of the Yukon River had periodic problems with bears, wolves, and foxes which became pests after being attracted to the sites by food sources (Milke 1977). Artificial food sources may keep canid populations at artificially high levels (Grace 1976, Douglass et al. 1980). Fine (1980) estimated that 200 or more arctic foxes were present at Prudhoe Bay during an average winter as compared to 35 adults with 26 to 35 pups during the summer of 1979. This was attributed to the large amounts of artificial foods sources available. He suggested that artificial food sources at Prudhoe Bay enabled more foxes to reproduce when lemming numbers were low. Eberhardt et al. (1983) found that the density of dens at Prudhoe Bay was approximately 3 times that on Colville Delta (an undisturbed area). In 1977, when lemming numbers were low, survival or production of juvenile foxes decreased on both areas, but the decrease was less pronounced in the Prudhoe Bay area. Lease holders in Prudhoe Bay have financed an active fox trapping program to control foxes (Weeden and Klein 1971).

Wolves and foxes were commonly fed by truckers along the haul road north of the Yukon River (Milke 1977). Wolves were frequently seen crouching along the road awaiting handouts and foxes were readily attracted to parked vehicles (Milke 1977).

Canids that congregate at camps may transmit diseases such as hydatid disease and rabies to humans as well as among themselves (Milke 1977). It is generally known that there are periodic outbreaks of rabies in arctic fox populations which may also affect red foxes and wolves. Happy Valley Camp experienced a rabid fox problem in the spring of 1974 (Follmann et al. 1980) and rabid arctic foxes were destroyed in several construction camps north of the Brooks Range (Milke 1977). On ANWR, a rabid fox was killed at the Kaktovik Inupiat Corporation (KIC) well in winter 1985 (D. Ritter Northern Regional Laboratory, pers. comm.). Animals around camps are sometimes destroyed if they are suspected of having the disease, bite someone, try to bite someone, or are in the vicinity when someone is bitten (Milke 1977). When animals are concentrated at camps, an outbreak of disease could pose a serious threat to wolves and lead to widespread killing of foxes (Klein and Hemming 1976). On Banks Island, dogs were used at camps to chase foxes away from inhabited areas (Urquhart 1973), however this control method is hazardous due to the possibility of dogs contacting rabies and resultant exposure to workers.

Foxes used stockpiles of pipe, culverts, underground utility corridors, and crawl spaces beneath buildings for shelter and foraging (Fine 1980, Follmann et al. 1980, Eberhardt et al. 1982, Eberhardt et al. 1983,). Wolves also occasionally used unskirted buildings for sleeping and shelter (Milke 1977, Follmann et al. 1980). Use of such areas not only increases the contact rates between workers and animals, but may result in damage to equipment and buildings. Foxes and wolves have been known to chew through seismic wires, telephone wires, electric wires, and cables, and remove geophones (Weeden and Klein 1971, Klein 1973, Urquhart 1973,).

Wild canids, if not habituated to artificial foods, are shy and tend to avoid direct contact with man (Follmann et al. 1980). Urquhart (1973) stated that arctic foxes would not be attracted to sites of human activity if food sources were eliminated.

In addition to mortalities from road kills and control of nuisance animals, canids that have become habituated to human presence are more susceptible to hunting, trapping, and poaching. Reports were commonplace of individual employees at Prudhoe Bay illegally trapping up to 30 foxes during winter (Fine 1980). As pipeline-related traffic along the haul road decreased, poaching of furbearers increased (Klein 1979; R. Stephenson, Alaska Dep. Fish and Game, pers. comm.). During the winter of 1977-1978, the north slope wolf population along the area transversed by TAPS was reduced from 35 - 40 animals to only 3 - 4 individuals by aerial trapping and poaching along the road (C. Cameron, Alaska Dep. Fish and Game, pers. comm. as cited by Douglass et al. 1980). Although these numbers are estimates, the actual decrease was of the same order of magnitude (K. Whitten, Alaska Dep. Fish and Game, pers. comm.).

Ice roads and airstrips used to connect well sites with supply areas on the coast would increase access to previously remote areas. Presently, during the winter, the study area is mainly used by local residents from Barter Island using snowmobiles. This use is limited to periods when snow cover is adequate to facilitate hauling freight sleds and when daylight is sufficiently long to allow tracking and hunting. Hunters usually travel to the foothills along a few restricted routes and stage out of camps to hunt surrounding areas. Some access is gained by travelling down the coast and then inland. Although at times large areas of the mountains, foothills and coastal plain are used, in most years, use is limited to areas around the Hulahula and Sadlerochit Rivers and a few areas near the coast. Ice roads connecting well sites and supply areas would provide access to areas not normally used. In addition this access would be much easier and faster, and the ice roads would provide for travel several weeks longer than normal snow conditions permit. Wolves and foxes in these areas and adjacent foothills and mountains would be particularly vulnerable to harvest due to the openness of the terrain.

Exploratory activities result in an increase in aircraft traffic. Exploration wells require extensive use of helicopter and fixed-wing aircraft for support activities. Increased access will result in increased presence of privately-owned aircraft. Increased aircraft activity can increase harassment of wildlife. Harassment can be intentional (low fights to observe or photograph animals), or inadvertent (low flights due to inclement weather). Helicopters generally invoke a stronger response from wolves and foxes than fixed-wing aircraft. Knowledge on the effects of harassment on canids is limited due to difficulty in study methods and variation in responses by individual animals.

Reaction of wolves to aircraft range from no observable reaction to very strong avoidance reactions. Some wolves may show strong responses to aircraft long after others have become habituated. During the ANWR study, wolves pursuing caribou were observed to break off the chase when aircraft fly overhead. Foxes may be most susceptible to harassment when natural food sources are scarce (Urquhart 1973). Harassment stresses even habituated animals and can be especially serious at critical periods in the animals lives (Geist 1975, as cited by Douglass et al. 1980).

Placement of wells, roads, etc. on or near landforms used for denning will limit use of those sites by foxes. Urquhart (1973), suggests that denning foxes generally avoid areas of human activity. Fine (1980) and Eberhardt et al. (1983) also found that arctic fox use of developed sites in the Prudhoe Bay area decreased at the start of the breeding season. Placement of structures at or near den sites may either destroy the den or cause foxes to den elsewhere. Displacement from denning locations could be critical in areas where den sites are limited. Wolves have not been known to den on the coastal plain of ANWR; therefore, the potential loss of wolf den sites is apparently not significant.

Wolverine

Impacts of continued seismic exploration and exploration drilling on wolverines are unknown as there are no published data on the effects of petroleum exploration on wolverines. Wolverines apparently are not vulnerable to problems associated with human feeding and attraction to garbage.

## Fish

Further exploration in the study area could effect fish populations in several ways. Severity of the effects would depend on location, timing and specific activity. Additional seismic surveys could result in stream bank erosion, siltation, and benthic disturbances from cat train stream crossings. Seismic surveys using explosives may adversely affect overwintering fish populations. If explosives were used too close to waterbodies, detonations can result in undue stress or mortality from seismic waves.

Exploratory wellsities involving drilling require much more water than seismic work and increase the potential for conflict with fish populations. Little water remains unfrozen during winter in the study area that is not associated with overwintering fish. Exploratory drilling sites on the north slope are generally accessed via ice roads which may require up to 4000 $km^3$ of water per 1.6 km of road to construct and 200 $km^3$ per 1.6 km to maintain (Peterson 1980). Exploration drilling rigs may require 160 $km^3$ of water per day for operation (Wilson et al. 1977). These needs, compounded by large quantities necessary for airstrip construction, camp and personnel needs, and miscellaneous uses, make the overall water requirements for exploratory drilling a serious threat to area fish populations.

If gravel pads are used for exploratory wells, effects of gravel removal from streams could eliminate fish spawning habitat unless removal was restricted to inactive channels.

Oil or other contaminant spills can occur during exploratory drilling. Effects from such spills should be localized except during the unlikely event of a well blow-out. Reserve pits that contain drill muds and fluids from the exploratory well may also leach or over top. If located near fish-bearing waters, spills not contained and cleaned-up immediately could pollute waterbodies.

Increased fishing pressure in some areas may occur with additional human activity in the region. This should be negligible for winter exploratory operations. Should exploration drilling be permitted year around, potential adverse effects to fisheries could be increased. Besides increased fishing pressure, more water withdrawal would be required, the need for gravel work pads would be more likely, and construction of some stream crossings may become necessary. Contaminant spills are more likely to become widely dispersed during the open water season.

Overall, exploration should only have minor effects on fisheries. Impacts should be localized and of short term. A major spill incident or water withdrawal affecting fish overwintering habitat could increase the severity of impacts.

Impacts to Human Culture and Lifestyle

<u>Archaeology and Human History</u>

Impacts to archaeological resources may be caused by surface vehicle traffic during geophysical exploration activities and the construction of exploratory wells. Potential effects of vehicle traffic during summer and winter over different surface conditions are summarized in Table 4. The amount of damage that could occur would depend on factors such as the type of vehicle involved, what part of it contacts the ground, ground pressure (psi), and driver skill. Damage to archaeological sites from surface travel can include: direct breakage of cultural objects; damage to vegetation and thermal regime leading to erosion and subsequent deterioration of organic artifacts and/or shifting and mixing of components in stratified sites; and loss of association between cultural objects.

Drillsites and campsites can cause impacts to archaeological resources not only because of the vehicles used around the camp, but also because of the associated pedestrian traffic. Summer camps, such as those used for surface geologic exploration, would have the greatest impact if large numbers of people are housed for an extended period of time. The impacts would be similar to those of surface vehicle use, although less severe. Fuel spills can have an indirect yet serious impact on archaeological sites by contaminating organic material associated with sites which would eliminate the possibility of using $C^{14}$ dating methods. This is potentially the most serious problem connected with ground vehicle travel in the study area. Studies of the Old Fish Creek Wellsite, where drilling took place 30 years ago, indicate that the effects of oil spills are pervasive and long term; soil samples from a depth of 40 cm still retain a strong smell of diesel fuel and thaw in some cases reached 70 cm, nearly twice the thaw depth in adjacent unaffected areas (K. Everett, Univ. Colorado, pers. comm.). Clean-up activities could also inadvertently damage cultural resources.

Table 4. Possible damages to archaeological sites as a result of ground vehicle traffic (source: Hall 1982).

| Conditions at archaeological site | Nature of possible damage |
|---|---|
| Summer | |
| Any subsurface, with or without ground cover; any ground cover. | Moderate to extreme breakage, loss of association, mixing of components and/or loss of cultural objects due to erosion, deterioration of organic artifacts due to lowering of permafrost tables. |
| Winter | |
| Bedrock or consolidated sand/gravel with no sod cover or with thin sod cover with/without denuded areas. | |
| Frozen ground and substantial snow cover. | Probably none |
| Frozen ground and relatively little snowcover. | None to slight breakage and/ or lateral displacement of objects. |
| Unfrozen ground and substantial cover. | None to slight breakage and/ snow or slight lateral/vertical displacement of objects. |
| Unfrozen ground and relatively little snow. | Moderate to extreme breakage, lateral and vertical displacement, possible erosion. |
| Wet tundra or other unconsolidated ground or upland tundra. | |
| Frozen ground and substantial snow cover. | Probably none. |
| Frozen ground and relatively little snow cover. | Slight to moderate damage due to erosion. |
| Unfrozen ground and substantial cover. | Slight to moderate damage snow due to erosion. |
| Unfrozen ground and relatively little snow cover. | Moderate to extreme damage little due to erosion. |
| All seasons | |
| Any condition | Contamination of organic material from fuel spills entering ground water; no possibility for $C^{14}$ dating of sites. |

Exploration drilling could result in the destruction of archaeological or historical sites if sites are located in gravel borrow areas or in areas where drill pads, airstrips or gravel roads are constructed. Crews at drill pads adjacent to archaeological or historical sites could also damage or destroy sites by collecting artifacts.

Archaeological and historical sites identified by Hall (1982) and Libbey (1982) could be avoided and protected by posting sites, and educating and informing individuals (Hall 1982). Site specific surveys would have to be completed before exploration drilling began to avoid damage to unknown archaeological and historical sites. Hall (1982) states that sod house sites with standing structures are in danger of being damaged by vehicle traffic no matter what operating conditions or environmental stipulations exist, and that tent ranges and flake scatters are less vulnerable to impact if environmental protection stipulations are established and followed.

Subsistence

Continuing petroleum exploration with geophysical surveys and the drilling of exploration wells will affect the subsistence economic system. In a sociocultural assessment of proposed oil and gas exploration in the ANWR, Arctic Environmental Information and Data Center (1982) identified potential sources of impacts and components within sociocultural systems which may be most sensitive to impacts. U.S. Geological Survey (1979) also identified socioeconomic impacts which may result from petroleum development and production in the National Petroleum Reserve in Alaska (NPR-A), an area 200 km west of ANWR. The following discussion combines information from these 2 sources. Focus is on the village of Kaktovik because of its close proximity to the study area.

Kaktovik. Components of the sociocultural system sensitive to change resulting from petroleum exploration of the ANWR include the local economy, cultural values and social organizations, facilities, and services (Arctic Environmental Information and Data Center 1982). Potential effects of exploration activities on these components are listed in Table 5.

As described in chapter 7, the economy of Kaktovik is comprised of cash and subsistence components (Worl & McMillan 1982). Employment and cost of living are sub-elements of the cash component while the subsistence component is comprised of economic, social and cultural spheres. Petroleum exploration activities could increase wage opportunities and possibly alter subsistence production. According to Arctic Environmental Information and Data Center (1982), an increase in local employment opportunities in Kaktovik could be a positive change, if it offsets the decline in employment by the North Slope Borough (NSB). But employment opportunities would be limited to the time and season when exploration activities were occurring and no long term employment would probably result.

An increase in the number of jobs would increase the amount of cash available to purchase gasoline, snow machines, and other items needed for subsistence. More cash will permit improvements to houses and increase the economic stability of the community. But as the demands for purchased goods increase, the cost of living will also increase (U.S. Geological Survey 1979). Increase in personal income will not necessarily result in a decrease in subsistence production (Arctic Environmental Information and Data Center 1982). Cash can

Table 5. Possible effects of petroleum exploration in the Arctic National Wildlife Refuge on the subsistence economic system. (source: U.S. Geological Survey 1979, Arctic Environmental Information and Data Center 1982).

| | Socio-Economic changes | | Environmental changes |
|---|---|---|---|
| Affected components | Employment opportunities | Increased population | Decreased availability of subsistence resources |
| Economy | | | |
| cash element | Less unemployment<br>More cash<br><br>Higher cost of living | Higher cost of living | |
| subsistence element | Less time for subsistence<br><br>Cash to increase hunting efficiency | Competition for subsistence resources | Less subsistence production |
| Social structure | Less time with families<br><br>Stress on kinship, social structure | Shift in sex ratios<br><br>More interethnic tension<br><br>Stress on kinship, social structure<br><br>More crime and health problems | Less sharing and cooperation<br><br>Less socialization and training of children<br><br>Possible decrease in extended families |
| Cultural values | Less time for traditional activities<br><br>More rapid cultural change | Shift in ethnic population ratios<br><br>Loss of regional isolation<br><br>More rapid cultural change | Loss of subsistence skills<br><br>Health problems |
| Government | More tax revenues | More demands on local government | |
| Facilities & services | | More demands on infrastructure, housing, transportation | |

improve the efficiency of subsistence activities with the use of modern equipment such as snow machines, motor boats and aircraft, by decreasing travel time to hunting sites. Time constraints of wage employment would effect subsistence, however, if employers ignore the hunting and seasonal needs of employees (Arctic Environmental Information and Data Center 1982).

Size of the local population may increase during petroleum exploration activities if skilled workers and support service are staged in or near Kaktovik. Increased job opportunities may also attract people to Kaktovik. An increasing population will cause the cost of living to increase (U.S. Geological Survey 1979). But major changes in population will be relatively short term and seasonal, limited to the duration of the exploration activities.

Alteration of the environment which affects distribution, numbers or access to wildlife populations, particularly caribou and fish, will also affect the economy of Kaktovik (Arctic Environmental Information and Data Center 1982). Potential effects of exploration activities on these species are discussed earlier in this chapter. If subsistence production (hunting, fishing, gathering of natural resources) is limited by petroleum exploration, a higher percentage of food would have to be purchased. The resulting decline in subsistence foods could affect diet and health, particularly of elderly citizens who depend on resources provided by others and have a limited income (Arctic Environmental Information and Data Center 1982). The technical efficiency of hunting obtained through practice may also decline if the availability of wildlife or fish decreases. But petroleum exploration activities will be limited in time and space and most environmental effects on access and wildlife distribution will probably not exceed the duration of the program.

Cultural values and social organization are major components of the subsistence economic system of Kaktovik and any changes to the economy will affect these aspects of society. Increasing employment opportunities may decrease the time and opportunity to pursue traditional activities and time spent with family. This may cause stress on traditional kinship patterns and social structures and make maintenance of cultural traditions more difficult. Population increase resulting from exploration activities will cause similar pressures on cultural values and social organization. In addition, a shift in ethnic composition and sex ratios may have a negative effect on interethnic relations (U.S. Geological Survey 1979). But population increase in Kaktovik associated with petroleum exploration of ANWR probably would be relatively small and only present for the duration of the program. Small increases in population size, would have a negligible effect on Kaktovik (Arctic Environmental Information and Data Center 1982).

Environmental effects which decrease the availability of subsistence resources could also weaken social bonds which maintain the extended family, and weaken sharing, cooperative behavior, and hunting skills which are major elements of the Inupiaq social structure and culture.

Worl and McMillan (1982) state that all cultures are constantly changing and no culture is completely stable. Chance (1966, as cited in Worl and McMillan 1982) found that in spite of social and cultural changes initiated by construction of the DEW line station, Kaktovik Inupiat made positive adjustments and maintained the internal stability of the group. The Inupiat culture and social organization has shown a remarkable resiliency and tenacity as political economic forces continued to accelerate throughout the past decade, (Worl and McMillan 1982). The following factors have contributed to this stability (Worl and McMillan 1982): small and predominantly Inupiat community with high levels of social interaction and communication; functional extended families although nuclear families are becoming increasingly by evident; a strong political government; local autonomy with successful intermix of local employment (by NBS and village corporation) and subsistence; subsistence still vital for economic and cultural purposes; equal employment opportunities for all sex and age classes. Maintenance of these factors will reduce the likelihood of socioeconomic impacts on the village of Kaktovik (Worl and McMillan 1982).

Other Villages. Because of their distance from ANWR, other villages in the region are less likely to have socioeconomic changes resulting from petroleum exploration on the ANWR. Environmental changes which may affect distribution or numbers of caribou in the PH would be one potential source of impacts on Arctic Village, located 170 km south of the ANWR study area, which depends on PH as a major subsistence resource. Effects of continuing petroleum exploration on caribou are described earlier in this chapter.

Recreation, Wilderness, and Natural Landmark

Continuing petroleum exploration on the ANWR coastal plain may affect recreation use of the refuge. Geophysical surveys, because of their transitory nature, would probably not physically restrain recreationists from participating in their chosen activities. Drill sites and associated areas of activity may be closed to recreationists for security and safety reasons. Closed areas would be relatively small and limited to the duration of the project.

Of more significance are psychological factors which may prevent recreationists from utilizing the ANWR study area. If visitors expect wilderness quality, they may be deterred from visiting the coastal plain if oil and gas exploration activities are present. As summer is the season when most recreationists use the study area, seismic or drilling operations conducted only in winter would have little direct impact on recreationists, but year round drilling of exploration wells may occur.

Equipment and logistical support required for petroleum exploration activities may cause disturbance in a wilderness environment. Most visitors support maintaining the wilderness in a pure state (Warren 1980) and disruption of the wilderness character will likely negatively affect the recreational experience even though the recreational activity itself is not curtailed or prevented. Direct disturbance factors can include noise from machinery, vehicles, explosives, helicopters and aircraft, visual intrusions from the presence of drill sites, and camps and their associated solid waste, and possibly air pollution from diesel engines or generators causing foreign odors in otherwise pristine air. On the flat tundra of the coastal plain it is possible to see objects for long distances, and seeing a camp with associated facilities in an otherwise pristine setting would impact the scenic resource and the esthetics of the view. There has not been any research to identify which, if any, of the above disturbances are most annoying or acceptable to recreationists or how far noise levels carry across the tundra. But, solitude and tranquility, both important components of a wilderness experience (Hendee et al. 1968, Rossman and Ulehla 1977) may no longer be available in the presence of petroleum exploration activities. By directly affecting the esthetics of the wilderness area, petroleum exploration may indirectly reduce recreational use of the study area.

Most effects on recreation will occur primarily during the times when exploration activities are on-going. But if obvious changes in the wilderness landscape occur, impacts may be more long term. Hikers crossing the coastal plain and encountering abandoned drill pads, tracks from vehicles, or other scars from man's activities, may be negatively affected. The impact of any recent evidence of man's presence in the pristine environment could have detrimental effects on the wilderness user's experience. Exploration activities affecting wildlife populations may also indirectly affect recreationists. Wildlife observation is an important part of most visitors' experiences (Warren 1980). If wildlife are frightened away or become exceedingly wary and difficult to view, this will lower the quality of experience that visitors receive. It may negatively affect hunter's trips if they are unable to have a successful hunt, and may also negatively affect the hunting guide operations in the study area.

Any permanent scars on the landscape will contribute to the ineligibility of the ANWR study area for inclusion in the Wilderness System. Although temporary intrusions of vehicle trains, helicopter flights or camps will not impact eligibility of the area. Natural landmark eligibility at the 2 nominated sites would probably also be jeopardized by permanent damage or permanent evidence of man's activities.

Consideration of the ANWR study area for Wilderness designation is a concern. Section 1317 of ANILCA requires that the Secretary of the Interior review all National Wildlife Refuge lands that were not designated Wilderness for suitability for designation and that the President must make recommendations to Congress regarding formal designation. Of all the Alaskan North Slope, presently only a small area in the northeast corner of the state, that area within the Arctic National Wildlife Refuge, has been formally designated as Wilderness. In addition to the study area, only one other federal land holding, the Central Arctic Management Area, managed by the Bureau of Land Management, is under consideration for potential Wilderness designation. Certain lands within the National Petroleum Reserve in Alaska (NPR-A) may constitute "de facto" wilderness, but there is no existing or proposed legal designation for those areas. In fact, much of NPR-A is being leased for oil and gas development and most state land north of the Brooks Range has been leased and explored, or is proposed for leasing. Native land holdings in the Alaskan arctic may or may not be opened for development; their future use is unknown. Retention of wilderness characteristics of the study area is important if inclusion into the Wilderness System is to be maintained as an option. Some impacts which may be acceptable in terms of fish and wildlife habitat or population loss could be unacceptable for protection of wilderness values and characteristics necessary to qualify the study area for Wilderness designation.

## Development, Production, and Transportation

Following a discovery or significant evidence of oil from exploration drilling, confirmation or delineation wells are drilled. Delineation drilling continues until enough information has been collected to determine whether or not a reservoir could be produced economically. The actual number and scheduling of delineation wells are tailored to each reservoir. Delineation wells are drilled similar to exploration wells except 2 or more well might be drilled during the same winter, and the airstrip and roads for support of the drilling rigs would be shared. Some of the roads and delineation-drill pads may be constructed with gravel to be used during production.

Infrastructure for any oil production on the NAWR study area requires many facilities, like those for the Kuparuk River and Prudhoe Bay oil fields. These major facilities include central production facilities (CPF's), drilling pads, roads, airstrip, pipelines, water and gravel sources, and possibly a marine facility . All would be of permanent construction and have a useful life of 20-30 years. The airstrip, roads, pads, and dock would typically be constructed of gravel mined from nearby upland sites, terraces, or streambeds; and most structures and production facilities would be built elsewhere as modules and transported to and assembled on location.

Once major production facilities, including gathering pipelines, are in place, production can begin. The productive life of the field is usually 20-30 years. After production from the reservoir is no longer economic, the field is abandoned. All surface facilities, buildings, and pipelines are removed from location.

The physical characteristics (size, shape and depth), and performance (well production rate and spacing) of a field determine the number and location of surface facilities needed for development and production. The size and shape of the productive field roughly defines the a real extent of surface disturbances from production-related facilities, and typically encompass all or most of the production facilities, such as drilling pads, infield roads, and gathering lines. The camp, airstrip, or other facilities not directly related to actual production are positioned to best suit environmental and engineering concerns. For environmental and technical reasons, it may be desirable to shift the location of the drilling pad. Directional drilling allows multiple wells to be drilled from a single surface location, and reflects economics, engineering considerations, and environmental impact mitigation.

Reservoir type and performance influences the spacing of production wells, which in turn affects the number of drilling pads required for development and production. The well spacing for a producing field is designed to effectively drain a specific area surrounding the well bore. On the north slope, well spacing, or well density, varies from 30-130 ha. Well spacing, may also be increased (area drained reduced) to increase oil recovery or sustain a field production rate. Production drilling on the ANWR study area is assumed to be on 65 ha spacing, the present practice in portions of producing field on the north slope. Injection wells are required for fluid disposal, gas reinjection for storage and pressure maintenance, and waterflooding also for pressure maintenance.

The central processing facility (CPF) is the primary operation center for production activities and typically the headquarters for each field. The CPF includes: production facilities; living quarters and administrative office center; workshops, maintenance buildings and garages; fuel and water storage; electric power-generation unit; solid waste and water treatment facilities; and crude oil topping unit (perhaps 1 for the entire 1002 area). All facilities can be located on a single gravel pad. If the field size is on a scale similar to Prudhoe Bay or Kuparuk River some facilities may be located on separate pads and additional CPF's would be necessary. Each pad would be about 1.5 m thick and could cover 8-40 ha, requiring 138,000-690,000 $m^3$ of gravel. Actual pad thickness depends on the amount of insulation necessary to protect the permafrost from thawing, but a 1.5 m thickness provides the needed insulation for most of the ANWR study area. Structures would be built on pilings and elevated above the pad surface to ensure foundation integrity for the project life. Pad size varies according to the magnitude of the field, good arctic engineering practice, and environmental concerns.

Living quarters provide sleeping accommodations, kitchens, food storage, dining areas, and recreation facilities for all production, maintenance, and administrative personnel at the CPF, about 200-500 people depending on the magnitude of operations. Support services, administration, engineering, communications, and project management would be housed in an adjacent administrative office center. The workshop, maintenance center, and main garage would be located nearby, with house fire, safety, and oil-spill equipment as well as parts and supplies.

Production facilities include the equipment necessary to process production from the producing wells, beginning with a series of 3-phase separators which result in 3 products--oil, gas, and water. Each product is run through additional separators until the required separation is obtained. The oil is piped through the sales meter and then onto the pipeline pump station. The gas is available for on-site fuel requirements or is used for producing additional oil (enhanced oil recovery or gas lift). The produced water is pumped to water injection wells for subsurface disposal or reservoir waterflooding.

A waterflood system for secondary oil production would may be necessary. Waterflooding involves injection of large amounts of water into the reservoir (400,000 barrels per day for the Kuparuk River field, and up to 2 million barrels per day for Prudhoe Bay field), to sweep oil toward producing wells and maintain reservoir pressure. Seawater is used for waterflood if sufficient quantities of produced water are not available. A seawater system includes a seawater-intake structure and treatment plant on the coast, an insulated pipeline from the coast to each CPF, and heat generators spaced at intervals along the pipeline to prevent the water from freezing. The treated seawater is then be piped to the drilling pads for injection. The entire plant could be built in a single barge unit and grounded at the coastal site.

Fresh water for camp use could be obtained from lakes, waterfill gravel pits, or desalinated seawater. Fresh water requirements for camp use could be up to 38,000 liters per day, and drilling water requirements could be as high as 114,000 liters per day per well. Water for drilling and production requirements would be difficult to obtain in sufficient quantities on the study area, so combinations of some or all sources may be necessary. Potable water for camp use would stored at the CPF in insulated storage tanks. Additional water and sewage treatment facilities are at each CPF. Fuel storage would hold diesel and other necessary refined petroleum products and would be diked to contain any spills. A crude-oil topping plant would provide the field's needs for arctic diesel and jet fuel. An electric generation plant, fueled with produced gas, would provide power for each field. Backup diesel power would be available at all sites for use in outages.

Production from the drilling pad could begin before all wells are completed, and production and drilling may occur at the same time. The layout of a pad during drilling activities typically includes the following: drilling camp, fuel and water storage, 1 or 2 drilling rigs, drilling supplies, reserve pits, production facilities and equipment, gathering facilities, and flare stack.

The drilling pad constructed with gravel, covers 8-14 ha. A pad thickness of 1.5 m requires 123,000-220,000 $m^3$ of gravel. The drilling camp is similar to the camp facilities at the CPF, but smaller and temporary. Housing is required for approximately 50 people per drilling rig, and support staff and some maintenance workers for the production wells. Once drilling is complete, the drilling camp is disbanded and remaining personnel are housed at a CPF.

Depending upon the depth of the productive horizon, a producing well takes as long as 40 days to drill, test, and complete. Production is piped from the wellhead to the gathering facility where the production of each well is usually tested and metered. From the facility, the production flows through gathering lines to the CPF.

Drill cuttings and drilling muds from the well are stored in the reserve pit adjacent to the drilling pad. A flare stack located near the drilling pad is used for routine and emergency gas flaring.

The number of pads required to develop and produce an oil reservoir depends upon its size and depth, the producing well spacing, and number of wells on a pad. These factors cannot be determined until engineering studies are completed. However, as an example, a relatively deep field of 14,000 productive ha developed on 65 ha production well-spacing may require approximately 220 production wells and 90 injection wells. If the wells drilled from a single pad could effectively drain 2,000 ha, 7 drill pads would be necessary. Forty to 50 wells could be drilled from each pad.

An airstrip to support field development and production in the study area would be a permanent, year-round structure used for the entire life of a field. It would be designed to accommodate fixed-wing aircraft and helicopters, and have a minimum length of 2400 m and a width of 45 m. The airstrip would cover approximately 8 ha; an adjacent taxiway, apron, terminal, and other airport support facilities could require another 4 ha. The airstrip and pad for support facilities would be constructed of gravel and be about 1.5 m thick. The estimated gravel requirements are approximately 192,000 $m^3$.

Gravel road would connect all permanent facilities in the field, that is, all drilling pads, CPF's, airport complex, water, and gravel sources, and waterflood and marine facilities. These roads have a crown width of approximately 11 m and a thickness of 1.5 m. Each mile of road occupies about 2 ha and requires approximately 31,000 $m^3$ of gravel. The extent of roads constructed depends upon the size and physical setting of the field. In-field pipelines or gathering lines run from each drilling pad to the CPF. Pipelines carry the produced oil stream from the drilling pad to the CPF. Parallel pipelines carry gas and water from the CPF to the drilling pads for fuel, injection, or disposal. The pipelines would probably be in the 20-40 cm diameter range and be built parallel to the roads connecting the drilling pads and the CPF. They are commonly placed on steel vertical support members (VSM) elevated at least 1.5 m.

Development and production in the study area would probably require a marine facility. Long hauls from the facilities in Prudhoe Bay area would be impractical. Siting the coastal facility would take into consideration the locations of the proposed developments, environmental, and engineering concerns. The facility would contain water-treatment facilities and various supporting operations and receive barges loaded with supplies, cargo, and production/support modules.

A marine facility requires 1 or more docks and sufficient storage pads to facilitate orderly and timely unloading of barges. A temporary camp and associated support facilities may be required during unloading periods if the main camp is too distant to provide necessary living quarters for marine facility workers. A transportation corridor would connect the marine facility with the development sites.

Transportation of crude oil by pipeline to an ice-free port on the southern coast of Alaska is assumed to be the most probable method. Because of permafrost an elevated pipeline is the most probable system for transporting oil produced from the study area west to TAPS Pump Station 1 at Prudhoe Bay. To prevent thawing, elevated pipelines would be supported by vertical support members(VSM) placed into the frozen ground. The pipeline could be designed like the Kuparuk River field pipeline, with support beams large enough to accommodate additional pipelines, depending on future needs for oil or gas or possibly water.

A pump station is required about every 80-160 km depending on topography: therefore, 2 to 3 pump stations could be required to cross the study area. Each pump station would contain pumping, oil-storage, power, and pipeline equipment; repair, and communication facilities; living quarters for about 30 people, and environmental-support systems. The station would be constructed on about a 3 ha gravel pad. Surge and storage tanks at each pump station would collect oil discharged through relief valves when surges occur.

Control of the pipeline from ANWR to Prudhoe Bay would require a complex communication system of permanent microwave stations to link all pump stations, remotely controlled gate valves, and pipeline maintenance centers with a control center. The remote stations typically include a self-supporting steel antenna tower, 2 small buildings, and 2 to 4 fuel tanks. Each station has a heliport. Such stations, if patterned after the TAPS system, are located on relatively high ground about 60 km apart.

A spine road would roughly parallel the pipeline across the study area to Pump Station 1. This permanent, all-season gravel road would be built in accordance with accepted arctic engineering practices on 1.5 m gravel fill, with a 11 m wide driving surface, and would support constructon of the pipeline and link central production and marine facilities. The pipeline would be constructed during winter from a snow pad or ice road. If snow or water is not available in sufficient quantities, a gravel work road may be neccesary. Gravel access roads would connect the main road to pump stations, valves, and maintenance stations. Emergency access to the pipeline during the summer would be accomplished by Rolligon or similar vehicles. Gravel could be mined from inactive streambeds, but additional pits would have to be opened to obtain the quantities of gravel required for roads, pump stations, airports, and maintenance-support facilities. Bridges and culverts would provide cross drainage for roads.

Airfields may be required at construction camps and pump stations. The typical airfield for these camps is 1500 m long and 45 m wide and consists of a gravel fill 1.5 m thick. Usual associated facilities are fuel tanks, electrical generators, lights, navigational aids, control tower, and buildings for maintenance and emergency vehicles.

## Impacts to Vegetation and Surface Stability

### Vehicle Trails

Development and production of oil and gas in the study area would likely result in the proliferation of vehicle trails in the vicinity of facilities. Walker et al. (1984) found that after fifteen years, a highly developed central portion of the Prudhoe Bay oilfield had 0.13% of the total area covered by deeply rutted vehicle tracks, 0.17% covered by not-rutted tracks, and an additional 4.1% covered by a combination of tracks, gravel, and construction debris. Over the course of development, areas which were initially covered by vehicle tracks were subsequently covered by gravel roads, pads, and other more severe impacts. All trails over water (38% of mapped area) did not leave tracks. Since the study area has fewer lakes, a somewhat higher percentage of land might be affected by trails.

The impacts of vehicle use on the tundra depend on, the season of use, type of vehicle, number of passes, and vegetation, and terrain types. The disturbance varies depending on ground pressures and the type of wheels or tracks. Vehicles which have been used for travel on the tundra include: D-7 Caterpillar tractors (10.5 psi), camp and fuel sleighs (6.0 psi), wheeled vibrator units (21 psi), tracked vibrator units (4.5 psi), tracked Chieftains (3.5 psi), tracked Nodwells (2.8 psi), Rolligons (4-5 psi), small tracked vehicles such as Bombardiers (1.3 psi), hovercraft, snowmachines, and three wheelers. In the summer, vehicles are used for gravel exploration, maintenance of powerlines and pipelines, and clean-up operations. Winter uses include seismic exploration and transport of equipment between sites.

The Alaska Department of Natural Resources permits only Rolligons and hovercraft to travel on the tundra in the summer, in order to minimize impacts to vegetation and surface stability. Many studies have shown that summer use of other vehicles can cause severe losses of vegetative cover, exposure of peat and mineral soil, thaw settlement, changes in moisture regime and drainage patterns, and permanent changes in species composition (Bliss and Wein 1972, How and Hernandez 1975, Chapin and Shaver 1981, Ebersole 1985, Everett et al. 1985). Hovercraft cause some damage due mostly to skirt drag, but trails recover quickly (Abele et al. 1984). However, hovercraft are rarely used because they are expensive to run and are restricted to fairly level terrain. Rolligons, with variable ground pressures (3 to 15 psi), are commonly operated in the summer at Prudhoe Bay (J. Larsen, Alaska Dep. of Nat. Resources, pers. comm.). Abele et al. (1984) found that 10 passes of Rolligons (3.5 to 5 psi) through wet sedge tundra in August left wide tracks of compressed vegetation and caused changes in surface depression and thaw depths, which were still measurable 7 years later. Mesic areas, which comprise much of the study area, are generally more resistant to initial damage, but less resilient (Bellamy et al. 1971, Walker et al. 1984).

Any activities which could not be conducted from Rolligons would likely occur during the winter. Winter seismic investigations would continue throughout the development of an oilfield in the study area, resulting in a closely spaced network of trails. The vehicles, trail types and impacts caused by winter seismic exploration are discussed in detail in earlier sections. Other winter vehicle uses which are limited to a few passes over at least 15 cm of snow would cause disturbances similar to winter seismic exploration. Multiple passes of vehicles over the same trail, especially vehicles carrying heavy loads, could cause severe, long-lasting impacts if adequate ice roads were not used. Almost total removal of vegetation, destruction of hummocks, increased thaw depths, and subsidence have been reported on compacted snow roads which were used to haul equipment and supplies (Kerfoot 1972, Lambert 1972, Hernandez 1973a).

<u>Gravel Roads and Pads</u>

<u>Gravel Cover</u>. Oilfield development requires large amounts of gravel for the construction of well pads, flow station pads, service camp pads, roads, airstrips, and pipeline construction pads (Plate 15). The gravel fill protects the thermal stability of the underlying permafrost and provides a stable work surface. At Prudhoe Bay most gravel pads and roads are 1.5 m thick but may vary depending on the weight-bearing capacity required and duration of use. Foam insulation is frequently used at the base to ensure sufficient insulation and to reduce the amount of gravel required.

Gravel road and pad construction creates a new landform and eliminates the habitat on which they are placed (Plate 16). In areas of dense oilfield development the amount of original habitat lost can be considerable. In 1983, after 15 years of development, gravel covered 2176 ha in the Prudhoe Bay field (an area of approximately 97,000 ha); 78% of the gravel cover was in pads and 22% in roads (Walker et al. 1984). The direct physical impacts associated with gravel roads extend beyond the loss of the area covered, and include alteration of drainages, erosion and sedimentation, thermokarst, and dust. In a 2088 ha area around the Sohio Base Operation Center, one of the most highly developed areas around Prudhoe Bay, 36% of the area (58% of the area when lakes and ponds are excluded) was found to be disturbed in 1983. Of this total, 11% of the area was in gravel roads and pads, 14% had continuous flooding (over 75% open water), 3% had construction induced thermokarst, 0.8% was covered by gravel and construction debris (over 75% cover), and 0.2% was covered by heavy dust.

Abandoned gravel roads and pads are modified by natural processes, such as frost action, thermokarst, wind and water erosion, and soil creep. These

*Plate 15.* *The ARCO complex at Prudhoe Bay, consisting of gravel roads, gravel pads for storage and buildings, and a gravel airstrip. The Sagavanirktok River empties into the Beaufort Sea in the background.*

Plate 16. Gravel road through wet sedge tundra.

Plate 17. Impoundment caused by gravel road blocking sheet drainage across an old lake basin. Pipeline parallels the road.

surfaces are slow to be colonized by pioneer species because of the brief growing season, limited nutrients, and the absence of fine-grained materials (Everett et al. 1985). Establishment of natural vegetation mayl take as long as hundreds of years, and is unlikely to duplicate the original vegetation.

Erosion and Sedimentation. Erosion and sedimentation can be expected from roads constructed in the more rugged foothills and some portions of the hilly coastal plain. The susceptibility of a disturbed site to hydraulic erosion depends primarily on the soil properties, slope, and corresponding flow velocity. Hydraulic erosion is often accompanied by thermal erosion in ice-rich terrain.

Erosion and sedimentation problems resulted from the construction of the Dalton Highway and Dempster Highway (Brown and Berg 1980, Claridge and Mirza 1981). Road cuts caused slumping and the flow of silt into the ditches requiring sediment traps downslope to prevent the eroded materials from entering streams. Water flow above and below road culverts caused hydraulic and thermal erosion of the adjacent tundra. Erosion was common during periods of peak flow when water velocities at culvert inlets were accelerated. Roadbed material was carried through the culverts by the high velocities and deposited beyond the outlet, filling small, incised channels and creating wide, flat streambeds. Low water-crossings, often used in place of culverts on temporary roads, also had this problem. To mitigate the erosion below culverts, broad drainage channels were constructed in some locations with gravel fill to channel water downslope. Although erosion was reduced in the channels, the area of impact was enlarged by the gravel cover. Since the gravel cover was thin, providing insufficient insulation, subsidence under the gravel was likely. Another source of concentrated flow and erosion was caused by small berms of gravel created during regrading of the road surface. During a rainfall, water could not readily pass through these berms and flowed downslope until the berm was breached. When the volume of water flowing through the breach was large, erosion of the side-slope occurred causing siltation of the adjacent tundra or stream.

Impoundments. Ponding, icing, and subsurface seepage problems result from the inadequate drainage and alteration of natural water courses caused by gravel road and pad construction. Waterlogging of soils, changes in plant composition, and increased thaw and subsidence often result from such alterations. Impoundments are the most extensive type of impact associated with gravel roads and pads, and would be an inevitable consequence of development in the study area.

Adequate design and placement of drainage features is difficult due to the complex drainage patterns on the tundra and sheet flow runoff in the spring. The flat terrain of drained thaw lake basins and abandoned floodplains are particularly prone to impoundments because of their non-integrated drainage patterns (Plate 17). Within the entire Prudhoe Bay oilfield, a total of 1380 ha was classified as permanently impounded (Walker et al. 1984). In a heavily developed portion of the oilfield, areas mapped as continuously flooded (over 75% open water) affected more area (13.9%) than the gravel cover itself (10.7%). In 1983, 93% of the impounded areas occurred on aquatic or wet sedge tundra although these vegetation types covered only 57% of the area. The network of water tracks in the foothills also confounds drainage placement. Numerous impoundments were observed along the Dalton Highway in the foothills region, often where access roads intersected the roadway (Brown and Berg 1980).

Poor performance of culverts contributes to many of the impoundments. Culverts can be damaged or clogged by gravel deposited downslope from frequent grading (Brown and Berg 1980) or temporarily blocked by icings (Claridge and Mirza 1981). Late melting snowbanks, formed by drifting snow trapped by the road, blocked culverts early in the summer (Klinger et al. 1983). Roadway compaction and thaw settlement also reduced the effectiveness of culverts by causing them to bow down on the ends or in the middle. In some instances the culverts were placed too high in the roadbed to fully drain the area. Drainage problems can also be further aggravated when subsurface drainage is impeded by compaction of the soil under the road surface or by permafrost aggradation into the gravel roadbed.

The ecological effects of flooding depend on the duration and depth of water. Along the Prudhoe Bay spine road, impoundments generally had no effect on aquatic graminoid tundra unless flooding was deep enough to eliminate all plants (Klinger et al. 1983). Moderate flooding in wet graminoid tundra decreased forb and moss cover, and increased graminoid production in some areas. In the deepest flooded areas, graminoids and algae were also reduced. Flooding in moist graminoid tundra reduced cover of Dryas integrifolia, lichens, and some mosses, while increasing sedge cover and hydrophilous mosses. No impacts were observed on dry prostrate shrub tundra in areas of high-centered polygons.

Drainage blocked by road construction can result in rapid growth of ice between the organic mat and impermeable frozen substrate, causing uplift and rupture of the vegetation and organic mat (Nelson and Outcalt 1982). Palsas, formed in this manner, were observed at several locations along the Dalton Highway. Some of them appeared to be stable while others have decayed. At one site, melting ice exposed beneath the ruptured organic mat, in addition to the normal flow of water, increased erosion and loss of vegetation across an area approximately 15 m wide (Brown and Berg 1980).

Gravel Spray. Gravel may be spread beyond the edge of roads and pads during construction, snow removal, surface regrading and heavy traffic. The gravel spray may extend up to 30 m and may accumulate sufficiently to form a thin cover directly adjacent to the source (Walker et al. 1984).

Dust. Road traffic and construction activities raise dust that settles on the adjacent tundra. The amount of dust distributed depends on the wind, amount and type of traffic, soil type of the road, and precipitation and dust control. Dust deposition is greatest immediately adjacent to roads and pads and decreases logarithmically with distance from the road (Everett 1980). Along the heavily travelled spine road at Prudhoe Bay, a heavy dust shadow accumulated within 25 m and the effects of dust were noticeable up to 75 m from the road.

Dust affects the vigor and composition of vegetation by increasing surface temperatures, reducing surface moisture, and adding substantial amounts of soluble calcium. Calcium has been shown to have a direct chemical effect on mosses which can be detrimental, particularly to Sphagnum spp. (Spatt and Miller 1981). The calcium input from road dust along the Dalton Highway was insufficient to affect either the pH or nutrient status of the soil (Everett 1980). Heavy dust accumulation smothered adjacent low-lying vegetation, eliminating virtually all mosses and liverworts within a few meters of the

Spine Road (Meehan 1985). Both mosses and lichens were noticeably affected up to 75 m from the road. Along the Dalton highway, shrubs were less affected by dust, and even a few of the more erect mosses were able to tolerate it (Brown and Berg 1980). A few taxa appeared to increase in relative abundance in the roadside environment, particularly the cottongrasses.

Dust accumulating on winter snow has led to early snow melt (2 to 3 weeks) which may extend 30 to 100 m on either side of the road (Everett 1980). This may have a positive effect on vegetation by lengthening the growing season and may also increase thaw depths. Thaw depths were significantly deeper within 25 m of the Spine Road, corresponding to the area where early snow melt had occurred and the moss layer had been eliminated or severely affected (Meehan 1985).

Snow Drifts. Late melting snowbanks may occur along lightly travelled roads and pads due to deposition by winds or snow clearing operations. Snow banks along roads in Prudhoe Bay were generally limited to 30 m on either side of the road, with about twice as much area covered on the lee side (Klinger et al. 1983). Roadside snow banks melted about two weeks later than snow in the rest of the area, delaying plant phenology. Live plants, particularly graminoids, had significantly lower leaf area indices, and more forbs were found in snow bank areas.

Thermokarst. The study area is underlain by ice-rich permafrost, which is sensitive to surface disturbance that increase heat absorption. In response to increased heat flux, the active layer deepens, melting the permafrost and causing settlement, resulting in thermokarst terrain. Such permafrost degradation may result from gravel placement, impoundment or rechannelling of water, and road cuts.

Gravel roads and pads cause permafrost degradation if the thickness of the material is insufficient to adequately prevent thaw penetration in the subgrade material. Thaw settlement has not been a problem on roads and pads near Prudhoe Bay, but has occurred underneath some portions of the Dalton Highway in the foothills region where the inland air temperatures are warmer (Brown and Berg 1980). Severe subsidence caused by thawing of ice-wedge polygons also occurred on one gravel road at Umiat (Brown and Berg 1980). A more common problem is thaw penetration along the side slopes of the roadway, where the gravel is not as thick. Increased thaw depths have caused subsidence in places, altering drainage and causing culverts to bow and reduce performance.

Exploratory well pads, airstrips, and pipeline construction pads may be designed for short-term use to economize on gravel requirements. These often do not provide sufficient insulation. Temporary pads and airstrips for construction camps for Taps have also shown large amounts of settlement. Numerous areas of work pad settlement were observed on the Taps construction pads (Metz et al. 1982).

Because water is very efficient at absorbing solar radiation, the thermal regime of an area is extremely sensitive drainage alteration, ponding water, and channelization of runoff. Small changes in surface moisture can be magnified as the surface subsides, further altering drainage and ponding water. The deepest and most extensive thermokarst features at Prudhoe Bay are next to heavily travelled roads and may be aggravated by heavy dust (Walker et al. 1984). Most of the thermokarst that they mapped occurred in wet sedge tundra and moist sedge, prostrate shrub tundra because of the impoundment of water. Culverts have also induced significant thermal erosion and gully formation downslope of roadways by concentrating flow onto the ice-rich soils where unconcentrated flow previously occurred (Brown and Berg 1980).

Roadcuts in ice-rich slopes also caused thermokarst along the Dalton Highway and can be expected to be a problem in the foothills portions of the study area. The ice-rich slopes tended to stabilize after a few years, but thaw degradation continued beneath the ditches and roadway embankment (Brown and Berg 1980). On a road cut for the Dempster Highway in the Northwest Territories, the excavated ice-rich slopes continued to slump and regress as segregated ice gradually thawed and silt flowed into ditches 5 years after the cut was made (Claridge and Mirza 1981).

Pipelines

The impacts of oil and gas pipelines depend on their design and mode of construction. Hot oil pipelines on the north slope are typically elevated in areas of ice-rich, fine-grained sediments to protect the stability of the pipe and permafrost. In areas of thaw stable gravel or bedrock the pipeline may be buried. Elevated pipelines are usually constructed on gravel workpads wide enough to include a single lane of traffic, while buried pipelines are covered with gravel and have adjacent gravel roads and work pads.

Natural gas pipelines are used to transport gas for space heating and to fuel the turbines of power plants and flow stations. These pipelines are usually buried for economical and safety reasons. Gaslines are small and require narrow trenches, but the zone of environmental impact is extended by pad construction, trenching, and backfilling operations.

The impacts of pipelines and their associated roads and construction pads include gravel cover and all the related physical disturbances discussed previously. Snow pads have been used during construction of elevated pipelines and buried gaslines to reduce the area covered by gravel and the need for gravel mines. A snow pad used for construction of an 8 km section of the TAPS protected the underlying vegetation (Johnson and Collins 1980). On a snowpad used for constructing the gasline along the Dalton Highway, debris from trenching and backfill operations impacted tundra vegetation (Brown and Berg 1980). Material was lost when gravel was transported to the trench and fine-grained material was transported away from it. Debris was 15-25 cm thick in areas where gravel was first dumped onto the pad before being graded into the trench. Later cleanup reduced these layers of gravel and spoil to scattered patches less than 3 cm in depth, but often disrupted upright vegetation. Filling the trench from the adjacent Dalton Highway helped reduce gravel spills on other portions of the gasline. In areas containing boulders (primarily glacial till) blasting was used to break up the material, and numerous pieces of debris were blown up to 30 m on either side of the trench.

The trench for a buried oil or gas pipeline affects drainage and can cause erosion, ponding, and subsidence. Drainage and erosion problems are aggravated by the settlement of the ditch backfill material. Settlement along buried portions of the TAPS was typically due to poor compaction of ditch backfill or thawing of backfill material which was placed in a frozen state (Metz et al. 1982). On flat terrain such settlement has led to ponding, while on slopes the settlement has intercepted and channeled water. Frequent serious erosion problems occurred along the gasline adjacent to the Dalton Highway and required repeated backfilling operations and installation of cross drainage structures (Brown and Berg 1980) .

Surface stability problems have been caused by heat transfer from TAPS. In some sections of the Sagavanirktok and Atigun River floodplains, the pipe is buried in an underlying stratum of thaw stable gravel or bedrock beneath an ice-rich, fine-grained cover deposit. This ice-rich material is susceptible to melting due to the growth of a thaw zone around the heated pipe (Metz et al. 1982). In areas of polygonal ground, melting of massive ice has resulted in large sinkholes, settlement, and ponding in the resulting depressions. On elevated sections of the pipe, heat transferred down the VSM's can affect thaw depths and subsurface temperatures (Metz et al. 1982). Where the VSM's are placed on the insulated workpad the heat transfer has little effect. However, where the elevated pipe was built with a snow workpad and vegetation was relatively undisturbed, small ponds (1-2 m) have developed around some of the VSM's (Jorgenson 1986). These ponds may have resulted from slumping of the backfill material or deepening of the active layer due to heat transfer from the VSM's. Even small ponds can greatly increase surface heat absorption causing further melting along the ice wedges.

Gravel Mines

Gravel is required for development in the arctic to provide a stable, insulative foundation for all facilities, including roads, well pads, and buildings. At Prudhoe Bay, this foundation has usually been 1.5 m thick. In places where gravel has not been readily available, a combination of 5-10 cm of polystyrene and 60 cm of gravel has been used (Woodward-Clyde 1980). The gravel volume required for a production well pad is approximately 30,000 $m^3$ (Hopkins 1978). The use of directional drilling at Prudhoe Bay has allowed 1 well pad to serve many different wells, reducing gravel requirements per well. These multiple-well pads use from 212,300 to 611,600 $m^3$ of gravel per pad (Meehan 1985). During the first 7 years of development at Prudhoe Bay, 10,000,000 $m^3$ of gravel were excavated (Hopkins 1978) [Plate 18].

Possible sources of gravel in the study area include river floodplains, upland areas, the thaw lake plain, coastal beaches, coastal lagoons, and offshore islands. River floodplains are the source of gravel most commonly used on the arctic coastal plain west of the study area. Floodplains offer a concentrated, thawed gravel deposit at, or close to the surface. Two uncommon vegetation types, riparian willow (1.5% of the study area) and *Dryas* river terrace (0.3% of the study area) are concentrated along floodplains (Felix et al. 1986b), and could be disturbed by mining. The impacts to vegetation depend on the type of excavation, the size and type of river, and the amount of gravel removed.

Most of the major rivers in the study area have braided floodplains with areas of unvegetated or sparsely vegetated gravel bars. Large amounts of gravel can be removed from these areas by scraping the surface down to about water level. As long as active channels are avoided, there is little impact on vegetation. The disturbance is very similar to natural transport of gravel,

Plate 18. Open pit gravel mine, Prudhoe Bay.

Plate 19. Patches of dead vegetation resulting from a two-year-old diesel fuel spill on wet sedge tundra.

and shallow scrapes will usually be reworked and replenished by changes in the river channel. Mining active channels could cause them to change course and erode vegetated banks. Woodward-Clyde (1980) described a winter gravel mining operation where 120,000 $m^3$ were removed from 40 ha on the wide braided floodplain of the Ivishak River, with almost no long-term impacts.

Medium-sized sinuous rivers such as the tributaries to the major rivers in the study area, sometimes have unvegetated gravel bars on the insides of meander loops. These point bars can hold a surprising amount of gravel, and can be mined with little impact to vegetation if done carefully. During the winter of 1972, 116,000 $m^3$ of gravel was extracted from the Shaviovik River. Only unvegetated gravel bars were scraped, and no excavation went below water level. Consequently, the only impact to vegetation was from the gravel ramp used to access the floodplain (Woodward-Clyde 1980).

High density development would require more gravel than could be obtained by scraping gravel bars. Large open pit mines on the Putuligayuk and Sagavanirktok Rivers have been used to extract gravel for the Prudhoe Bay oilfield. Similar mines in the study area could eliminate areas of riparian willow or Dryas river terrace vegetation. Typically the vegetation and soil are scraped off and stockpiled to allow access to the underlying gravel. Deep mines minimize the surface area disturbed, but offer little chance of recovery. Usually the pits fill with water once abandoned.

The location or magnitude of gravel deposits or bedrock in the hilly coastal plain or foothills of the study area is unknown. However, since hauling distances are one of the major cost factors of gravel mining, the area around any facility planned in the uplands of the study area would be searched thoroughly for gravel deposits. Gravel would likely be excavated from open pit mines, after removal of the overburden. The area of vegetation lost would include the area of the mine, as well as the area covered by the overburden, and any loss due to erosion. Such mines would result in long-lasting visual and vegetational impacts, unless rehabilitation was complete. Recontouring, followed by redistribution of the overburden, would greatly enhance revegetation, and decrease the long-term vegetation loss. However, successful rehabilitation of upland gravel mines has not yet been reported.

Mining in the thaw lake plain (3.1% of the study area) would access an extensive deposit of Pleistocene gravel which lies 3 to 10 m beneath the surface (Hopkins 1978). Many of the mines in the Kuparuk oilfields are pit mines, excavated through the permafrost of the thaw lake plain. Vegetative losses due to this activity affect mostly wet sedge tundra. Once abandoned, the pits usually fill in with water from the saturated surroundings.

Mining barrier islands would cause loss of some sparse vegetation, but would be unlikely to be permitted, as the islands are extremely important in maintaining the ecology of the coastal lagoons, and are no longer accumulating gravel. Mining of the lagoon floor or of narrow gravel beaches would not cause any impacts to vegetation, except that caused by access roads.

Fuel Spills

Spills of crude oil and refined petroleum products are an inevitable consequence of oilfield exploration and development. During the construction of the TAPS, over 16,000 oil spills occurred totalling over 2,600,000 l

(Johnson 1981). While many of these spills were confined to gravel pads or roads where they caused little damage, many spills were on vegetated tundra. The effects of oil spills depend upon type of material, size of spill, time of year, and vegetation and soil type.

Most spills can be expected to be either crude oil or diesel fuel, both of which are toxic to plants. Diesel fuel generally kills all plants on contact and often penetrates deeply into the soil killing roots and rhizomes, and remaining toxic for decades (Walker et al. 1978, Lawson et al. 1978, Mackay et al. 1980) (Plate 19). Crude oil can cause severe decreases in vegetative cover but may not kill all vegetation, even in heavily saturated areas (Johnson 1981). It also more easily degrades and penetrates less deeply than diesel.

Large spills not only cover larger surface area, but also penetrate deeper into the soil. Reported spills in the north slope oilfields in 1985 totalled 280,000 l, including 335 spills less than 130 l and 148 spills from 130 l up to 40,000 l. (Alaska Dept. of Environmental Conservation 1986). Crude oil spills from pipelines in Alaska have ranged up to 2,000,000 l (Johnson 1981).

Spills which occur in the summer are generally more damaging than spills in the winter (McFadden et al. 1977, Johnson et al. 1980). During the winter the oil cools rapidly and can not travel as far or penetrate as deeply. In addition, spills during the summer subject actively growing vegetation to toxic volatiles, whereas winter oil spills may lose some toxicity by evaporation before the vegetation resumes growth. Oil spills on frozen ground are also easier to contain and clean up.

Direct contact with oil often results in immediate damage to above ground vegetation. Injury to the root system may not be immediately obvious and can cause a slow deterioration of plants and a high degree of winterkill in future years (Deneke et al. 1975, Mackay et al. 1980). Damage to vegetation is clearly related to soil moisture since oil spills can penetrate deeply into the rooting zone in dry tundra. Saturated soils or standing water prevents this penetration and protects the roots and rhizomes (Walker et al. 1978, Sexstone et al. 1978, Johnson et al. 1980). Wet sedge tundra and moist sedge, prostrate shrub tundra are thus more resistant to oil spills than are other vegetation types in the study area. Sensitivity to oil spills is also related to the dominant life forms and species within each vegetation type (Wein and Bliss 1973, Deneke et al. 1975, Freedman and Hutchinson 1976, Walker et al. 1978, Johnson et al. 1980). Evergreen shrubs, forbs, grasses, mosses, and lichens are sensitive to oil spills. The sedges (Carex aquatilis and Eriophorum angustifolium), willows (Salix spp.), and dwarf birch (Betula nana s.l.) are some of the most resistant species. The tussock-forming sedge Eriophorum vaginatum is also resistant to oil damage because of its raised tussock habitat and deep, vertical roots (Freedman and Hutchinson 1976, Johnson et al. 1980).

Recovery of vegetation following oil spills depends upon the size and type of spill, and the vegetation type affected. Diesel spills cause severe damage (Deneke et al. 1975, Walker et al. 1978). Lawson et al. (1978) found that an area of 30-year-old diesel spills in northern Alaska showed little recovery. Mackay et al. (1980) noted that crude oil degraded much faster, especially if it had not penetrated deeply into the soil, and revegetation sometimes began in less than 3 years. Areas where the oil had penetrated deepest (20-30 mm) remained toxic for more than 4 years. Large spills inhibited recovery by altering the physical properties of the soils, making them drier, thus reducing or preventing seed germination and vegetative growth. Deep spills may also resurface in later years with toxic effects on the vegetation. Because oil penetration is related to soil moisture, wet vegetation types suffer less initial damage than vegetation on dry sites and usually recover faster. In addition, those species most resistant to oil spills (sedges and deciduous shrubs) are also the best recolonizers following disturbance (Walker et al. 1978).

Drilling Muds and Reserve Pits

Drilling muds and cuttings can be disposed of either by reinjection into an existing well or in reserve pits. Subsurface disposal by reinjection is currently being used in some Alaskan oilfields and can handle 80% or more of the total volume of drilling muds and cuttings (L. Dietrick, Alaska Dep. of Environmental Conservation, pers. comm.). This method reduces impact to the surrounding area and provides for permanent disposal of the contaminants.

Most Alaskan oil wells, however, discharge drilling muds into large reserve pits enclosed by gravel berms (Plate 20). When the pits become full, the top fluid is removed and either deposited on roads, injected into a waste-water well, or pumped directly onto the tundra (Meehan 1985). Potential problems associated with reserve pits include leaching of fluids through the pit walls, breaching (and subsequent spillage of the contents), and overflow (Plate 21) (French and Smith 1980, J. Stroebele, U.S. Fish and Wildl. Service pers. comm.). Overflow spills are preventable and result from either underestimating the size of pit needed, or from inadequate removal of snow leading to overflow in the spring when the snow melts. The extent of spills which have occurred in the past have not been well documented. Effective closure of these pits requires stabilizing the waste material (by drying) and providing an impermeable cap to prevent future leaching (L. Dietrick, Alaska Dep. of Environmental Conservation, pers. comm.). Improper closure can result in significant future leaks and erosion (French 1980).

Few studies have been done on the effects of drilling muds and reserve pit fluids on tundra vegetation, and the long-term effects are essentially unknown. Breaching of reserve pits, or direct dumping of drilling muds would result in burial and death of the existing vegetation. Pits located on hills or other areas of raised relief may exhibit chronic leaching down slope. The effects of a spill or leak depend largely on the type of drilling mud used. Modern drilling muds are highly variable in their constituents and, consequently, in their toxicity. Deep wells generally require more toxic muds than do shallow wells. Drilling muds commonly contain large amounts of soluble salts and smaller amounts of ethylene glycol, diesel oil, and heavy metals, all of which can be toxic to vegetation (Smith and James 1980). Although most damage appears to be from direct contact with soluble salts (Younkin and Johnson 1980, Myers and Barker 1984), high concentrations of toxic heavy metals have been found at distances up to 80 m from reserve pits (Smith and James 1980). Because some plants take up and concentrate these heavy metals (Smith and James 1980), the full effects of these spills may not be apparent for a number of years. Myers and Barker (1984) found that shrubs and forbs were very sensitive to soluble salts in reserve pit fluids, but

*Plate 20. Plastic-lined reserve pit adjacent to the Chevron exploratory well, near Barter Island.*

*Plate 21. Overflow of drilling muds from reserve pit onto tundra vegetation.*

graminoid species showed few effects (see section on Seawater Spills). They also found that dry tundra vegetation (dry prostrate shrub, forb), shallowly rooted plants, mosses, and lichens were particularly vulnerable. Salts, especially on drier sites, may migrate and accumulate in the rooting zone, killing roots and inhibiting recovery (Smith and James 1980). Pit fluids also raise the pH of the soil, which may affect vegetation in the study area, where many sites are already highly alkaline.

Recovery of vegetation following exposure to drilling muds and reserve pit fluids is poorly understood and will probably depend on the type of mud, the size of the spill, vegetation type, and terrain. Seedling growth and tillering may be inhibited for over 3 years (Younkin and Johnson 1980). Ebersole (1985) found good recovery of wet tundra vegetation 35 years after a spill of drilling mud (older drilling muds were generally less toxic than modern muds). Dry sites, though revegetated, contained strikingly different communities than the surrounding undisturbed tundra. Little or no recovery was seen on sites in Canada 3 years after leaching or spillage of drilling muds occurred (Smith and James 1980).

Seawater Spills

Waterflood activities could result in salt water spills on tundra. Seawater spills have not yet occurred in tundra areas, however, the U.S. Army Corps of Engineers (1980) estimated that rupture of a seawater pipeline near the module staging area at the Prudhoe Bay oilfield could result in a spill of up to 16,500 $m^3$, most of which could be channeled to the coast without flooding large areas of tundra. The maximum spill on tundra was estimated to 5,000 $m^3$ which could flood over 50 ha of tundra. The effects of such spills on tundra vegetation and soils are poorly understood and will depend on the size of the spill, season of occurrence, moisture and pH levels of the site, and vegetation type.

Simmons et al. (1983) found that vegetation in dry sites was the most severely affected (up to 90% reduction in plant cover) while wet tundra vegetation was largely unaffected. Seawater rapidly penetrated the soil on dry sites resulting in high salt concentrations near the rooting zone, inhibiting recovery of these sites for many years. In contrast, seawater tended to be diluted and rapidly flushed away at wet sites; salinity at these sites approached pre-spill levels within 30 days. Salt water contamination of inland ponds and lakes would severely affect aquatic vegetation and could require up to 5 years of normal flushing to restore normal freshness (Reimnitz and Maurer 1979). Simmons et al. (1983) found that the characteristic species and life forms of different sites varied in their sensitivity to saltwater. Shrubs, forbs, and mosses, which are common on dry and moist tundra sites, were far more sensitive to salt water damage than were the sedges and grasses which dominate the wet tundra sites. Plants with ectomycorrhizal root systems, such as willows, were especially susceptible to seawater damage. The soil microflora was also severely decreased, thus reducing the available nutrients for plant growth.

Many of the sedge and grass taxa, especially those in coastal areas, are salt tolerant plants adapted to seasonal tidal flooding and storm surges. Even in these naturally resistant communities, however, large seawater pipeline spills that inundate wet tundra sites could damage vegetation. Reimnitz and Maurer

(1979) studied the effects of a major storm surge that flooded low-lying tundra up to 5 km inland. Observations showed that even on wet tundra sites the vegetation was entirely killed and the site took from 3 to 7 years to recover. Similarly, a late season spill, when normally wet tundra sites are often dry or moist, would be more destructive than a spill early in the season.

Recovery of the experimental sites of Simmons et al. (1983) was related to pH, with alkaline sites (both dry and moist) showing reduced recovery after 3 years when compared with similar sites in acidic tundra (Meehan 1985). Many taxa in acidic sites showed strong recovery after 3 years. Indirect impacts of seawater spills could also include erosion on dry sites following significant loss in vegetative cover.

Habitat Rehabilitation

The feasibility of restoration or rehabilitation in arctic Alaska should be included in the consideration of impacts on vegetation and surface stability. Under the State of Alaska's oil and gas lease terms, all drilling sites, roads, buildings, airstrips, or other facilities must be removed upon abandonment, and rehabilitated. On the north slope oil fields, new facilities are presently being built, and successful rehabilitation techniques have not yet been developed. A number of literature reviews on revegetation in Alaska have concluded that areas north of the Brooks Range are the most difficult to revegetate and that further research is needed (Johnson and Van Cleve 1976, Johnson 1981, Kubanis 1982, Oakley 1984). Most of the available information on revegetation in northern Alaska comes from studies conducted along the TAPS. Although a few revegetation efforts have been made on trails and abandoned well pads in other areas, follow-up studies have not been conducted to determine their success.

Ideally, restoration to predisturbance conditions should be the goal of habitat rehabilitation on an abandoned oil field. However, complete restoration may not be possible, since construction activities dramatically alter surface features which determine plant species composition in the natural habitat (Meehan 1985). Rehabilitation includes the steps necessary to prevent erosion, site preparation, as well as revegetation. Oakley (1984) defines rehabilitation as the recovery of a disturbed site to a biologically productive, self-perpetuating condition, which may or may not be similar to predisturbance conditions. The main goals of a rehabilitation program should be to reestablish native vegetation and prevent thermal and hydraulic erosion (Kubanis 1982). Revegetation to establish plant cover over disturbed areas often includes species different from those found in the undisturbed plant community. Natural revegetation occurs when pioneer species invade a disturbed site, and artificial revegetation involves planting of agronomic species.

Site Preparation. Site preparation is an important step in rehabilitation of disturbed sites. Stockpiling and replacing the upper organic layer is an effective method of promoting recolonization of native species (Johnson 1981, Knapman 1982, Gartner et al. 1983, Shaver et al. 1983). Replacing the top organic layer reduces soil thaw and thermokarst erosion, increases available nutrients, and provides a supply of buried roots and seeds of native plants. Stripped organics were stored in berms along the Trans-Alaska Pipeline, however the material was not segregated and stockpiled properly and much of it was unusable (Johnson 1981). At material sites north of Toolik Lake, revegetation by grasses was more successful where the stockpiled organic topsoil and fine-grained mineral soil had been spread.

Soil texture is an important factor in the re-establishment of vegetation. Along the Trans-Alaska Pipeline, plant cover was greater on sites with higher percentages of organic matter and silts, and lower on sites with high percentages of gravel (Native Plants 1981). Organic material and silts have higher nutrient levels and water-holding capacity than gravels.

Scarification of compacted soils (30-45 cm deep) by raking or other mechanical means will improve plant growth by increasing soil aeration, improving moisture infiltration, and producing better contact between seeds and soil (Kubanis 1982). Contour harrowing (to depth of 10 cm) was done before and after seeding on the Trans-Alaska Pipeline. Harrowing improved water infiltration and increased seed germination, but was not deep enough to be effective at severely compacted sites (Johnson 1981, Densmore 1982).

Water bars and retaining dikes are important for temporary erosion control (Johnson 1981). Organic mulches (hay, wood fiber) or inorganic mulches (visqueen, fiberglass blanket) can be used for erosion control, to moderate soil temperatures, and to conserve moisture. However, organic mulches may slow plant recolonization by decreasing available nutrients which become tied up in the decomposition process, and fertilization may be required (Kubanis 1982).

Seeding. Many agronomic grass species have been used in revegetation studies in the arctic. Of these, Arctared creeping red fescue (Festuca rubra) and nugget Kentucky bluegrass (Poa pratensis) have been the most successful (Johnson and Van Cleve 1976, Oakley 1984). Revegetation using non-native grasses may impede re-invasion of native species in northern areas (Younkin and Friesen 1976, Johnson 1981, Native Plants 1981, Densmore 1982, Kubanis 1985). For this reason, agronomic species should only be used on sites where immediate erosion control is needed.

Most studies report good cover of introduced grasses in the first year or two after planting, but declines in the following years. In a bulldozed site in northern Alaska introduced grass species established readily during the first year; after 3 years only fescue remained; and after 5 years all introduced species had been eliminated (Chapin and Chapin 1980). Agronomic species planted along the Trans-Alaska Pipeline showed limited success north of the Brooks Range, as plant cover decreased from 1977 to 1981 (Kubanis 1985).

Two cultivars of native Alaskan grasses, "Tundra" glaucous bluegrass (Poa glauca) and "Alyeska" polar grass (Arctagrostis latifolia), have been released for use in the arctic tundra (Mitchell 1981). Polar grass is best suited for moist to wet sites north of the Brooks Range. Test plots of polar grass along the Trans-Alaska Pipeline had good cover and abundant seedheads at the end of the second year (Johnson 1981). Bluegrass was the most successful grass at Prudhoe Bay and is best suited for dry, well-drained sites. Native species are better adapted to arctic conditions than agronomic species. These adaptations include winter hardiness, ability to reproduce in cool short summers, and the ability to extract nutrients in cool nutrient-poor soils (Savile 1972).

Seed mixes result in the best cover, because they provide a variety of species suited for microsite differences in soils, moisture, and fertility (Johnson and Van Cleve 1976, Kubanis 1982). A mixture of polar-grass and bluegrass could successfully colonize both moist and dry microsites on the tundra. Recommended seeding rates for native grasses are 15 to 30 kg/ha, with the higher rate for areas where erosion control is needed the most (Kubanis 1982). Permanent seeding should be done early in the summer season, before July 15 north of the Brooks Range, while temporary seeding can be done later in the season (Johnson 1981). Dormant seeding late in the season just before snowfall was also successful along the Trans-Alaska Pipeline.

Johnson (1981) reported that the use of sod chips was a feasible method for vegetating disturbed sites. Live vegetative cover averaged 10-50% on sod chips after 3 weeks in a laboratory chamber, with the larger chips (up to 46 cm) having the greatest cover. Cottongrass (*Eriophorum vaginatum*) and Bigelowii's sedge (*Carex bigelowii*) showed the best growth, while the shrubs (*Cassiope tetragona* and *Arctostaphylos rubra*), mosses, and lichens showed slower regrowth. Some vegetative cover from tundra sodding (mainly with cottongrass) remained after 2 years at 2 experimental restoration sites along the Trans-Alaska Pipeline.

Shrub cuttings have not been widely used for revegetation in the arctic. Rooted felt-leaf willow cuttings (*Salix alaxensis*) were planted at 6 sites along the Trans-Alaska Pipeline in 1977, but only 2.5% survived until the end of the first season and less than 1% survived to the following season (Zasada et al. 1981). High survival rates (88-96%) of unrooted cuttings of felt-leaf willow were reported after 3 years at a boreal forest site in northern Canada (Younkin and Friesen 1976). Diamond-leaf willow cuttings (*S. planifolia* ssp. *pulchra*) had high survival after 1 1/2 growing seasons while birch cuttings (*Betula nana*) had low survival rates at 2 experimental sites in northern Alaska (Johnson 1981).

*Fertilization*. Plant production on the tundra may be limited by nutrient availability, since cold soil temperatures limit the decomposition of organic matter and restrict the rate of nutrient cycling (Savile 1972, Shaver and Chapin 1980). Fertilization will increase native plant growth in the first few years after disturbance (Younkin and Friesen 1976, Chapin and Chapin 1980, Shaver et al. 1983). Fertilization of a wider area surrounding a disturbance may increase seed production of native species and aid in natural recolonization (Chapin and Chapin 1980). However, fertilization may prevent re-establishment of a species composition similar to the natural predisturbance community. Nitrogen and phosphorus fertilization on an undisturbed tussock tundra site increased production of graminoids and decreased evergreen shrubs, a response similar to that caused by disturbance (Shaver et al. 1983). Fertilization increased *Carex* and grass seedlings but not *Eriphorum* seedlings in a disturbed tundra community (Gartner et al. 1983). Seeded species must be fertilized the first year to allow establishment and growth under arctic conditions (Hernandez 1973b, Younkin and Friesen 1976, Johnson and Van Cleve 1976, Johnson et al. 1981). Repeated fertilization is needed to maintain a permanent cover of seeded species.

Fertilizer should be applied early in the spring after snow melt. Nitrogen and phosphorus are the most effective nutrients for promoting plant growth in the tundra (Van Cleve 1972, Hernandez 1973b, Shaver and Chapin 1980).

Kubanis (1982) recommended applications of 350 - 500 kg/ha for native species, and 500 - 650 kg/ha for seeded species. Sewage sludge, which contains both organic matter and nutrients, was more effective than fertilizer at increasing seedling establishment on a gravel construction site near Fairbanks (Palazzo et al. 1980).

Fuel Spill Clean Up. Effective clean-up methods for oil spills are important in reducing the amount of vegetation originally affected and the length of time needed for recovery. Clean-up at a large spill along the pipeline north of the Brooks Range used hand labor to dig ditches around the spill to collect oil for removal by suction pumps (Johnson 1981). Sand bags were then placed around the area, and it was flooded with water so that oil could be skimmed off the surface. Trampling during clean-up activities was a major cause of vegetation damage at the spill site. Burning has also been used to remove oil residue, but is not an effective method on arctic tundra. Attempts to burn oil on the snow at Prudhoe Bay in the winter were unsuccessful, and summer burning reduced plant cover more than the oil spill alone (McKendrick and Mitchell 1978a).

Pope et al. (1982) reported that a recently developed clean-up procedure allowed 80% plant recovery at an oil spill in wet sedge tundra in the first year. The clean-up procedure included the following steps:

1) Oil-covered water was pumped into nearby reserve pits, and the oil was recovered by using mop machines.

2) Absorbents were used to pick up oil when standing water was not present.

3) Oil-affected vegetation was trimmed with hand clippers or weed-cutting machines.

4) The area was raked to collect oiled vegetation and debris, and to provide aeration and mixing of natural vegetation and root mats.

5) Trampling during clean-up was reduced by using small crews and using planks for walkways.

On an oil spill 200 km south of Prudhoe Bay, heavy applications of fertilizer (20-20-10, 1100 kg/ha) and soil tilling (by hand with a concrete rake) were effective methods of reducing soil oil content and increasing the survival and yield of grasses (Brendel 1985). Phosphorus fertilizer increased growth of sedges and grasses and allowed re-establishment of mosses on an oil spill in wet tundra near Prudhoe Bay (McKendrick and Mitchell 1978b). Seeding with alkaligrass (Puccinellia borealis) and fertilizing with phosphorus were successfully used to establish plants on a barren area in the fourth year after the spill.

Gravel Structures. Rehabilitation of gravel pads, roads, and airstrips on the north slope will be particularly difficult. Removal of gravel and reapplication of topsoil may not be practical because of permafrost and the associated problems of thermokarst erosion. Coarse gravels do not retain water or nutrients, and therefore support little plant growth (Hernandez 1973b, Everett et al. 1985). Plant establishment on seeded exploratory well pads in northern Canada was lowest on gravel sites due to the dry surface conditions and seed loss caused by winds (Younkin and Martens 1976). Plant establishment was more successful on the toe and slope of gravel berms in northern Alaska than on the crest, because of better moisture conditions and wind protection (Mitchell and Loynachan 1977). Rehabilitation on gravel pads will require additions of fine-grained soils or mulch to hold moisture. Plant cover was successfully established on gravel structures in subarctic Alaska using a combination of seed, fertilizer and mulch (Palazzo et al. 1980, Johnson et al. 1981).

Impacts to Wildlife and Fish

## Birds

### Oil Pollution

Oil pollution of tundra, lagoon, or wetland habitats may result from a variety of sources small spills of a few cc up to several thousand liters are possible during construction and operation of the pipeline, oil field, and support facilities. During construction of the TAPS in 1974-1976, 11,295 oil and fuel spills totaling 285,865 were reported (Kavanagh and Townsend 1977). The spills resulted from leaky equipment, repair of equipment, broken hydraulic lines, refueling accidents, overturned equipment, damaged drums, and other equipment breakage.

Catastrophic large volume spills from well blowouts, pipeline or storage facility failures are rare. Such a spill would create long-term ecological damage (Bliss 1970, Teal and Howarth 1984). Arctic ecosystems are highly sensitive to stress because of the low species diversity and slow growth and maturation rates of many arctic species (Bliss 1970). Therfore, recovery from damage to arctic plant and animal populations take much longer than in temperate regions. Oil and fuel spills generally kill vegetation (Mackay et al. 1980), perturb food chains (Teal and Howarth 1984), and cause direct and indirect mortality of birds which ingest the oil or come into contact with it (Bourne 1968b, Clark 1969, Vermeer and Vermeer 1975). Avian species on ANWR most vulnerable to oil pollution include loons, oldsquaw, eiders, scoters, and phalaropes (King and Sanger 1979, Hunt 1984).

Physical Behavior of Oil Spills. Physical factors which determine the movement and persistence of oil spills include the type of oil spilled, quantity of the spill, physiography and hydrography of the area, season, weather, and nature of the biota. Mackay et al. (1980) discussed the physical and vegetation effects of land spills. Crude oil or refined petroleum products spilled on arctic tundra will immediately kill the vegetation, and if the ambient and ground temperature is sufficiently high, the moss and detritus layer will be flooded with oil down to impermeable soil or frozen ground. The oil may flow across the surface and through subsurface soil and possibly reach ground water and surface waters. In the spring, the oil may be spread rapidly by moving water from snow melt and high water conditions. Experimental spills of oil became immobile in a few hours as the oil coated the soil material and increased in viscosity through evaporation. Weathering from evaporation, dissolution into the ground water, biodegredation, photolysis, and chemical reactions rendered the oil asphalt-like within a few weeks, or years in some cases.

Oil spilled on water can combine with the water column in a variety of ways including dissolving (Rice et al. 1977), emulsion, dispersion, or accommodation (Peake and Hodgson 1966, Rice et al. 1977). The water temperature, duration of mixing, pH, salinity, and viscosity of the oil regulate the amount of soluble fraction entering the water phase (Rice et al. 1977). At low temperatures, the viscosity of oil is increased and more energy is needed to mix the water and oil. When oil is violently mixed with water, such as in heavy wave action, many dispersed droplets are formed (Rice et al. 1977). In this state and when dissolved, the oil may spread throughout the aquatic system (Conover 1971). Oil may weather through bacterial decomposition, photolysis and evaporation of light aromatic fractions, with slower evaporation at low temperatures (Rice et al. 1977). Finally, oil may be transported to the sediments where it degrades more slowly (Blumer and Sass 1972, Percy and Mullin 1975). Oil contaminated sediments may be intermittently eroded and result in the contamination of a much wider area.

Degradation of oil in the arctic is slowed by low evaporation and decreased biotic degradation. An experimental spill of 4 barrels of crude oil was made by Barsdale et al. (1980) on a tundra pond (1.6 liters/$m^2$) near Barrow. The oil soon became trapped in vegetation and litter and had sunk within 2 months. After several years, the oil was still present on the sediments and it entered the water column when disturbed. Five years after the spill, the remaining oil had nearly the same chemical composition except for the loss of the lighter hydrocarbons.

In a review of the literature on the long-term effects of 6 major oil spills in temperate regions, Teal and Howarth (1984) reached the following general conclusions. Oil in the water column persisted for half a year, but was diluted or sedimented (attached to sediment particles and settled out). Hydrocarbons were highest immediately under a slick or where the oil was mixed by wave action. Oil was transported to the bottom sediments and was more persistent in the sediments than the water column. These anoxic sediments were long-lasting. In 1 spill, oil in the sediments were still present 12 years later. Oil reached the bottom sediments by mixing and sorption to suspended sediments or it was taken up by zooplankton and packaged in fecal pellets which sank to the bottom.

Direct Effects. Direct avian mortalities from oil spills have been reviewed by Bourne (1968a). In most documented incidents, seabirds and diving ducks were the primary victims (Vermeer and Anweiler 1975, Vermeer and Vermeer 1975). Although large spills from tanker accidents or blowouts of offshore wells were involved in most cases, small spills from unknown sources have caused significant mortalities. Barrett (1979) reported 10-20,000 seabirds killed by a small oil spill (1000 $m^2$ slick) of unknown origin in a fjord in northern Norway.

The detrimental effect from oil pollution on populations has been disputed (Hunt 1984, Clark 1984). However, oil tanker spills have decimated some seabird colonies in southern England and the Brittany Coast (Monnat 1969, as cited by Hunt 1984; Bourne 1971; Cowell 1976; Hope-Jones et al. 1978) and decreased populations of oldsquaw and scoters in the Baltic Sea (Bourne 1968a, Clark 1969, Cowell 1976). Other seabird species in these regions have maintained or increased their populations (Clark 1984, Hunt 1984).

Oil contamination of a bird's plumage damages the water-repellent properties and air is displaced by water under the plumage (Clark 1984) if the bird is on the water. The disruption of fine feather structure, matting of the feathers, and loss of trapped air in the plumage results in the loss of buoyancy and thermal insulation (Hartung 1965). The bird may sink and drown (Holmes and Cronshaw 1977). The loss of thermal insulation causes an increase in energy expenditure by the bird to maintain body temperature (Hartung 1967, McEwan and Koelink 1973, Lambert et al. 1982), which may deplete body energy reserves and cause death (Croxall 1977, as cited by Clark 1984). Thus, birds in cold climates and in aquatic habitats are more susceptible to mortality from oil contaminated plumage (Erasmus et al. 1981, Brown 1982). Birds that were lightly contaminated (15% of body surface) and dry may exhibit no increase in metabolic rate (Jenssen et al. 1985).

Birkhead et al. (1973) observed that moderately oiled guillemots (Uria sp.), razorbills (Alca tundra), and greater black-backed gulls (Larus marinus) adequately cleaned themselves within 2 weeks by preening. However, oiled birds may ingest up to 1.5 g of oil per day from preening contaminated plumage (Hartung and Hunt 1966). Single experimental doses of birds have caused lipid pneumonia, gastro-intestinal irritation, fatty livers (loss of fat mobilization), adrenalcortical hyperplasia, toxic nephrosis, and atrophy of the pancreas (Hartung and Hunt 1966). Autopsies of oiled birds have revealed atrophy of the nasal salt glands, reduction of the white blood count, and abnormal conditions of the lungs and kidneys (Croxall 1977, Brown 1982), in addition to the problems described above. However, it is unclear if these pathological conditions caused the death of the birds, or if drowning or hypothermia was the cause (Clark 1984).

Experimental studies of chronic low-level ingestion has shown sublethal conditions that may affect reproduction and long term survival. A single experimental dose of crude oil interfered with the transfer of water and sodium ions across the intestinal tract, and excretion of the nasal salt gland, which lead to dehydration in young mallards (Anas platyrhynchos) and herring gulls (Larus argentatus) (Crocker et al. 1974, Miller et al. 1978). The oil ingestion inhibited the adaptation of these birds to a marine environment. Low-level long-term exposure (0.1 - 5.0% of the diet for up to 90 days) in mallard ducks has caused increased adrencortical atrophy, thyroid enlargement, lymph tissue atrophy, hemalytic anemia, loss of immune defense to bactorial infection, and high mortality in stressed birds (Holmes et al. 1978, Szaro et al. 1978, Holmes et al. 1979, Leighton et al. 1983, Rocke et al. 1984). Apparently, increased hydrocarbon metabolism in the liver of dosed birds also accelerates metabolism of some endogenous hormones (Rattner and Eastin 1981), including steroid hormones secreted by the adrenal cortex, ovaries, and testes (Gorsline et al. 1981). As a result, corticosterone blood levels are reduced (Gorsline and Holmes 1981, Gorsline and Holmes 1982a) and hypertrophy of the adrenal and reproductive glands ensue. The birds show an inability to respond to environmental changes that increase adrenal function (Crocker et al. 1974, 1975, Holmes et al. 1978, Holmes et al. 1979). Holmes et al. (1978) witnessed high mortality of otherwise healthy mallards on an oil contaminated diet during removal of blood samples.

Reproductive effort and success may be affected by sublethal ingestion of oil by breeding adults or chicks. Atrophy of gonads in experimentally dosed adult ducks lead to abnormally long periods of gonadal maturation (Harvey et al.

1982, Cavanaugh et al. 1983) due to depressed prolactin levels (Cavanaugh et al. 1983). Precise timing of nesting and gonadal maturation is necessary in arctic breeding geese (Raveling 1978, Barry 1962) and eiders (Korschgen 1977) for successful reproduction.

Japanese quail (Coturnix coturnix) and mallard hens fed chronic low-levels of crude oil layed fewer eggs with lighter weight, smaller size, less yolk and lower hatchability than controls (Grau et al. 1977, Wotton et al. 1979, Vangilder and Peterle 1980, Cavanaugh et al. 1983). Ducklings hatched from eggs layed by hens fed crude oil suffered higher mortality rates than controls when subjected to starvation and cold stress (Vangilder and Peterle 1980). A single dose of 0.1 ml Prudhoe bay crude oil administered to wild leachis storm-petrel adults reduced the ability of the adults to feed chicks and caused chicks of experimentally-dosed adults to gain less weight than other chicks in the colony (Trivelpiece et al. 1984).

Ingestion of oil by chicks from contaminated food or plumage may have greater effects than ingestion by adults. Wild herring gull and black guillemot (Cepphus grylle) chicks given a single dose of 0.5 ml of crude oil suffered significant reductions in weight (Butler and Lukasiewicz 1979, Peakall et al. 1980). A single dose of 0.1 to 1.0 ml of crude oil given to gull chicks caused disrupted endocrine balance; increased thyroxine and corticosterone levels (Peakall et al. 1981), cessation of growth, osmoregulatory impairment, and hypertrophy of hepatic, adrenal, and nasal gland tissue (Miller et al. 1978).

Perhaps the most crucial issue of oil pollution is the toxicity of oil to eggs. Breeding birds with petroleum on their feet or plumage may transfer the oil to incubated eggs (Hartung 1965, Albers 1980). Gross contamination with crude or refined oil reduces hatchability of eggs to low levels (Hartung 1965, Kopischke 1972). However, external applications of only microliter amounts of crude oil or fuel oil have proven highly toxic to embryos in eggs of waterfowl (Albers and Szaro 1978, Szaro 1978, Hoffman 1979a, Hoffman 1979b, Szaro 1979, Albers 1980), gulls (McGill and Richmond 1979, White et al. 1979), and herons (Macko and King 1980). Thus even light oiling of the feet or the plumage of the breast of laying or incubating birds may drastically reduce reproduction through embryotoxicosis. Oil applied late in incubation caused less embryo mortality in eggs of mallards (Albers 1978) and laughing gulls (Macko and King 1980). Reduced avoidance behavior and higher mortality, however, may occur in chicks or ducklings hatched from contaminated eggs (Albers and Heinz 1983).

Inconsistencies in some laboratory studies, and other studies which document limited effects of oil ingestion (Pattee and Franson 1982, McEwan and Whitehead 1978) have incited some critics to dispell the effects of oil pollution on bird populations (Clark 1984). Inconsistencies in the results of experimental studies stem from different rates of experimental ingestion (Clark 1984), differences in sensitivity between species and age classes within a species (Szaro et al. 1978, Coon and Dietor 1981, Pattee and Franson 1982) and high variability in the toxicity of different crude oils, refined products and their fractions (Gorsline and Holmes 1982c). Southern Louisiana crude oil caused more pronounced effects in mallards than No. 2 crude oil or Kuwait crude oil (Holmes et al. 1978). Nestling herring gulls and black guillemots suffered depressed endocrine function in response to single doses of Prudhoe Bay and south Louisiana crude oil, but showed less reaction to alyphatic and aromatic fractions with 3 or fewer rings (Peakall et al. 1981). Outdoor weathered No. 2 fuel oil produced less sub-lethal effects on mallard, eggs. More than 3 weeks of weathering was necessary on Prudhoe bay crude oil to depress the toxicity to eggs (Szaro et al. 1980). Weathered Libyan crude oil, in which most aromatic compounds had evaporated, still caused high embryo mortalities when placed in microliter amounts on heron and gull eggs (Macko and King 1980). When Gorsline and Holmes (1982c) examined the toxicity of 4 fractions of south Louisiana crude oil they found that high molecular weight material caused little effect, the middle weight fractions caused liver disfunction, and the light weight fraction caused hyperphagia. They stated that the observations "suggest that even though a large amount of volatile material may be lost through evaporative weathering soon after spillage, the toxicity of the residual petroleum may not necessarily diminish (Berridge et al. 1968, Crocker et al. 1975, Jordon and Payne 1980)". In the arctic, weathering from bacterial decomposition and evaporation of spilled oil will be lower (Barsdale et al. 1980) than experienced elsewhere.

Ecological Effects. The alteration of habitat and food chains by oil spills may affect birds through direct ingestion or contact. These effects are apt to be more subtle and prolonged. Since most breeding and many nonbreeding birds depend on invertebrate food sources during at least a portion of their stay on the north slope, pollution-induced depression of invertebrate populations may influence survival and reproduction.

Oil spills can affect invertebrates through direct mortality by smothering, contact toxicity, toxicity of soluble compounds, destruction of sensitive eggs and larvae, and sublethal effects such as destruction of food sources, reduced tolerance to stress, interference with behavioral and integrative mechanisms, and concentration of carcinogens or other toxic compounds in the food chain (Percy and Mullin 1975). A closer examination of sublethal effects upon physiological functioning shows that such sublethal effects may cause death of an organism over an extended period (Percy and Mullin 1975). Severe reductions in mobility and feeding has been shown for the arctic bivalves *Mocoma balthica* (Shaw et al. 1981) and *Yoldiella intermedia* (Percy 1974, Percy and Mullin 1975), and the arctic amphipod, *Osnismus affinis* (Bushdosh 1981). Depressed metabolism occurred in the isopod *Atylus carinatus* (Percy and Mullin 1975) in an oil contaminated environment. Mortality may result from a combination of behavioral and physiological disfunction, reduced feeding and stress, increased predation, and long-term increases in metabolic rate (Percy and Mullin 1975).

In their study of major oil spills, Teal and Howarth (1984) concluded that the effect on aquatic invertebrates ranged from massive kills and total eradication of microbenthos communities to elimination of only the sensitive species. Effects on phytoplankton populations included changes in species dominance, depression of biomass, or increased biomass brought about by the reduction of zooplankton grazers. In some cases, invertebrate populations were still depressed 6 to 7 years after the spill. In other spills, recovery occurred within a year. Recovery of aquatic systems in arctic waters would be much slower (Percy and Mullin 1975).

An experimental spill of Prudhoe Bay crude oil by Barsdale et al. (1980) on a tundra pond killed all fairy shrimp (*Branchnecta* and *Polyartamiella*), *Daphnia*, and *Heterscope* within 5 days. The *Daphnia* and fairy shrimp did not repopulate the pond until 6 years later. Phytoplankton suffered a 50% reduction in primary productivity for several weeks then recovered with new dominant species. Other invertebrates eliminated from the pond for at least 6 years included a species of chironomid, beetles (Agabus), caddis flies (Asynarchus, Micrasema), stone flies (Nemoura), and snails (Physa). These are the primary freshwater aquatic invertebrates utilized by breeding tundra birds (Holmes 1966, Holmes and Pitelka 1968, Custer and Pitelka 1978, Taylor 1986).

Effluent Pollution

The sources of effluent pollution in an actively producing oil field will be reserve pits and waste water treatment facilities. Reserve pits will be above grade basins located within gravel drilling pads and will contain drilling muds, cuttings, overflow water and waste water from production drilling. West and Snyder-Conn (1985) summarized the extent of toxic materials in the pits. Contents of drilling muds are variable and may incorporate weighting agents, viscosifiers, thinners, dispersants, corrosion inhibitors, lubricants, emulsifiers, foams, defoamers, and flocculants. These materials may be modified by microbial degredation (Zobell 1973, as cited by West and Snyder-Conn 1985), emulsification (Berridge et al. 1969), and photochemical and physical oxidation. Contents may escape from the reserve pit through limited leaching of walls and bottom, over-topping, breaching (failures) of the berms, or road watering with fluids (West and Snyder-Conn 1985).

Fluids from 22 reserve pits were sampled by West and Snyder-Conn (1985) at Prudhoe Bay. The fluids held high levels of turbidity, pH, alkalinity, salinity, lead, copper, zinc, nickel, barium, chromium, aluminum, and arsenic. Visible oil sheens covered half of the pits and hydrocarbon concentrations were high in several others. Dissolved oxygen levels were diminished in ponds and wetlands near the pits and levels of pollutants in adjacent waters tended to decrease with distance from the source.

Another source of pollution from reserve pits is the direct discharge of drilling effluents into adjacent waters or onto the ice of adjacent waters. In high and moderate energy marine waters, the pollutants may become well dispersed (Northern Technical Services 1981, 1982). However, several instances of drilling effluents discharged into shallow waters with low currents near Prudhoe bay resulted in aluminum, barium, chromium, lead, and zinc in sediments at 3 to 68 times background (control location) levels (Snyder-Conn et al. 1986).

Direct Effects. Heavy metal pollution and ecological effects of effluent discharges may impact birds through direct toxicity, toxic biomagnification in tissues, or disruption of the food chain. Heavy metals and other effluent pollutants may not be directly ingested by birds, but may become biomagnified in the upper levels of the food web. A number of laboratory studies on the bioaccummulation of some metals in drilling fluids or drilling fluid ingredients show that heavy metals are bioavailable in marine organisms (Brannon and Rao 1979; Esprey Huston & Assoc. 1981; Gerber et al. 1981; Liss et al. 1980; McCulloch et al. 1980; Page et al. 1980; Rubinstein et al. 1980, as cited by National Research Council 1983, Carr et al. 1982). Although drilling muds are fairly benign when sufficiently diluted (National Research Council 1983), high levels of chromium, lead, zinc (West and Snyder-Conn 1985, Snyder-Conn et al. 1986), and possibly mercury are of concern because of their acute and chronic toxicity (Environmental Protection Agency 1980, Environmental Protection Agency 1985a, b, Eisler 1986).

Chromium from chrome and ferro-chrome lignosulfonate drilling mud (Snyder-Conn et al. 1986) has been found to bioaccummulate in grass shrimp at low sediment levels (0.248 mg/kg) (Carr et al. 1982) and cause large cuticular lesions in crabs, lobsters, and shrimp at concentrations of 100mg/kg (Doughtie et al. 1983). Lead is taken up by invertebrates (Moore and Ramamoorthy 1984). Although some researchers have considered biomagnification unlikely (Kay 1985, as cited by Snyder-Conn et al. 1986), high tissue levels of lead have been found in laughing gulls (Larus atricilla) and green herons (Bitorides striatus), which fed in lead polluted waters (Munoz et al. 1976, Neithammer et al. 1985). These elevated lead levels were probably not due to lead shot ingestion. Invertebrates, fish, and mammals have been found to bioconcentrate zinc from sediments or the water column (Duke et al. 1969, National Research Council 1979, Seelye et al. 1982, Moore and Ramamoorthy 1984). Zinc toxicity has been shown to cause reductions in muscle contraction rates, and decreased reproduction in crustaceans; coagulation or precipitation of gill mucus in fish; and anemia, poor bone mineralization, arthritis and joint lesions in mammals (National Research Council 1979). Mercury is bioavailable from polluted environments (Vermeer 1971, Vermeer and Armstrong 1972) and low dietary concentrations can lower reproductive success in some birds through adverse effects on adults, lowered egg hatchability, and reduced survival of young (Spann et al. 1972, Fimreite 1974, Heinz 1976 and 1979, Finley and Stendell 1978).

Ecological Effects. Polluted effluents discharged from reserve pits may also impact birds through reductions in invertebrate food sources. West and Snyder-Conn (1985) documented significantly lower diversity and abundance of invertebrate species with proximity to reserve pits. Chironomids increased in abundance close to reserve pits, while other groups, particularly crustaceans diminished in abundance and diversity. Invertebrates constitute the primary diet of oldsquaw (Taylor 1986), shorebirds (Holmes 1966, Holmes and Pitelka 1968), and lapland longspurs (Custer and Pitelka 1978).

## Birds in Tundra Habitats

Impacts to avian populations resulting from habitat alteration and disturbance during oil and gas development are certain to occur. Potential short term effects include reduced nesting density (Troy 1985, Hampton and Joyce 1985), increased predation on nests and young (Ream 1976, Bart 1977) nest abandonment (U.S. Deptartment of Interior 1976, Schmidt 1970), reduced bird density (Barry & Spencer 1976), increased stress during molting, staging, and migration (Wisely 1974, Derksen et al. 1979), and direct mortality (Malcolm 1982, Crawford 1981). These effects vary with species and habitats involved and are discussed in more detail in the major habitat sections which follow. Long term impacts have not been determined.

Habitat Alteration. Drillsite pads, airstrips, roads, and pipeline corridors are constructed on thick gravel pads causing the destruction of underlying vegetation. The resulting habitat most closely resembles unvegetated gravel bar and constitutes direct and permananent loss of habitat. Fifteen years of development at the Prudhoe Bay oilfield has resulted in coverage of approximately 22 $km^2$ of the ground surface with gravel (Walker et al 1984). However, much larger areas were impacted by flooding, construction induced thermokarst, accumulation of construction debris, and dust (refer to Impacts to Vegetation and Surface Stability).

Flooding can be a widespread problem as gravel roads and pads block or alter natural drainage systems and sheet flow during spring melt on the tundra (Meehan 1985, Troy 1985). Habitats directly flooded are no longer available to nesting birds (especially early nesting species). Troy (1985) found that road induced impoundments within 100 m of the West Road at Prudhoe Bay effectively eliminated or reduced habitat quality for 6 of 15 study species (greater white-fronted goose, king eider, semipalmated sandpiper, dunlin, buff-breasted sandpiper, and Lapland longspur) during the breeding season. Artificially flooded areas provided habitat frequently used by northern pintails and red-necked phalaropes, although two other species which use natural aquatic habitats (pectoral sandpiper and red phalarope) appeared to avoid impoundments (Troy et al. 1982).

Changes in snow-melt characteristics along road corridors could influence the vegetation and bird use of the area. The major effect would be reduction of habitat available to early nesting species because of persistent snow cover banked against roads by drifting and by road maintenance vehicles. Unexpected low densities of some species were found within the zone of persistent snowbanks along the West Road at Prudhoe Bay by Troy (1985). Snow melting from deep snow banks collects along roadsides and can increase thermokarst activity already induced by gravel fill to create larger areas of impoundments.

Dust blown from the road during winter can induce more rapid snow melt within 30 to 100 m of the corridor (Everett 1979). Zones of early snow melt may attract early migrants(Klein and Hemming in Troy 1985) as these are among the first areas available for foraging (Troy 1985). Birds attracted to these areas may be exposed to contaminants from pipeline oil leaks and from toxic reserve pit fluid used to water roads in summer (West and Snyder-Conn 1985).

Man-made structures may benefit certain opportunistic avian species. Power poles and other elevated structures provide perch sites for predatory birds (Meehan 1985) such as ravens, glaucous gulls, owls, and rough-legged hawks. These structures provide an increased view of surrounding habitat and could enhance foraging success over a wider area. In turn, the raptors may impact nesting shorebirds and passerines. Ravens habituate to human presence and often concentrate to roost and nest in abandoned buildings, oil tanks, and other structures (National Petroleum Reserve in Alaska Task Force 1978, Barry 1976). Pipelines and debris along roadsides provided nest sites for snow buntings and resulted in increased use of the West Road corridor at Prudhoe Bay (Troy 1985). Gravel pads of abandoned rig sites on the Mackenzie delta were used as nest sites by 3 pairs of semipalmated plovers (which typically nest on gravel or sand near water) (Barry 1976 and Harrison 1978). It is uncertain to what extent this species would nest on the gravel pad of an active well site.

Contaminants. Reserve pits replace natural habitat with polluted impoundments that have several potentially adverse impacts on avian populations, particularly waterfowl and shorebirds. Widespread dispersal of reserve pit contaminants, particularly heavy metals and hydrocarbons, occurs when the toxic fluids are used to "water" roads for dust control (Meehan 1985, West and Snyder-Conn 1985). Visible oil sheens were observed at 52% (n=33) of Prudhoe Bay Oilfield Reserve Pits in 1983 (West and Snyder-Conn 1985). The pits are available to birds in early spring prior to the thaw of natural water bodies, thus promoting incidences of avian oil contamination for early migrants. Another important impact to the avifauna results from alteration of the invertebrate prey base which provides high-protein resources for brooding females, growing chicks, and birds preparing for migration. The following information was extracted from studies conducted at the Prudhoe Bay Oilfield (West and Snyder-Conn 1985). Investigations showed that reserve pits did not support invertebrate fauna. Furthermore, a gradient of decreased invertebrate diversity and abundance surrounded the pits, as excess fluids were often discharged into adjacent natural ponds where seepage promoted further dispersion of contaminants. Nearby ponds receiving discharge contained only 1-3 invertebrate taxa, far ponds supported 4 to 7 taxa, while 8 to 12 taxa were found in control ponds. In ponds receiving direct discharges, dipterans, particularly chironomids, tended to increase in abundance while crustaceans, the numerically most important zooplankton group, diminished in both abundance and diversity. Some species of Chironomus exist as larvae in pond sediments for as long as 7 years (Butler et al. 1980) and therefore are potentially significant bio-accumulators of heavy metals.

Studies of metals in European shorebirds, herons, and their prey suggest reason for concern for the proper disposal of reserve pit fluids. Knots, redshanks, and bar-tailed godwits accumulated elevated, and in some instances, harmful levels of mercury, arsenic, selenium, zinc (Goede 1985), lead, and cadmium (Goede and Voogt 1985) while undergoing post-nuptial molt along the shores of the Dutch Wadden Sea. Goede (1985) believed the sources of these chemicals to be invertebrate prey species which, in this case, were known metal accumulators (Bryan 1974, Gibbs et al. 1983), indicated that differing levels of metals in the different bird species were likely a reflection of levels found in prey species selected. Van der Molen et al. (1982) suggested that grey herons ingesting sub-lethal doses of mercury (liver concentrations greater than 120 ppm) succumbed when subjected to undernourishment and cold weather. Birds subjected to stress associated with breeding and fall migration may have increased sensitivity to metals accumulated on the north slope. The consequences of reserve pit pollutants entering the tundra ecosystem are not fully understood, but if biomagnification processes are successively concentrating heavy metals along food chains, detrimental effects on avian populations may be developing.

Direct Mortality. Man-made structures modify habitats and affect bird species in various ways. Direct avian mortality resulting from collisions with power lines and other above ground wires has been well documented, particularly waterfowl casualties where obstructions were associated with wetland habitats (Cornwell and Hackbaum 1971, Anderson 1978, Malcolm 1982, McNeil et al. 1985). Other structures such as towers act as collision sites, and artificial lights appear to compound the problem by occasionally attracting large numbers of nocturnal migratory birds (Dick and Donaldson 1978, Crawford 1981, Verheijen 1981). Gas flares may also attract birds to man-made structures (Dick and Donaldson 1978), but direct mortality from flames is probably minimal (Jones 1980).

Increased predation is a potential source of of direct mortality to tundra bird. Birds and eggs are a significant element in the summer diet of arctic foxes (Chesemore 1967, Eberhardt 1977, Fine 1980). One of the highest reported densities of arctic fox dens occurred immediately around the major oilfield facilities in the Prudhoe Bay area (Fine 1980). Man-made structures provide shelter and improper garbage disposal or free handouts provide food and may have attracted foxes to the Prudhoe oilfield. The virtual absence of successful duck nests in both experimental and control plots in the Prudhoe Bay vicinity led Troy (1985) to suggest that fox predation pressure was high throughout the greater oilfield area. Glaucous gulls and common ravens are also attracted and sustained by garbage sources or handouts. Both species are opportunistic omnivores and will readily include eggs and chicks in their diets.

Surface Disturbance. Oil fields facilities, pedestrians, and ground and water vehicles, are potentially major sources of disturbance of birds in tundra habitats. Although pedestrian and vehicular activities can act independently as sources of disturbance, some of the disturbance associated with facilities is invariably the result of vehicles and pedestrians. Some of the observed impacts of facilities might be minimized through controls on pedestrian and vehicular activities.

Several studies documented disturbance due to the presence of facilities and compressor noise simulators. Significantly lower numbers of tundra swans, white-fronted geese, Canada geese, northern pintails, green-winged teal, and scaup were observed on plots within 2.5 km of an operating drill rig than on plots more than 8 km distant (Barry and Spencer 1976). Family groups and flocks of molting tundra swans, white-fronted geese, Canada geese, and snow geese remained more than 2.5 km from the drill rig. Five years after removal of the drill rig, three towers, empty fuel tanks, gravel pads, a 50 m long x 3-4 m high logpile, and a diesel powered generator remained on the site. The generator ran constantly (barely audible at 500m) and was visited at least bi-weekly by helicopter. Waterfowl no longer avoided the area but numbers of shorebirds and passerines were still higher in the control areas. Whereas differences in waterfowl numbers were apparently related to the decline of disturbance, the differences in shorebird and passerine numbers could have resulted from a relatively higher interspersion of habitat types near the control plots than the plots associated with the drill site (Barry 1976).

Wright and Fancy (1980) found similar avian community structures and no differences between total bird densities at a drill site and a control site at Point Thomson. Semipalmated sandpipers were present in similar numbers within 1000 m and from 1000-2000 m of the site. However, there were fewer Lapland longspurs observed within 1 km of the drill site than between 1 and 2 km of the drill site. Significantly fewer nests of waterfowl, (tundra swan, Canada goose, greater white-fronted goose, brant, king eider, and oldsquaw), loons (Pacific and red-throated), and gulls (glaucous and Sabine's) than expected were observed within 600 m of facilities at the Lisburne Development Area (Hampton and Joyce 1985).

A gas compressor noise simulator, when placed on a tundra site for one season where Lapland longspurs had established breeding territories, did not affect population density or reproductive success of these birds (LGL Ltd. 1972, Gollop et al. 1974a, Gollop et al. 1974b). However, gas compressor noise simulators disturbed snow geese in two studies and they fed only as close as 800 m (Wisely 1974) at one half maximum sound level and 2.4 km (Gollup and Davis 1974) at an unspecified sound level. The simulator did not prevent east-west migration but caused flocks to detour (Wisely 1974). Detours were greater if sound was directed at the flocks than at a right angle to the flight path. Reactions of white-fronted and Canada geese and tundra swans were similar to those of snow geese but other species' reactions were generally less (Wisely 1974).

Waterfowl, particularly geese, swans, and loons, appear to suffer reduced productivity and energy loss due to avoidance behavior in the vicinity of operating facilities. The limited information available on shorebirds and passerines suggest fewer impacts than on waterfowl for the species studied. However, results cannot be considered valid for all species in these groups and are inconclusive.

The presence of human pedestrians may disturb birds. Hampton and Joyce (1985) reported increased alert behavior in snow geese grazing 10 m from a road in the Lisburne Development of Prudhoe Bay oilfield when an observer walked the road. These birds were from the nearby Howe Island colony and apparently had become somewhat habituated to human activity. Staging snow geese on ANWR (from breeding colonies in western Canada) were disturbed when approached within 300 m (A. Brackney, U.S. Fish and Wildl. Service, pers. comm.). Ream (1976) deduced that frequent disturbance of nesting common loons by campers and canoeists resulted in higher rates of nest predation. However, a Pacific loon near the Lisburne oil development hatched one chick successfully despite being flushed on "many occasions" by persons walking by at an unspecified distance (Wright and Fancy 1980). Tundra swans flushed and remained off their nests when observers approached to within 200 m (Martin and Moitoret 1981). Eider nests experienced more depredation after hens were flushed by observers, but there was no significant reduction in clutch size or frequency of robbed nests (Gotmark and Ahlund 1984). Simulated nests which were covered with down (as done by undisturbed departing females) by observers were depredated at significantly lower rates than simulated nests which were not covered (Gotmark and Ahlund 1984).

Low levels of ground vehicle traffic (280 axles per day) during June probably did not influence bird use near a road in the Prudhoe Bay oil development area (Troy 1985). In The Netherlands, lapwings and black-tailed godwits avoided roads and areas near roads over distances (200-2000 m) which were positively correlated to traffic volume (Van der Zande et al. 1980). Oystercatchers displayed no avoidance. Waterfowl were largely intolerant of an air cushion vehicle in coastal tundra (F.F. Slaney and Company 1973), tundra swans flushed at a distance of 430 m, white-fronted geese flushed at 225 m, and a flock of 70 brant flushed at increasingly greater distances with repeated exposures (225m to 1190 m in 3 passes). Dabbling ducks displayed relatively more tolerance and flushed at an average distance of 83 m. In the Prudhoe Bay development area, a flock of brant swam 2 km after being disturbed by a motor boat (Hampton and Joyce 1985).

Aircraft Disturbance. Helicopters generally created greater disturbance impacts on birds than fixed wing aircraft (U.S. Department of Interior 1976, Gollop et al. 1974c, Sellers 1979). Molting brant and Canada geese at Teshekpuk Lake exhibited escape responses to 9 of 10 overflights by a single engine aircraft at varying altitudes (Derksen et al. 1979). Maximum response occurred when the aircraft was below 600 m and no response occurred to the one overflight above 1500 m. Birds also exhibited escape responses to multi-engine aircraft overflights ranging in altitude from 800 m to 2000 m. Helicopter overflights of 75 to 150 m altitude induced "strong escape responses" in molting geese. A helicopter 10 km distant (unknown altitude) caused molting brant and Canada geese to run to open water. Some brant swam for 42 minutes and came ashore 4.5 km from their original location (Derksen et al. 1979). Duck (scaup, scoter, oldsquaw, wigeon) and loon numbers were reduced 60% on a small lake (0.21 $km^2$) after 4 days of 5 or 6 landings per day by a Cessna 185 on floats (Schweinsburg 1974a). Results on larger lakes were inconclusive.

Waterfowl, shorebirds, and bald eagles suffered reductions in nesting success through nest abandonment and egg loss as a result of aircraft disturbance, particularly helicopters (U.S. Department of Interior 1976). Schmidt (1970) reported that a pair of swans abandoned a nest prior to laying when a helicopter landed nearby. Sellers (1979) tentatively concluded that geese were more sensitive to disturbance than ducks, and that waterfowl (particularly ducks) could become habituated to aircraft above 120 m if they were not subsequently directly harassed. Predation of eggs by gulls and jaegers increased while snow geese were off their nests as a result of disturbance (Barry and Spencer 1976). Overflights resulted in territorial trespassing by returning geese, and resettling on nests required a maximum of 45 min. Similarly, colonial-nesting herring gulls near Kennedy airport suffered reduced mean clutch sizes (compared to nearby solitary nesting herring gulls) as a result of fights which broke out as large numbers of gulls landed simultaneously after being flushed from nests by aircraft (Burger 1981). Lapland longspurs had lower reproductive success on human and aircraft disturbed sites than on control sites (Gollop et al. 1974b).

Helicopter overflights and ground observers did not cause abandonment (after eggs were laid) or reduced success of gyrfalcon nests (Platt and Tull 1977). However, distubance may have caused some birds to choose a new nest sight or not nest the following year. Overflights of less than 150 m above the nest site always disturbed nesting gyrfalcons. Reactions decreased with overflights of 300 m altitude and no reactions were observed from overflights of 600 m altitude.

Migrating birds utilize fat as fuel during sustained flight (King 1963, Farrar 1966, West and Meng 1968, Child 1969) and the amount of stored fat reserves available at the onset of migration will determine the maximum distance a bird can travel without stopping (Odum and Perkinson 1951, Odum et al. 1961, Nisbet et al. 1963, West and Mang 1968b). Juvenile snow geese arriving on ANWR for fall staging in 1984-1985 had insufficient fat reserves to fly to their first major migration stop (Chapter 4). Cooch (1958) suggested that snow geese of the eastern arctic populations stopped more often during migration in years in which they left the autumn staging grounds with low body weight. He concluded that those geese which stopped more often during migration were more vulnerable to hunters and suffered higher mortality than geese that were in better condition at the start. Barry (1967) stated that snow geese of the western arctic population stopped among the islands and lakes of the MacKenzie River when they did not have sufficient energy reserves. The additional stopovers resulted in increased hunting mortality. (Barry 1967).

While direct habitat loss and ground disturbance may deny the geese the use of optimal foraging areas, aircraft disturbance has the potential of affecting the geese over a large area at frequent intervals. At Prudhoe Bay, recorded radio contacts of aircraft other than commercial jets by the Federal Aviation Administration (FAA) in September 1986 was 3616 (120/day) (Len Carter, FAA pers. comm.). This figure does not include multiple contacts with aircraft working in the area. Thus air traffic in an oilfield of similar size to Prudhoe Bay could potentially overfly otherwise undisturbed staging habitat many times per day.

The snow geese of the western arctic population on the Yukon and Alaskan north slope in 1974 were highly sensitive to aircraft flying at altitudes up to 3048 m feet and as much as 14.5 km miles away (Davis and Wisely 1974, Schweinsburg 1973). Various aircraft types elicited different reactions (Davis and Wisely 1974, Table 6) and repeated harassment tended to break up flocks and may drive geese from the area of the harassment (Schweinsburg 1974). Whether the geese returned was unknown.

The reaction of snow geese to approaching aircraft is generally the cessation of feeding or other behaviors for alert behavior. If the stimuli is sufficient the geese will take flight (Table 6). Some habituation may occur. Davis and Wisely (1974) compared the reaction of snow geese to experimental overflights with a small fixed wing aircraft and a helicopter at 2 and 1/2 h intervals for 1 day. The geese did not habituate at 2 h overflights. However, during overflights at 1/2 h intervals the geese took flight significantly less in the afternoon (24%) than in the morning (76%) in response to the fixed-wing aircraft. The geese responded in a similar manner to the helicopter (46% and 80%, respectively).

Table 6. Response of snow geese to non-experimental overflights of different types of aircraft at various distances and altitudes. (source Davis and Wisely 1974).

| Aircraft type | N | Mean length of interruption (min.) | | % Flocks flying | Mean linear response distance (km) | |
|---|---|---|---|---|---|---|
| | | Total | Flying | | Some reaction | Flying |
| Small fixed wing[a] | 88 | 6.3 | 2.2 | 86.4 | 2.6 | 2.3 |
| Medium fixed wing[b] | 17 | 5.2 | 1.6 | 76.5 | 2.4 | 1.9 |
| Large fixed wing[c] | 19 | -- | -- | 68.4 | 4.0 | 2.7 |
| Helicopter | 57 | 5.0 | 2.3 | 77.2 | 3.7 | 3.2 |

[a] Single-engine Cessnas, Beaver and Supercub.
[b] Twin engine aircraft such as DHC-6 Twin Otter, F27 and MU2.
[c] Large multiengine aircraft such as Hercules, Electra, and DC-3.

The physiological effects of frequent aircraft disturbance was first examined by Davis and Wisely (1974) with a simplified model derived from time budgets, wet weights of excised fat tissue (Patterson 1974), and the energy cost of basal metabolic rate and flight. They concluded that overflights at 2 h intervals (7-8/day) would decrease energy stored by juveniles by 9.5% and at

1/2 h intervals (30-32/day) would result in a 20.4% reduction in stored energy. The model did not account for habituation or compensation for lost feeding time.

Davis and Wiseley's snow goose energy model suffered from estimates of fat deposition based on indices (wet weights), lack of distinction between age classes in time-budget analyses, and oversimplification of energy expenditures. Typically, simplified energetic models overestimate energy expenditures in birds by up to 40% (Utter and LeFebvre 1973, Weathers et al. 1984, Williams and Nagy 1984). Brackney et al. (1986) developed a more complex energetics model incorporating thermoregulatory costs, heat increment (heat loss from digestion), separate time-budget estimates for adults and juveniles, and energetic costs for all activities. Habituation and compensation for lost feeding and increased alert and flying behavior from aircraft overflights were included in the model at levels of 0-100% compensation. The model predicted that at 0% compensation, as few as 20-30 overflights per day would reduce daily fat deposition by juveniles by up to 50%. Overflights at a rate of 40-50 per day would reduce fat accretion to zero. If the geese were able to compensate by substituting a percentage of lost feeding time for other behaviors and by reducing normal flying and alert times, adults could tolerate 75-80 overflights at 50% compensation and 90-100 overflights at 100% compensation before the rate of fat deposition was cut in half. Because juveniles spend 11.7 h per day feeding, compared to 8.3 h per day for adults, the model predicted that juveniles would be less able to compensate for decreased feeding time caused by disturbance. The model showed a 50% decrease in daily fat deposition by juveniles at 25-30 overflights/day with 25% compensation and at 60-70 overflights/day at 100% compensation. Zero fat deposition was reached at 60-70 overflights/day, and 80-90 overflights/day at 50% and 100% compensation, respectively.

While compensation may mediate the detrimental effects of frequent disturbance, it is doubtful that the geese could compensate for more than 25-50% of lost feeding time. Walking and normal flying behavior are necessary if the geese are to locate suitable feeding sites. Maintenance behaviors such as preening and comfort movements can only be partially reduced since maintenance of the plumage is essential for survival.

Reduced fat deposition caused by aircraft disturbance, as indicted by the model, would be more a function of lost feeding time than the increased energy expenditure from extra flying and alert behavior. Habituation, through a decrease in flight response to aircraft (Davis and Wiseley 1974), would have little effect on the impact of disturbance. More complete habituation, such as reduced alert behavior has not been observed.

Relative Vulnerability of Tundra Habitats. Beginning in late May each year, large numbers (probably over 1 million) of migratory birds arrive on the coastal plain of ANWR to breed or otherwise spend the summer. Many others pass through during spring, summer, and fall enroute to and from other breeding areas. These birds are widely distributed across the coastal plain and impacts are an inevitable consequence of oil and gas development of tundra habitats. The extent of these impacts will be dependent upon facility location (whether development is inland or coastal and what habitats are proximal to construction sites) and the timing of disturbance in relation to avian activities (spring migration, breeding or post-breeding season, fall migration, winter). A relationship between habitat and species composition, diversity, and density has been demonstrated (Chapter 4). Grouping these habitats as wetlands (Flooded, Wet Sedge, Moist Sedge, Mosaic), riparian zones, and uplands (Moist Sedge-shrub, Tussock) will facilitate the discussion involving potential impacts of habitat modification on avian populations. The comparative impacts of coastal versus inland development, timing and nature of disturbance relative to annual avian cycles, pollution problems from oil spills and reserve pits, and direct mortality will also be discussed in the context of the habitat groupings. Long term impacts of petroleum development on bird populations are largely unknown.

Wetlands are particularly sensitive to impacts of petroleum development because of their great importance as breeding and staging areas for numerous species of birds and because of the potential for water movements to distribute oil and reserve pit contaminants over much larger areas than the initial spill site. The thaw-lake plain areas located near the Canning, Okpilak, and Aichilik river deltas, and the small lakes scattered between the Okpilak and Sikrilurak Rivers are of particular concern because of their importance to birds and restricted representation on the coastal plain (Chapter 4). Coastal areas typically supported the highest wetland bird densities, particularly during fall staging and migration periods. Oil spills or contaminants released by dewatering of reserve pits have the potential of affecting any individuals which stop to feed while staging or migrating. Whereas petroleum products might disperse and degrade within a few seasons, heavy metals from reserve pits may persist in sediments for years, eliminating some invertebrate prey species and being accumulated by others. The result could be a locally reduced and chronically contaminated food source.

Impacts related to the presence of structures and gravel pads or corridors would be particularly severe in wetland habitats. Potential for blockage of sheet flow and alteration of drainage systems by pipeline and road corridors and pads would be great. Loss of nesting habitat due to late melt of snow drifts along gravel corridors would probably affect more birds in wetland than upland habitats. In addition, the potential for direct mortality due to oil or reserve pit contamination or collisions with wires or structures would be maximal, particularly for fall migrants moving through coastal wetlands.

Disturbance related to the presence of facilities would probably result in reduced waterfowl nesting effort in adjacent habitats. Although some species of passerines and shorebirds appear to be largely unaffected, the impacts on most species are unknown.

Pedestrians, ground vehicles, and aircraft all create disturbance problems which could result in reduced productivity for tundra swans, brant, and red-throated and Pacific loons, all species that associate with coastal or inland (Pacific loons) thaw lake areas. Disturbance of Lapland longspurs would probably be negligible, but some effects on other passerines and shorebirds while likely, are not well documented. Bergman et al. (1977) recommended that construction activities be prohibited within 1 km of thaw lakes and coastal wetlands from 15 May to 1 October.

Riparian habitat supports high densities of birds (although species composition changes) through spring, summer, and fall (Chapter 4) and is largely complementary to wetland in breeding bird composition. The importance of protecting riparian habitat is magnified by its low representation on the coastal plain (less than 14%) (Walker et al. 1982). In addition, erect riparian willows, on which most passerine species (except longspurs and ravens) are dependent for nesting habitat represents only 1.5% of the coastal plain. Gravel or mud bars, important to several shorebird species (Chapter 4), comprise less than 5% of the total area (Felix et al. 1986b).

Oil spills and reserve pit contaminants would have a high probability of entering drainage systems and eventually, marine systems. Birds feeding on gravel or mud bars (waterfowl, shorebirds, gulls, passerines) or in river channels (waterfowl, loons) downstream from the spill site would also be exposed. Low water years or dry summers would aggravate this problem as birds congregate in remaining drainages and wetlands.

Species dependent upon gravel bars or erect willows could be impacted by loss of habitat (direct loss or disturbance) if facilities or gravel mining operations are located in or near riparian areas. Gravel removal by scraping numerous gravel bars down to water level would probably affect all species far more than would excavation of a few deep gravel pits. However, if gravel pads or roads are inactive during the breeding season, they may be used for nesting by some species which normally nest on gravel bars. Inland development of riparian areas would probably have greatest impact on passerines while coastal development would primarily affect shorebirds and waterfowl (Chapter 4).

Disturbance of waterfowl during the breeding season would likely result in reduced nesting and brood rearing success near facilities or gravel mining areas. All species would probably exhibit increased energy expenditures and increased susceptibility to predation resulting from escape behavior if vehicles (ground, water, or air) or pedestrians traverse river corridors.

Upland habitats comprise over 55% of the ANWR coastal plain and are of major importance to fewer species than riparian or wetland habitats (Chapter 4). Extensive uniform upland areas on the western and more inland portions of the 1002 area probably receive less bird use than upland areas interspersed with wetlands or adjacent to riparian areas.

Oil and contaminant spills would probably be much more localized in upland habitats, particularly if facilities (and associated spills) are located on flat, level areas without significant drainage (determined at breakup). However, initial impacts of petroleum on vegetation may be greater and more persistent in relatively dry upland sites (refer to Impacts to Vegetation and Surface Stability). Impacts on invertebrate prey species (particularly several genera of Tipulidae, (Holmes and Pitélka 1968), may be locally severe; but would probably not be as severe on a population level as those resulting from a spill of the same initial size in wetland or riparian habitats.

Direct loss of habitat in upland areas would probably have less short term impact on birds than the same size losses in riparian and wetland habitats. Disturbance problems would probably be greatest for short-eared owls which abandon or remain off nests for long periods when flushed by persons on foot (Oates, unpubl. data). Snowy owls observed during the ANWR study were also extremely shy of observers on foot and consistently flushed at the approach of helicopters less than 300 m above ground level (R. Oates, U.S. Fish and Wildl. Service pers. comm.).

Birds in Shoreline Habitats

Shoreline habitats include beaches or bluffs of mainland shorelines adjacent to lagoons and ocean, barrier islands composed of low sand and gravel bars, and river delta areas composed of broad mudflats. Twelve species of birds are known to breed on barrier islands and 59 species have been observed on shoreline areas (See chapter 4). Although most bird species nest in colonies, some are dispersed. Nests average 1.1 nests/linear km of shoreline and may reach 2.2 nests/linear km. Shorebird use during from late July to early September averages 5.3 - 11.3 (range 3.5 - 18.3) birds/linear km (Chapter 4). As many as 16,000 phalaropes have been counted along ANWR barrier islands during the September migration period (Bartels and Doyle 1984).

Habitat Alteration. The consequences of habitat alterations on shorelines will be similar to those discussed under tundra habitats. Alterations of barrier islands or spits through the construction of drilling pads or roads will constitute a direct habitat loss for nesting, loafing, and foraging birds. Erosion/deposition processes on barrier islands may be altered by facility construction. Gravel removed from island habitats may not be replaced by deposition.

Contaminants. Oil from direct spills into rivers, lagoons, or offshore waters could wash up onto shoreline habitats, or onto mud flats in delta areas. Course grained, and mixed gravel beaches such as those along the ANWR coastline allow deep penetration of oil which limits clean up operations (Gundlach and Hayes 1978). Sheltered mud flats may experience long term deleterious effects. Contact with the oil by breeding eiders, oldsquaw, glaucous gulls, arctic terns, black guillemots, black brant, tundra swans, ruddy turnstones, and phalaropes would be possible from the persistent contamination of shoreline habitats.

Shoreline habitats receive heavy use by non-breeding, postbreeding and migratory shorebirds which depend on large marine zooplankton for food (Connors and Risebrough 1977). Long term effects on invertebrate populations from persistent oil pollution may negatively affect shorebird populations. Except for some tundra habitats, oil pollution of shoreline habitats may have more long term effects than in other areas.

Direct Mortality. The effects of facilities on shorelines and barrier islands upon direct avian mortality was reviewed under lagoon habitats in this chapter.

Surface Disturbance. Ground disturbance and the presence of humans in and around the colonies at Nunaluk Spit caused nest departures by all species and proved to be the most severe type of disturbance for all nesting species (Gollop et al. 1974c). Human disturbance has been shown to affect egg and chick survival in western and glaucous-winged gulls (Robert and Ralph 1975, Gillett et al. 1975), but light disturbance had no impact on a glaucous-winged gull nesting population in Washington over a 13 year period (Larrison 1977). Egg and chick loss in gulls usually results from chicks entering neighboring territories and being attacked by adults (Gillett et al. 1975, Robert and Ralph 1975). As breeding adults loose their eggs or chicks they may undertake conspecific predation (Hand 1980) and thus accelerate reproductive losses. In waterfowl, predation on exposed nests where the female has been driven from the nest by human disturbance is well documented (Strang 1980, MacInnes and Misra 1972).

Onshore drilling operations may directly disturb birds within a 2.5 km radius with most severe reactions by molting flocks and family groups of tundra swans and geese (Barry and Spencer 1976). Shoreline species apparently less affected by drilling operations are jaegers, glaucous gulls, and ravens (Barry and Spencer 1976).

Aircraft Disturbance. Disturbance studies by Gollop et al. (1974c) at Nunaluk Spit, Yukon Territories provide the best clues to the reaction of arctic shoreline nesting species to aircraft and human disturbance. Experimental helicopter overflights and human disturbance to nesting colonies, in conjunction with the weather, caused abandonment of 9 of 11 arctic tern nests, and the 2 brant nests located in the study area. Arctic terns and brant readily left their nests in response to overflights under 460 m. Common eider and glaucous gulls were more tenacious, and did not react to helicopter passes at 915 and 760 m. Below 760 m, glaucous gulls showed an increased tendency to leave the nest and at 152 m and 76 m overflights all incubating gulls left their nests. Glaucous gull reproductive success was unaffected by the study; however, common eiders suffered high rates of egg loss, possibly due to human activities.

Aircraft overflights of post breeding shorebirds, glaucous gulls, and brant at 33 m altitude during aerial lagoon surveys have resulted in severe escape reactions by these species (A. Brackney, U.S. Fish and Wildl. Service, pers. comm). Glaucous gulls are more tolerant than brant or most shorebirds. Brant were particularly sensitive and showed escape-flight reactions 100% of the time. Molting, flightless brants have been observed to form very tight groups in response to the aircraft.

Birds in Lagoon and Offshore Habitats

The 17 estaurine lagoons along the ANWR coastline are primarily pulsing and limited exchange systems (Hachmeister and Vinelli 1983). Low barrier beaches protect the seaward edge of the lagoons and generally make up more than 75% of the outer face of most estuaries. Several lagoons, including Simpson Cove and Tamayariak, are open which allows direct high energy wave movement from the Beaufort Sea into the interior of the lagoon. The 30,000 or more water birds inhabiting the lagoons during the peak of the summer season include molting oldsquaw, white-winged and surf scoters, black brant, tundra swans, breeding and nonbreeding yellow-billed arctic and red-throated loons, breeding and non-breeding glaucous gulls, common and king eider, and a variety of other species (Chapter 4). From late July to mid August a large number of oldsquaw, brant, and eider are flightless and depend heavily on the lagoons for shelter and food.

Habitat Alteration. Gravel removal from barrier islands may affect aquatic birds through the alteration of physical processes and subsequent changes in biological components of the lagoons. Removal of barrier islands could change erosion and deposition patterns, flushing rates, temperature, and salinity patterns. Such alterations will affect fish and invertebrate food resources. Oldsquaw mainly inhabit lagoon and offshore areas with 3 m or less in water depth (Bartels et al. 1984). Increased depths in the lagoons may constitute a direct habitat loss.

ANWR lagoons may be easily impacted by facilities placed in the lagoons due to the closed (pulsing) nature of most lagoons and the low flushing rates. Facilities such as causeways or drilling pads that slow circulation patterns will alter salinity and temperature patterns, flushing rates from tides, and freshwater flushing which may impact invertebrate food sources. Such facilities impede migration of marine invertebrates and fish. Mysids, an important foods of oldsquaw, migrate into the lagoons from offshore during the open water season (Jewett et al. 1983). Thus, mysid populations may be impacted by facilities placed in lagoons.

Contaminants. Birds inhabiting lagoons during the short-open water season will be highly vulnerable to oil pollution in the lagoons. The flushing rate of pulsing lagoons is extremely limited such that only small amounts of pollutants (5% or less) spilled in lagoons will be cleared from the system (Hachmeister and Vinelli 1983); the high densities of oldsquaw in the lagoons, particularly Oruktalik, Tapkaurak, Angnun, Nuvagapak and Jago Lagoons, coupled with the limited mobility of the birds make them highly vulnerable to oil spills. In Simpson Cove, or Tamayariak Lagoons the birds could more easily escape through the open face of the lagoon.

Since the oldsquaw are highly dependent on available food resources to complete the molt (Brackney and Platte 1986) oil and effluent contamination and reductions of invertebrate populations in the lagoons could have significant effects on their ability to prepare for migration. Individuals without sufficient body fat reserves at the onset of migration may be unable to migrate or suffer mortality enroute. Peterson and Ellarson (1979) found that oldsquaw wintering on Lake Michigan increased their body weight and body lipids substantially prior to spring migration. Those premigration weights were similar to weights of pre and post molting oldsquaw at Beaufort Lagoon in 1985 (Brackney and Platte 1986). Thus, molting oldsquaw in the lagoons were able to find sufficient food to maintain their body weight through molt in preparation for migration. Loss of those food resources could decrease the oldsquaw's ability to maintain body protein and fat reserves and thus put them at a disadvantage prior to migration.

All three loon species are common in the lagoons, and many may be breeding individuals since breeding loons, particularly red-throated loons, commonly enter lagoons to forage for fish (Bergman and Derksen 1977). Salmonid fishes, a likely prey of the loons, are highly sensitive to Prudhoe Bay crude oil and benzene (Moles et al. 1979). Pollution induced mortality or displacement of these fishes may effect survival or reproduction of loons breeding within 5 km or more of the coast. The fish diet of loons also places them higher within the food chain than most other birds and make them more susceptible to bioaccummulation of pollutants.

Breeding black brant and eider use the shorelines and barrier islands of the lagoons for nesting and brood rearing. Contact with oil spills by incubating adults or by young could reduce reproductive success and possibly survival of adults.

Finally, oils spills may impact migratory water birds following the coastline. In some years, large numbers of postbreeding common and king eiders follow the lagoons and shoreline on a westerly molt migration (McWhorter et al. 1986, Martin and Moitoret 1981). Large migrations of tundra swans, brant, and oldsquaw may also follow the coastline. Should these flocks, which stop occasionally for brief periods, encounter an oil spill heavy mortalities may result.

Direct Mortality. The effects of collisions with powerlines, above ground wires, and towers was reviewed under tundra habitats in this chapter. Lagoons and the associated shoreline and barrier islands act as navigation guides for large numbers of migrant waterfowl from mid-July through September. Large numbers of eiders, and oldsquaw fly along the shorelines and through the lagoons at altitudes under 33 m. Black brant, various species of gulls, and phalaropes migrate through the lagoons in late August and September. These birds may be highly susceptible to impacts with facilities placed in the lagoons or on the barrier islands, particularly during periods of fog which is common during late summer and fall.

Surface Disturbance. Increased boat and shoreline traffic in the lagoons will have an unknown affect on aquatic birds. Glaucous gulls and oldsquaw at Beaufort Lagoon in 1985 were tolerant of onshore facilities but were displaced by human activity (A. Brackney, U.S. Fish and Wildl. Service pers. comm.). Loons were not observed close to onshore facilities such as buildings and storage tanks. Boat traffic appeared to have little effect on oldsquaw numbers or use of the lagoon. However, capture operations of oldsquaw at Simpson Cove in 1984, which involved extended boat disturbance of the birds, apparently caused oldsquaw flocks to break up and disperse. Barry and Spencer (1976) observed escape-flight reactions by red-throated and arctic loons, white-winged scoters, pintails, oldsquaw and tundra swans in response to a supply tug boat on the Mackenzie River. Escape responses were not displayed by glaucous gulls, arctic terns or sandhill cranes.

Aircraft Disturbance. Frequent aircraft overflights of lagoons could impair the capability of molting oldsquaw and other species to complete molt in good physical condition. Gollop et al. (1974d) studied the reaction of oldsquaw and surf scoters to experimental overflights and concluded that the aircraft caused molting waterfowl to alter their normal behavior. Population levels did not change during the one day disturbance tests, primarily due to the immobility of the birds. However, frequent overflights drove oldsquaw off of resting sites on land and into the water. The disturbance also caused increased flocking activity and alert behavior.

During the waterfowl molt period lagoon waters range in temperature from 2 - 10° C (Hachmeister and Vinelli 1983). Considerable numbers of molting oldsquaw were observed on barrier islands at the water's edge during aerial lagoon surveys (Brackney et al. 1985). Presumably, oldsquaw bask on the beaches to decrease thermoregulatory costs caused by the higher heat conductivity of water. Gollop et al. (1974d) observed more undisturbed waterfowl on land during the warmest period of the day. It is possible that frequent aircraft overflights could increase the normal amount of time the ducks spend in the water and thereby increase energy expenditures through additional heat loss. Frequent overflights also caused increased flocking behavior and decreased the dispersion of oldsquaw and surf scoters through the lagoon (Gollop et al. 1974d). Although, the swimming and feeding activity of oldsquaw were not altered (Gollop et al. 1974d), the lack of dispersion could have affected feeding success.

No quantitative information is available on the reaction of nonbreeding individuals of other species. Eiders and glaucous gulls on nests are tolerant of aircraft disturbance (Gollop et al. 1974c). Breeding black brant and arctic terns are particularly sensitive (Gollop et al. 1974c). Vermeer and Anweiler (1975) conducted aerial surveys of the Yukon coastline and noted that eiders flushed well ahead of the aircraft. Qualitative information on loons (A. Brackney, U.S. Fish and Wildl. Service, pers. comm.) indicates that most loon species, and particularly arctic loons, are sensitive to aircraft overflights at altitudes up to 100 m. During aerial lagoon surveys many loons could not be identified to species because they dove well ahead of the aircraft. Whether frequent overflights may affect energetics, fishing success, or cause displacement of loons is not known.

## Mammals

### Caribou

Development and operation of oil and gas production and transportation facilities in the study area constitutes the greatest potential for long term negative impact to caribou. Concern over possible impacts of oil and gas development on caribou in northern regions has generated numerous studies and investigations, many of which have been conducted in the vicinity of the TAPS and oilfields in the Prudhoe Bay area. Reviews of the literature pertaining to the caribou-disturbance issue can be found in Shiedler (1986), Cameron (1983), and Jakimchuk (1980). While many important relationships between caribou and disturbances have been identified through the examination of other case histories, many complex variables complicate the matter of determining impacts.

Porcupine Caribou Herd (PH). Impacts of oil and gas development and production on the PH in the ANWR study area will depend in large part on where such development takes place and to a lesser degree on how such developments are managed. Development within the traditional or "core" calving grounds of the PH poses the greatest risk for adverse impact. This area is the most consistently used calving habitat by the largest concentrations of calving caribou within the over-all calving grounds. Negative influences exerted in the "core" calving grounds would affect the greatest number of calving caribou at any one time. Because of the demonstrated sensitivity of females and cows with young calves at calving and post-calving, displacement from this preferred habitat by disturbance associated with oilfield activities (Dau and Cameron in press, Cameron and Whitten 1980, Whitten and Cameron 1985) can be predicted.

The traditional calving grounds of the PH occur within a relatively narrow band of habitat lying between the Canning and Babbage Rivers (Chapter 5, Fig. 1). This elongation is likely the function of topographic restrictions exerted by mountainous terrain on the south and the Beaufort Sea on the north. The "core" calving area occurs south of Barter Island, at the widest portion of the coastal plain, suggesting that the configuration of calving distributions of the PH may be influenced by topography. Densities of calving females within this "core" area commonly exceed 50/km$^2$ and are at least 15 times that of calving densities on calving areas of the (CAH) which are not topographically restricted (Whitten and Cameron 1985). Oil and gas production and transportation facilities placed within the traditional calving grounds of the PH will further restrict calving distributions due to loss of habitat by physical structures and as result of behavioral displacement. Additional restriction of calving distributions could interfere with spatial/temporal relationships of anti-predator strategies and prevent optimum forage utilization.

The results of recent studies indicate that natural mortality of calves on the PH calving grounds occurred predominately in peripheral areas (southern and eastern foothills) (Whitten et al. 1984, 1985, 1986). Predators (brown bears, wolves, and golden eagles) were more abundant in these peripheral areas (Garner et al. 1984, 1985, 1986; Weiler et al. 1985, 1986; Mauer 1985, 1986). If development in the "core" calving area displaces calving into these peripheral areas, increased calf mortality could result from higher predation. Normal predator avoidance strategies may also be disrupted by impairment of caribou movements by oil field infrastructure (pipelines, roads, and traffic).

The "core" calving grounds of the PH coincides with extensive rolling uplands where abundant Eriophorum communities (Walker et al. 1983) are a highly preferred forage of lactating females (Lent 1980, Kuropat and Bryant 1980). Eriophorum communities are less abundant south of the "core" calving area where glacial moraines, scour areas and alpine tundra predominate (Walker et al. 1983). Displacement of calving distributions into these southern or peripheral areas could result in impaired nutrition of lactating females and negatively influence calf growth and survival. The current movement pattern of pregnant females entering the calving grounds is for the east in a north-west orientation along the northern perimeter of mountainous and foothill terrain (Chapter 5). Disturbance associated with oil and gas development and production within the "core" calving area could deflect this movement pattern to the west and/or southwest. In years such as 1974 and 1975 when caribou arrive early on the calving grounds (Roseneau et al. 1975, Roseneau and Curatolo 1976) deflected movements may continue westward, resulting in an elongated calving distribution located in a constricted zone between mountainous terrain on the south and possible pipeline/road/oilfield complexes on the north. If other oilfields are developed in the western sector of the study area, additional constriction could occur in the narrow zone between the Sadlerochit Mountains and Camden Bay. Increased mortality would be expected to occur due to lack of adequate space for anti-predator strategies to function. Constriction to southern mountainous areas could also result in nutritional deficiency, and reduced growth and survival of calves. Overgrazing could also occur if large numbers of caribou concentrate in poor forage areas. If calving/post-calving ranges become over-grazed, caribou may evacuate north slope habitats prematurely, resulting in prolonged exposure to insect harassment with attendant negative consequences on calf survival and herd productivity. Additional energy costs may be incurred if caribou must move greater distances to achieve basic habitat requirements.

Caribou not initially displaced from developments within calving areas could experience disturbances during the parturition and post-partum period. Disturbance at this time can interfere with mother-infant bonding and maternal care of young calves and result in mortality of calves that become abandoned. Disturbed adults can also injure or kill young calves due to trampling during panic and flight reactions. Caribou utilization of habitats associated with oilfields may be reduced due to disruptions of feeding activity and also from impairment of movement patterns associated with foraging behavior. Such impacts could reduce energy intake, increase energy expenditure and thus lower growth rates of young calves and impede body maintenance and energy storage in adults.

Development facilities/activities on the northern and western periphery of the "core" calving grounds may also affect caribou. Due to the dynamic nature of annual calving distributions that have occurred during the past 15 years (Fig 2 - 15, Chapter 5) it is likely that major concentrations of calving caribou will occasionally encounter and/or be displaced from facilities located peripheral to the "core" calving grounds. Peripheral areas such as the rolling uplands bordering the Niguanak River were used in 1978, 1983, and 1984 (Figs. 8, 13, and 14) by concentrations of calving caribou. Portions of thaw-lake plains south of Barter Island were used by calving concentrations during 1977, 1983, and 1985 (Figs. 7, 13, and 15). During 1974, 1975, and 1977 concentrated calving occurred in the uplands south of Camden Bay (Fig. 4, 5, and 7). All of these areas have received repeated use by large concentrations of caribou in the past and will likely be used in the future. Caribou would likely be displaced from preferred habitats, and/or disturbed while occupying habitats within or adjacent to developments.

While it is generally assumed that oil and gas development in the "core" calving area constitutes the greatest risk to the welfare of the PH, developments in northern and western peripheral areas could be nearly as serious if herd productivity during "normal" calving distributions can not compensate for periodic losses suffered as a result of impacts occurring in these peripheral areas. Ungulate species with small home ranges demonstrate a capability to increase reproductive output in response to favorable conditions (Geist 1982). However, nomadic ungulate species such as caribou, have a very constant reproductive output and cannot compensate for years of poor productivity by increasing output during more favorable seasons (Geist 1982). Thus, periodic impacts incurred from developments in peripheral calving areas could influence herd productivity over the long term.

The potential for interaction between the PH and oil and gas facilities during the post-calving season exists over a large portion of the study area. Following calving, female caribou with young calves form into small "nursery" bands which usually move gradually in a wide variety of directions within the calving grounds. During the second week following calving, nursery bands gradually coalesce into increasingly larger groups which move at greater rates. The direction of movement becomes unified as groups merge. Eventually, extremely large aggregations form which can consist of over 80,000 caribou in a single group. The emergence of mosquitos, during the latter half of June greatly influences movement and behavior of caribou within the study area. There are two basic movement patterns that tend to prevail: 1.) movement to coastal environments where cool, breezy conditions may alleviate insect harassment or 2.) movement to barren mountain terrain where conditions reduce harassment. Caribou also seek relief on isolated aufeis fields on the Sadlerochit, Hulahula, Okerokovik, Aichilik, Egaksrak, Ekaluakat, Kongakut, and Clarence Rivers. A considerable variety of post-calving movement patterns have been demonstrated by the PH during the past 15 years (Chapter 5).

Oilfield and transportation facilities if located across the southern portion of the ANWR study area would severely restrict space available for calving, post-calving movements, predator avoidance mechanisms, insect relief movements, and forage utilization. The degree of these impacts decreases with distance toward the northern portions of the study area near the coast which are usually used by scattered groups of caribou during calving. Thus, location of developments in the northern portion of the study area would interact only with only small numbers of calving caribou of the PH. Large groups of caribou usually do not use the northern coastal habitats until well into the post-calving season (late June-early July) when insect harassment conditions sometimes force aggregations to coastal areas. The frequency of use of coastal habitats by large aggregations during the past 15 years has been irregular, occurring approximately every other year. During those years when insect harassment conditions occur, conflicts may arise if development facilities and activity interfere with caribou movements. Location of facilities proximal to coastal insect relief habitat would presumably constitute the greatest disruption, however, developments far inland could also cause serious disruptions if they prevent caribou from reaching the coastal insect relief habitats.

Interference with caribou movements to insect relief habitat and subsequent movements returning to forage areas increases energy expenditure and prevents energy uptake, resulting in retarded growth of the calves, and reduced vigor maintenance in adults (Helle and Tarvanien 1984, Reimers et al. 1983). Caribou under severe insect harassment tend to clump into very dense aggregations (Helle and Aspi 1983). If dense, insect-harassed aggregations of caribou are obstructed by development facilities or disturbance from reaching relief, injury and death of calves and adults from trampling can occur as groups mill around seeking relief. Injury and mortality of caribou under natural conditions of severe insect harassment have been suggested (Gavin 1945, Kelsall 1968).

The most prevalent interaction between the PH and development facilities in the ANWR study area will involve cow/calf groups. Adult females with young calves are the predominate sex and age categories of the PH using the ANWR study area. Yearlings and non-productive females are present in lesser numbers, and are usually most abundant east of the study area during the calving season. Adult males sometimes move into the study area from the east during late June.

As described earlier, cow/calf groups aggregate rapidly after calving. By late June, groups numbering in the tens of thousands are common. Smith and Cameron (1985a and b) indicated that large groups (up to 1,000) of CAH caribou had less success in crossing roads and road/pipeline systems associated with oil developments. Large groups of females with young calves of the PH could be expected to demonstrate this same difficulty in crossing areas of development.

Success in crossing roads and pipeline may also be influenced by the nature and intensity of insect harassment. Caribou of the CAH demonstrated decreased success in crossing roads and pipelines while harassed by mosquitos, but increased crossing success during harassment by oestrid flies (Curatolo and Murphy 1983). During the period when the PH is in the study area nearly all insect harassment is due to mosquitoes. The PH herd usually vacates the study area prior to emergence of oestrid flies (Pank et al. 1984, 1985).

It is likely that movements to relief areas will be disrupted by developments in the study area, given that most groups of PH in the study area are females with young, which are inherently sensitive to disturbance and that large mosquito-harrassed groups apparently have greater difficulty crossing areas of disturbance. The consequences of such disruptions will depend on factors such as the duration of the disruption, number of caribou involved, and the proximity of alternative relief sites. Other factors which may influence the impacts of disrupted movements are traffic levels on roads, proximity of roads to pipelines, height of elevated pipe and/or location of buried sections, ramps and topographic features (Smith and Cameron, 1985, Murphy 1984, Curatolo 1984, Curatolo 1985).

A substantial portion of potential impacts to this herd depend on how its movements within the study area are affected. How successful caribou of the PH may be in crossing roads, pipelines and related facilities that may be constructed in the ANWR study area is not known. Caribou of the CAH have demonstrated some ability to cross roads and pipelines under certain conditions (Curatolo 1985). The portions of the CAH which interact with oil field disturbances do so quite frequently over much of the year, and have likely habituated to some extent to these disturbances. Most caribou of the PH use the ANWR study area only during a brief period in the summer. These caribou may react more strongly to disturbances due to a lack of experience; it is not known if PH caribou will habituate to oil and gas development because the infrequent nature of exposure to disturbance stimuli. If habituation does occur, it will likely be relatively slow because of this low exposure frequency (Klein 1980).

The interaction between oil-gas development facilities/activities and large post-calving aggregations of the PH within the study area present potentials for impacts which do not occur for CAH caribou near the Prudhoe Bay development. In this case groups several times larger than the entire CAH would may be affected by oil field facilities. The PH, leaving the study area during late June to mid-July, could be deflected or disrupted by developments in their path. Trampling injuries, overgrazing and excessive trampling of vegetation may occur. Deflections of aggregations that interfere with natural herd movements would require additional energy expenditure to overcome obstructions and resume normal movement patterns. Disturbance and disruption of post-calving aggregations may also interfere with socialization processes and influence re-establishment of social units within the herd (Miller 1974). Such disruptions could theoretically influence the herd throughout the remainder of its annual cycle.

<u>Central Arctic Caribou Herd (CAH)</u>. The CAH caribou which use portions of the study area on a year round basis will be directly affected by oil and gas developments located west of the Sadlerochit River. It would also be affected by transportation facilities from developments east of the Sadlerochit River that cross the study area to the TAPS. The magnitude of potential impacts will depend on the location, and intensity of development activities and facilities in relation to habitat utilization patterns.

Because caribou tend to demonstrate seasonal variations in sensitivity to disturbance, the potential impacts associated with developments will likely reflect seasonal differences (Bergerud 1974a, Calef et al. 1976, Davis and Valkenburg 1979).

Spring movement of pregnant females from winter ranges located in the southern foothills of the Sadlerochit Mountains and Brooks Range west of the ANWR to calving habitat in the vicinity of the Canning River delta will be affected by an east-west road/pipeline system. Oil field developments located within the path of spring migration routes would also influence movement of caribou to the calving grounds. Since approximately half of the CAH uses calving grounds in the Canning River delta area (Whitten and Cameron 1985), developments will potentially affect a significant portion of the herd. Potential impacts could occur if road/pipeline facilities prevent caribou from reaching calving habitat or require additional expenditure of energy. Factors such as vehicular traffic levels, pipe size and elevation, proximity of roads to pipelines, topography, and snow berms and drifts will likely influence crossing success (Smith and Cameron 1985, Curatolo 1985). Caribou of the CAH migrating to calving areas west of the TAPS have managed to cross road/pipeline systems associated with the Kuparuk oilfield, but demonstrate an avoidance of roads and human activity within the calving grounds (Dau and Cameron in press). If oilfield developments occur within calving habitats in the Canning River delta area, a similar avoidance response would be expected. The consequences of displacement of CAH caribou from calving habitats in the Canning River delta may not be as severe as those expected to occur from displacement in the PH calving grounds, since the density of calving on the Canning River delta area is about 1/15 that of the PH calving areas (Whitten and Cameron 1985). At this relatively low density, alternative calving habitat may be available.

Oil and gas facilities/activities located in the Canning River delta area and/or in coastal areas adjacent to Camden Bay may interfere with post-calving movements and insect relief habitat of the CAH. In most years during July-August several thousand caribou of the CAH move in east and west directions across the Canning River delta to use utilize coastal habitats of Camden Bay for insect relief (Cameron and Smith 1985). Inland habitats between the Canning and Katakturuk Rivers are important summer forage areas (Cameron et al. 1985). Disruption or obstruction of post-calving movements and interruption of access to insect relief areas and summer forage by oilfield facilities/activities in these areas could have negative impacts to the CAH. The magnitude of such impacts will depend on location of facilities, intensity of disturbances, road/pipeline design and specific caribou movement patterns.

Transportation facilities crossing the study area will biset the fall migration route of the CAH. Fall movements are generally southward perpendicular to an east-west transportation corridor. Studies have identified increased sensitivity of caribou during the fall rutting season (Surrendi and DeBock 1976, Calef et al. 1976). The degree such sensitivity may influence crossing success of road/pipeline facilities has not been studied. Factors such as traffic levels, road/pipeline design, and topography also influence crossing success.

Facilities and activities associated with oil and gas development between the Canning and Sadlerochit Rivers may affect wintering caribou in this area. Up to 1,000 CAH caribou use the area for winter range. Local displacement of caribou from areas of intensive activity will be expected. The consequences of displacement from winter range will depend on how many caribou become displaced and if there are sufficient alternative winter habitats available.

Increased Access. Roads and airfields associated with oil and gas development will greatly improve year-round access to the study area. This could create additional disturbances to caribou from increased sport and subsistence hunting, non-consumptive recreation, and other subsistence activities (fishing and trapping). Current caribou hunting within the study area occurs primarily along coastal areas during the period of open water (July-September) when access is by boat and to a lesser extent in both coastal and inland areas during the winter season (late October to early May) when access is by snow mobile (Pedersen and Coffing 1984).

Most other subsistence activities currently occurring in the study area are also restricted to these areas and seasons by seasonal travel conditions. Recreational activity in the study area occurs primarily during the summer (mid-June to mid-August) at relatively low levels. Calving activity of both the PH and CAH occurs during late May to mid-June when current surface access is limited by breakup conditions. Consequently, disturbances associated with current subsistence and recreational activities are essentially non-existant. The initial post-calving season (mid-June to early July) is also essentially free of disturbance from these activities. Currently, hunting seasons for both are closed during 30 April to 1 July, and provides protection to calving and post-calving caribou. Access made possible by all-season roads and airfields associated with oil and gas developments within the study area would, however, facilitate access for other activities such as fishing, small mammal hunting and sightseeing, etc. These activities could be an additional disturbance in the calving and post-calving areas.

The degree of additional disturbance will depend on the location of access into caribou habitats and how intense such activities may become. If legal or illegal hunting of caribou occurs from road systems and airfields associated with oil and gas, additional impacts to caribou can be predicted. The magnitude of such impacts will depend on location of access in relation to caribou distributions and movement patterns. Some years the PH will have left the region prior to the hunting season opening (1 July) and may not experience any hunting from road systems or airfields. During years when the herd remains in the study area beyond 1 July, large post-calving aggregations could be effected by hunting. In addition to impacts of increased harvests, hunting caribou in large aggregations from industrial road systems and airfields would also greatly exascerbate impacts previously identified (obstruction of movement patterns, deflections of caribou away from preferred habitat, interference with anti-predator mechanisms, increased energy expenditure, injury and trampling, and habitat loss due to behavioral avoidance of developed areas). These impacts would be particularly significant during those years when residual groups of the PH remain in the study area throughout the summer and fall seasons. (Roseneau and Stern 1974, Whitten et al. 1986).

Caribou of the CAH would be exposed to additional hunting pressure if road systems and airfields provide access into the area west of the Sadlerochit River. Since the CAH uses this area year round, hunting could occur throughout the open season (1 July - 30 April). If road systems and airfields provide access for hunting in the Canning River delta and Camden Bay areas, post-calving aggregations could be hunted. Effects of hunting would be additive to those due to industrial disturbances in a similar manner as described above for the PCH.

The impacts of disturbance due to industrial activities could be significantly enhanced if caribou learn to associate the negative experiences of being hunted and shot at with other human activity and disturbance (Klein 1980). For example, caribou of the Western Arctic herd (WAH) that were exposed to intensive hunting by snowmobile demonstrated greater sensitivity to aircraft disturbance than did caribou of the Delta herd which experienced greater levels of aircraft activity but were not exposed to high levels of hunting by snowmobile (Valkenburg and Davis 1985). The strong behavioral reactions elicited by caribou in response to hunting disturbance will likely retard or negate habituation to industrial disturbances in the study area (Klein 1980). Hunting from roads and airfields associated with oil and gas developments in the study area can be regulated or closed, but will require compliance by hunters and enforcement, neither of which are usually totally effective. Thus, in spite of regulation, it is likely that additional impacts will occur. This impact will be long term. Since roads and airfields may remain in the area long after industrial activity terminates, the impacts of additional human access will continue well beyond the period of industrial activity. Excessive hunting from roads and settlements that expanded into caribou ranges has been identified as a major factor in the decline of many caribou populations in North America (Bergerud 1974b).

The impact of additional access to the study area for non-consumptive recreation is not expected to be great, and probably will actually decline as a result of industrial development. A majority of current non-consumptive recreation occurring in the study area is largely due to visitors attracted for the wilderness values of the area. If access to calving and post-calving caribou are improved as a result of development, some disturbance can occur as a result of human activity such as hiking, camping, and photography. As previously mentioned, caribou, especially females with calves and large post-calving groups are particularly sensitive to human disturbance. Caribou are also more vulnerable to disturbance at river crossings (Kelsall 1968). Concentrations of tourists or photographers at river crossings may disturb post-calving aggregations resulting in increased trampling and drowning (Calef and Lortie 1973).

Habitat. Several types of impacts to vegetation resulting from oil and gas development will also affect caribou. A certain amount of vegetation that is currently used by caribou for forage will be destroyed by placement of gravel and structures over it. The amount of direct loss of forage will depend on the location and number of developments. Habitat losses may not be very significant, as compared to the much greater losses due to behavioral displacements and disruption of normal feeding behavior by development-related disturbances. A greater amount of forage resources will also be subject to modification due to the dust shadow effect caused by wind blown dust from roads and pads. Changes in snow melt patterns and road dust covering vegetation will affect vegetation. Loss of caribou habitat may also occur due to oil spills and contamination of vegetation, water, and soil by pollutants associated with oil and gas development. The effects of such pollutants on caribou feeding on contaminated forage has not been studied adequately to predict the magnitude of impacts that may occur. Air pollution, especially from sulfur dioxide ($SO_2$) are known to affect lichen communities (Schofield 1975). Increased air pollution resulting from oil and gas activities may affect lichen communities over a fairly large area. The most direct affect to caribou would be reduction of lichen resources used by CAH wintering in the study area between the Canning River and the Sadlerochit River, and in the Schrader Lake area. Adequate assessment of lichen utilization by caribou in the study area has not been done and therefore impacts due to air pollution currently remain largely unknown. Since lichens are very slow growing especially in the arctic environment, the impacts from loss of lichen forage would prevail for a long time period.

Muskoxen

Several aspects of muskox biology make this species vulnerable to impacts related to petroleum development. Muskoxen are year-round residents on the ANWR coastal plain and will be subjected to impacts in winter as well as summer. Muskoxen show high fidelity to specific geographic areas (Jingfors 1984, Reynolds et al. 1986) which encompass most of the major rivers in the ANWR study area (Ch. 5, Fig. 6). Development of petroleum resources on the coastal plain will result in activities and permanent structures in at least some and perhaps many of the high use areas currently used by muskoxen.

Muskoxen exhibit seasonally different activity patterns and rates of movement. In winter, muskoxen are apparently more sedentary,spending more time resting than feeding, and remaining within relatively small areas for weeks at a time (Ch. 5, Fig. 31) (Reynolds 1986b). This energy conserving strategy may not be so adaptive if animals are subjected to disturbances in winter. The behavior of grouping together in a defensive formation when approached by predators or other disturbances is an effective method of protection from carnivores (Hone 1934, Tener 1965, Gray 1973, 1984), but may not be adaptive as human access into areas of muskox use increases.

Muskoxen occur in areas of northern Canada and Greenland where little or no development has taken place. Therefore, little is known about responses of these animals to potential disturbances resulting from large scale petroleum development. Miller and Gunn (1979, 1980, 1984) looked at the effects of helicopter overflights on muskoxen herds, but information is lacking on the effects of ground activities such as construction and maintenance of a large oilfield and the presence of physical structures. Gunn (1984) found that results of studies describing muskox responses to seismic activities and aircraft were largely inconclusive in predicting consequences of industrial activities on muskoxen. Extrapolations from studies of other ungulates such as caribou may not be relevant. Muskoxen have apparently evolved much different survival strategies than caribou. They are much more sedentary, remaining within relatively small areas throughout the year, show a high fidelity to specific geographic areas, and apparently utilize decreased movements and activity to conserve energy in winter (Reynolds et al. 1986, Reynolds 1986b).

Impacts on muskoxen may result from 4 major sources associated with oil field development and production: aircraft, construction activities, maintenance activities and permanent physical structures.

Aircraft. Effects of aircraft overflying muskoxen herds will depend on the type and volumn of aircraft traffic, its location, flight altitudes, season of the year, and the size and location of development sites. Based on observations made during the ANWR baseline study (Reynolds 1986c) and results from experiments by Miller and Gunn (1979, 1980, 1984) a certain percentage of muskoxen will respond to aircraft by grouping into defensive formations and/or running. Helicopters may cause more responses than fixed wing aircraft. Mixed-sex herds may respond more strongly than bulls. Animals may be more reactive during the winter, pre-calving, and calving seasons than during the summer, rut or fall. Aircraft altitude will also affect muskox respons. Observations of muskox responses to aircraft during the ANWR baseline study (Reynolds 1986c) were based on relatively few overflights (once or twice a week maximum). Animals in an area of petroleum development and production may be subjected to many overflights a day, particularly during construction periods, which will increase the probability that muskoxen will be affected.

If muskoxen are subjected to high levels of aircraft overflights during petroleum development and production activities, muskoxen will respond by 1) being displaced from the area, 2) increasing local movement and activity, or 3) habituating to the presence of aircraft. Habituation is described by Marler and Hamilton (1967) as a waning of responsiveness to repetition of a constant stimulus. Some habituation to fixed-wing aircraft overflights apparently did occur during the 3 years of the ANWR baseline study (Reynolds 1986c). But 10% of all herds observed continued to run or group in response to aircraft overflight after 3 years, suggesting individual tolerances to disturbances exist. Miller and Gunn (1980) suggested that some short term habituation occurred during their studies of helicopter overflights. Nothing is known about the amount of disturbance which will cause animals to leave an area. If aircraft activity in an area of high muskox use increases rapidly over a short period of time, muskoxen may leave the area before habituation can take place. Increased movements or activity resulting from aircraft overflights, would be most detrimental during winter, pre-calving, and calving periods when muskoxen appear to be most responsive to aircraft overflights (Reynolds 1986c). During these same periods, muskoxen reduce their activity and movement as an energy conserving strategy (Fig. M-2; Ch. 5, Fig. 11). Increases in activity or movement could negatively affect individuals already weakened by winter.

Effects of aircraft on muskoxen will be highly dependent on the type of aircraft, volume of traffic and location of permanent and temporary airstrips. Most impacts on muskoxen might be expected to occur during phases of oil field development when construction activities reach a maximum. In later phases of production, muskoxen will have probably left areas of activity or habituated to aircraft overflights. But as oil field development and production expand in time into more and more areas, the likelihood that muskoxen will leave the study area will also increase.

Construction Activities. Direct habitat loss to muskoxen will result from the construction of wellpads, roads, airstrips, pipelines and support facilities. The total area covered by these structures will be many times greater than that observed during exploratory drilling. But the effect of this direct habitat loss is highly dependent on the location and size of the facilities. The removal of gravel required to build these structures will be of more significance. Unlike exploratory drilling where gravel extraction will be needed for a relatively few wells and possibly short roads or airstrips, development of petroleum resources requires large amounts of gravel for the construction of permanent wellpads, airstrips and an extensive road system, as well as support facilities and a pipeline system. Removal of gravel from riparian areas used by muskoxen would result in important habitat loss (Jingfors 1980, Robus 1984). Effects would be highly dependent upon the location and extent of gravel mining operations. Muskox distribution in 1982-1985 (Ch. 5, Fig. 25) was associated with major drainages within the ANWR study area. Rivers and creeks were the major terrain type used by muskoxen in 1982-1985 (Ch. 5, Fig.). Muskoxen used riparian areas along the Okerokovik, Niguanak,Angun and Sikrelurak Rivers on the east side of the study area and along the Sadlerochit River, Carter Creek, Marsh Creek, Katakturuk River, and forks of the Tamayariak River, and the Canning River in the western portion of the study area. These areas apparently contribute to the high productivity observed in the ANWR muskox population (Robus 1984, Reynolds et al. 1986).

Noise and other stimuli, such as human presence, and surface vehicles associated with construction activities, will be other major sources of disturbance which may cause animals move away from areas of activity. During the course of developing petroleum fields, construction activities may encompass relatively large areas and at least some of these activities will probably occur in areas of high muskox use (Ch. 5, Fig. 25). Although little is known about the effects of oil field construction on muskoxen, other types of ground activities have been observed. Harassment by snow machines may have resulted in relatively rapid long range movements in ANWR muskox herds in 1983-1985 (Reynolds 1986a). One large herd moved 30 km in 24 hours from a river valley to high ridges after hunters on snow machines approached and shot 1 bull in 1983. This same herd also moved about 15 km in about 15 hours along a ridge system, possibly after being approached by a snowmobile in 1984. In 1985, this herd ran over 1.6 km after being approached by hunters on snow machine. Observations of muskoxen near ground vehicles associated with winter seismic operations in the ANWR study area showed a variety of responses. Two herds responded by grouping and running when vehicles were 3.0 - 3.2 km away. By contrast, at least 1 herd showed no response to a Bombardier approaching within 0.2 km (Table 3).

Muskoxen will either be displaced from areas of construction activity, increase their activity or localized movements, or will habituate to the presence of construction activities. Levels of disturbance resulting in displacement are not known for muskoxen, but displacement is most likely to occur when construction activities are located in areas currently used by muskoxen (Chapter 5, Fig. 25).

Many construction activities will probably take place in late winter when muskoxen may be most vulnerable to disturbance. Muskoxen apparently decrease their activity and movement (Reynolds 1986b) and may have evolved intrinsically lower energy expenditures and food requirements in winter (White 1984) as an adaptive mechanism to conserve energy (H. Thing, Denmark, Game Biology Station, pers. comm.). Disturbances which result in decreases in time spent resting and increases in movements may cause energetic costs exceed to critical limits.

Construction activities will result in an increased human presence within the study area. Food handling and waste disposal could result in attractants to predators in local areas. Habitat modification due to solid waste disposal, waste water disposal, and fuel handling would occur in small localized areas. Increasing human numbers during construction would also increase the probability that animals may be harassed or killed illegally.

Production Activities. Direct habitat loss, caused by ground removal operations and the land surface being covered with gravel pads, or damaged by waste disposal or contaminants such as fuel spells, will occur primarily during construction phases and may be at a maximum as oil field production commences. But if ancillary facilities, such as stores and other services, continue to expand throughout the life of the oil field, direct habitat loss will also slowly increase. Amounts of direct habitat loss which will affect the ANWR muskox population are not known, but if losses continue to occur, the probability of impacts resulting in effects, will increase.

Noise and other stimuli including human presence, and surface vehicles, resulting from activities associated with oil production will occur on a year round basis, but will be limited to relatively small sites around active wells, pumping stations, support facilities and airstrips. Travel along roads and pipelines may be less than that occurring during the construction phase. Dispersal of muskoxen out of the study area is not likely to increase during production activities, as animals not tolerant of disturbance will have probably left areas of activity during the construction phase. Magnitude of impacts will be highly dependent on the location and extent of activities.

Numbers of humans may reach a maximum during the construction phase and decline during the production phase, unless ancillary facilities continue to grow. Food handling and waste disposal could result in continued attractions of predators into local areas. Increasing numbers of humans in the study area would increase the probability that muskoxen may be harassed or killed illegally.

Permanent Physical Structures. In addition to activities associated with construction and production of oil fields, the presence of physical structures may impact muskoxen. Such structures would include pipelines, roads, wellpads, airstrips, and central support facilities. Physical structures may be physical or psychological barriers to movement which result in restricting access to habitat. Habitat losses caused by animal avoidance or physical barriers will encompass much larger areas than areas in which direct habitat loss occurs.

The presence of both physical structures and on-going human activity will probably result in more potential for disturbance than physical structures alone. Displacement or avoidance of areas by muskoxen is more likely to occur in the proximity of large support facilities and permanent airstrips than along pipelines after the cessation of construction activities. Little is known about distances at which muskoxen will avoid such areas. Avoidance and permanent displacement is most likely to occur if permanent structures associated with activities are located in areas of high muskox use (Ch. 5, Fig. 25).

Permanent physical structures, such as roads, airstrips and port facilities, will permit increased human access into the study area. Although access may be theoretically controlled, in practice this is difficult to enforce, as experiences along the Dalton highway between the Yukon River and Prudhoe Bay would indicate (K. Whitten Alaska Dep. Fish and Game, pers. comm.). Increased access by humans will probably result in increased numbers of muskoxen being killed illegally as people learn how easy muskoxen can be taken using snow machines or other all-terrain vehicles. Increased harassment of animals and habitat modification may increase as human access increases. Displacement of muskoxen out of the study area may result in areas most accessible to human traffic.

Distribution, mortality and productivity . Distribution of muskoxen on the ANWR coastal plain will be affected if increased dispersal or movement of animals away from human activities on the coastal plain occurs. Disruption of normal movements and activities and loss of habitat due to avoidance may be major factors in causing displacement. Displacement of muskoxen from areas of traditional use may result in a permanent significant loss of animals in some areas, if animals disperse out of the study area. Decreased productivity and increased mortality could also result if muskoxen disperse into areas of lower nutritional quality or higher predation.

Habitat loss, if extensive, may also force muskoxen to disperse into new areas. Direct habitat loss through habitat destruction will probably be minimal because of the relative abundance of habitat availability. But physical and psychological barriers which prevent muskoxen from utilizing preferred areas will have a more significant impact. Increased predation may also cause animals to disperse into new area. Most significant would be increased harrassment or illegal human hunting which could occur as human access into new areas increases.

Increased mortality in ANWR muskox populations resulting from activities associated with petroleum exploration and development will be most likely caused by disruptions of normal movements and activity patterns. Impacts occurring in winter, particularly in mid-March to mid-April may be more serious than those occurring during other seasons of the year, as muskoxen apparently restrict both movements and activity during winter as an energy conserving strategy (Reynolds 1986b). If muskoxen are disturbed in winter and are forced to increase their activity, they may use energy reserves which are critical to winter survival. Higher overwinter mortality could result.

Increased mortality in ANWR muskox populations may be affected by increased predation, primarily by humans. Increased access by humans will occur as a result of petroleum exploration and development as roads and airstrips are built in the area. Illegal hunting and/or harassment of muskoxen will probably increase as more people have access to the coastal plain, during all seasons. Because of their behavior of grouping together into a defensive formation which approached by predators, muskoxen are particularly vulnerable to harassment and overhunting. Muskoxen were exterminated from Alaska in the mid-1800's by human hunters (Hone 1934, Cambell 1978, Wilkenson 1978, 1972, Will 1984).

Predation on muskoxen by grizzly bears and wolves is currently low on the ANWR coastal plain (Reynolds et al. 1986). But if predator populations are effected by petroleum development, muskoxen populations will also be affected. Improper handling of food and garbage, and the creation of garbage disposal sites associated with large support facilities may result in attractions to bears which may ultimately result in increased predation in local areas.

Mortality may also increase due to decreases in habitat availability. If the rapidly expanding muskox population is suddenly restricted into smaller areas because of physical or psychological barriers, animals within a local area may exceed the carrying capacity of the area, resulting increased mortalities as food supplies decline.

Decreased productivity of muskox herds on the ANWR coastal plain is most likely to be effected by habitat loss. Gunn (1984) states that productivity in muskoxen is apparently related to quality of forage. The high productivity observed in the ANWR muskox population is apparently related to the current availability of high quality forage (Robus 1984, Reynolds et al. 1986). If these areas become unavailable to muskoxen because of avoidance of areas of human activity or physical barriers which prevent access into such areas, productivity of the population could decline. Increased predation could affect overall productivity if an excessive number of cows were taken by human or animal predators. Disturbance of muskox activities and increased stress, if of a severe nature just prior to calving, may cause birth-associated mortalities. During the ANWR muskox study, 1 cow gave birth to a still-born calf 2 weeks after begin captured in mid-April. Another tagged during the same time period, died within a month, possibly as a result of birth complications. No mortalities occurred when animals were tagged before April 3 in subsequent years (Reynolds et al. 1983), suggesting that cows are sensitive to extreme disturbance during the two weeks prior to calving. T. Smith (Alaska Dep. Fish and Game, pers. comm.) also had mortalities occur when muskox cows were tagged during the last 2 weeks in April.

The ANWR muskox population is currently growing rapidly, experiencing high productivity and low mortality in all age classes (Reynolds et al. 1986). Impacts on this healthy population will be of less significance than if the population were declining. Effects on the population, if they occur, may cause a decline in the rate of population growth. Location of development activities will influence the magnitude of effects. The ANWR muskox population appears to be composed to 2 subpopulations, one occurring on the west half of the coastal plain primarily between the Canning and Hulahula rivers (Tamayariak/Sadlerochit) subpopulation and one on the east half of the coastal plain between the Jago River and the Canadian border (Okerokovik subpopulation). Productivity has been lower in the Okerokovik subpopulation (Reynolds et al. 1986), possibly because of habitat availability. Petroleum development in this eastern geographical area may be of more significance to this smaller, less rapidly growing population.

Moose

If oil and gas development and production facilities were limited to the coastal plain (i.e. drill rigs, pads, roads, pipelines, etc.) the potential impacts described in Chapter 8 would still apply. In addition to those impacts, moose using the coastal plain would be subject to human habitation of the area. Moose are normally very tolerant of most human activities (Kucera 1974). However, elevated pipelines may impede movements through a given area (Hinman 1974). Use of the coastal plain by moose appears to be a wandering type of use and the effect of an elevated pipeline on those segments of moose populations using the coastal plain is unknown.

Habitat alterations on a relatively small percentage of the coastal plain would also occur as a result of development, but summer use by moose would be only slightly affected. However, if development activities were to take place in the more critical wintering habitats along the Canning and Kongakut Rivers, then impacts to moose population could be expected, dependent upon the type of development. Again, the overall effect of development on moose populations is unknown.

## Polar Bears

The effects of oil and gas development, production and transportation on polar bears may include direct habitat loss, indirect habitat loss or degredation, impacts to food supply, or problems associated with oil spills.

Denning Bears. A large development facility might be located in an area used for denning by pregnant female polar bears. Because polar bears are thought to show fidelity to birth sites and try to reach the area previously used for denning (Lentfer and Hensel 1980), a large facility could deflect bears from preferred onshore den sites. The importance of traditional sites and the effects of such deflections are not known, although it is thought that denning success is much lower on the pack ice (Lentfer 1974).

Noise and activity associated with an oilfield facility or road, or the presence of a pipeline, may also deflect female bears from traveling to denning sites onshore. A road parallel to the coast which has heavy use could cause bears to avoid inland denning sites along the length of the road. Roads perpendicular to the coast would have a much smaller impact (Lentfer and Hensel 1980), although a road within a floodplain where potential denning habitat exists could have an impact on denning female bears and cubs and emerging females and cubs as described previously.

Non-denning Bears. The impacts of oil and gas development to non-denning segments of polar bear populations are not well known. This segment of the population generally inhabits the pack ice throughout the year, although in the fall a number of animals, primarily family groups composed of females and juveniles, are seen along the coast (Amstrup USFWS, Anchorage pers. comm.). The potential direct impacts to bears inhabiting the pack ice would be disturbance due to oil tankers or an accidental oil spill from an oil tanker or loading facility. Simple disturbance is not likely to have a great effect on non-denning bears. Direct effects of oil contamination are not well known. Initial results of a study conducted in Canada (Hurst et al. 1981) indicate that bears forced to enter an oil slick and then subjected to cold temperatures and wind are likely to die. However that study did not determine if polar bears will enter an oil slick of their own accord.

Family groups of bears which scavenge on whale carcasses along the coast may be affected by oil and gas development in the ANWR study area if they are attracted by garbage or curiosity to a populated area. Because bears are attracted to the Barter Island area due to whale remains, an oil and gas facility located nearby may have a higher occurence of nuisance bears than other existing facilities presently report.

Polar bears may be affected indirectly through their primary prey, ringed seals. Local reductions in ringed seal populations may cause bears to desert an area in search of prey. Lack of an immediately available food supply may be critical to survival of females and cubs just emerging from the den (Lentfer 1974). Such a reduction in ringed seal numbers may be caused by ice breaking tankers as described below.

Ringed and Bearded Seals

Potential impacts to seals from petroleum development include disruption of feeding or food supplies, but would probably remain minor in magnitude because the ANWR study area contains relatively poor seal habitat. Development, production and transportation of oil and gas resources could affect ringed seals primarily in 2 ways: an oil spill caused by a well blowout or tanker crash, or chronic pollution from small scale fuel or oil spills or other chemicals kept at shore based facilities (Burns et al. 1980). A catastrophic oil spill may cause either local short term or extended long term impacts. If the spill were to occur within a lagoon system, it is likely that oil would remain mostly in the lagoon, and impacts to seals would be minor. Also, if a spill were to occur during the summer, it could be cleaned up fairly easily, thereby keeping impacts to a minimum. However, if the spill were to occur offshore and during the winter or early spring, the impacts would be major. Adult seals could experience severe eye damage, affecting their feeding. Young seals could be oiled and die. Prey species such as arctic cod could experience egg, larval, or adult mortality. Nektonic invertebrate populations could also be affected. However, the severity of these impacts depends on many variables and no quantitative description of them is possible (Burns et al. 1980).

Chronic pollution of waters inhabited by seals may be a greater long term problem than an oil spill. The effects of low level contamination of waters to seals or their prey are not known.

If ice breaking tankers are used to carry the oil to market, and travel through ice areas that are used by seals for denning and pupping, a large area of seal habitat may be destroyed. The extent of impact depends on the timing and amount of tanker traffic, and the location of the routes.

Bowhead Whales

Potential sources of impacts to whales during development, production, and transportation of oil and gas resources in the ANWR study area are shore-based facilities, ocean freight traffic, and ocean-going oil tankers or submarines. Oil spills or noise generated at shore-based facilities may disturb bowheads. Supply shipping could disturb whales, while tankers pose the additional risk of an oil spill. Heavy boat traffic could cause bowheads to desert areas near the coast which they normally use (Fraker et al. 1981). The long-term impact of such disturbance is not known.

The effects of toxic substances to whales are unknown. It is possible that foreign substances might disrupt a whale's ability to locate food by masking its chemoreception. Damage to active epidermal cells is also possible (Fraker et al. 1981). Oil might foul the baleen of bowheads, making them less efficient in feeding, or causing the whales to stop feeding (Fraker et al. 1978).

Other Marine Mammals

Beluga whales and bearded seals are found only occasionally near the study area. Impacts of oil and gas development, production, and transportation to these animals are expected to be negligible.

Brown Bears

Brown bears use the coastal plain of ANWR throughout the summer, however, this use in most intensive when the PH is present in the area in June and July (Garner et al. 1984, 1985, 1986). Caribou is an important food source for portions of the brown bear population at this time. The readily available protein source is believed to be the results of higher productivity and density of brown bears in the ANWR study area (Reynolds and Garner In press). If the petroleum development program results in a decline in use of the area by PH caribou, a corresponding decline in brown bear population will be expected.

Petroleum development woudl affect denning bears on the coastal plain. Bears are sensitive to helicopters (Quimby 1974) and fixed-wing aircraft (Garner et al. 1984) overflights at denning and they may abandon their dens. This disruption of denning manner did not result in any apparent mortality and the distrubed bears new dens (Garner et al. 1984). Only 11 of 199 documented den sites in northwestern ANWR was within the ANWR study area (Garner et al. 1986b), because urban development acitvities will be confined to the ANWR stydy area, effects on the population of denning bears are expected to be negligible.

Petroleum development in areas that brown bears frequent will result in increased bear-human interactions. Brown bears have historically not abandoned previously occupied areas when those areas were developed by man. Instead bears continue to use the nearly occupied areas and eventually are eliminated by killing because they pose a threat to human safety (Jonhel 1970, Reynolds 1979). The mortality rate of these encounters are unknown. Also, the accumulation of garbage at industrial sites will attract bears and these attractions can result in bear mortality (see previous section on Further Exploration, Chapter 8). This mortality could be reduced by use of proper garbage disposal and removal programs (Follman et al. 1980).

The establishment of action petroleum industrial sites in the ANWR study area will also increase access to the area by hunters (Both sport and subisitence). This increased?? access has the potential for increasing mortrality of bears on the coastal plain. This phenomenon was noted by Follman and Hechtel (1983) for the TAPS corridor during construction. Schallenbeiger (1980) also reported increase in bear harvest tha resulted from increased presence of humans associated with petroleum development.

Wolves and Foxes

Impacts previously discussed would apply to development, production, and transportation of oil and gas on ANWR but the magnitude of such impacts, if they occur, would be greater. Activity would occur year round at greater intensity. Structures and staging areas being permanent. Additional impacts would result from the development and use of a pipeline and haul road connecting ANWR to Prudhoe Bay and a public airport and facilities.

Artificial Food Sources. During construction of TAPS, feeding of animals by pipeline workers became such a problem that the Alaska Board of Game passed a regulation prohibiting feeding of animals in 1976 . In 1977, the state of Alaska passed a similar law. Three years later in 1979 - 1980, garbage and handouts were still readily available to animals at Prudhoe Bay (Fine 1980, Eberhardt et al. 1983). Milke (1977) states "some people suffer from chronic apathy and for them education is not enough". Problems with feeding of animals can be expected on ANWR with impacts as discussed previously. Grace (1976) found that both local and non-local wolves used dumps during summer. Some wolves using ANWR during summer, appear to follow caribou movements to and from the area (Weiler et al. 1986). These wolves may be enticed to remain where human food is available rather than follow the caribou and may be forced to rely on handouts later in the year when alternate prey are scarce (Milke 1977).

Disease. Rabies outbreaks among arctic foxes are most often associated with high population levels following a decline in microtine members. Peaks in arctic fox populations in Alaska occur approximately every 4 years (Chesemore 1967). During these periods, problems with rabid foxes can be expected at well sites and staging areas.

Habitat. Habitat changes due to development in the area will affect foxes in several ways. Den sites are used repeatedly over the years, becoming traditional den sites. Direct loss of such den sites would cause foxes to den at less preferred sites or not at all if den sites in the area are limited. In arctic Alaska, lemmings (Lemmus and Dicrostonyx), voles (Microtus), and nesting birds, eggs, and young are the main food items for both arctic and red foxes (Chesemore 1967, Eberhardt 1977). Microtine populations in the Prudhoe Bay area have not been known to cycle as in other areas of the arctic (MacLean pers. comm.). What effect development and habitat loss over a large area will have on microtine population cycles on ANWR is not known. Activity on the tundra during winter will compact snow and may impede microtine mobility under the snow and decrease over-winter survival (Schmidt 1971, as cited in Bury 1978).

Loss of habitat may also result in lower numbers of nesting birds available to foxes. This may be especially important during years when microtine numbers are low. Burgess (1984) found that arctic foxes relied almost exclusively on avian prey when small mammal densities were low. Birds feeding on invertebrates around well sites may have increased levels of pollutants. The presence of industrial pollatants, especially polychlorinated biphenyls in arctic fox tissues has been documented (Clausen and Bery 1975, Clausen et al. 1974, Nurheim 1978). These pollutants may have long term effects on foxes which are at the top of trophic level.

Habitat changes are not apt to influence the wolf population in a serious way (Brooks et al. 1971). However, wolves would be affected by any changes in habitat which altered behavior or movements of caribou. Wolves in the northeastern Brooks Range do not appear to have seasonal changes in territories as has been found in other areas of the arctic (Weiler et al.

1986). Radio tracking data on ANWR has shown 4-5 wolves extensively using the coastal plain when caribou were present in 1984 and 1985, but it is likely that actual numbers of wolves utilizing the coastal plain are several times higher. Wolves, both collared and uncollared, were often found near post-calving caribou when the caribou had moved into the foothills and mountains. Analysis of scats collected at den sites show that caribou are important prey species during summer (Haugen 1985, Weiler et al. 1986). Areas west of the Jago river are devoid of migration routes used by the PH. In addition, most of the CAH utilizes the area west of the Canning river. Wolves in areas between the Jago and Canning Rivers had much lower pup production and survival than wolf packs in the central and eastern areas of ANWR (Weiler et al. 1986). It is not known if nutritional stress was a factor in pup survival in this area. It appears that pup survival of wolf packs on ANWR may be related to pack size (Weiler et al. 1986). Packs with fewer than 5 adult members may not be able to effectively utilize alternate prey species and their ability to successfully raise pups may be impaired.

Deflection of caribou movements south toward the foothills would make caribou more accessible to wolves in the central area of ANWR. Alternatively, the restriction of caribou to the eastern part of ANWR, would cause wolves from the central area to travel farther to utilize caribou or possibly make them inaccesible. This displacement could result in lower pup survival and increased winter mortality resulting from a decrease in nutritional condition at the end of the summer. Van Ballenberghe and Mech (1975) found that pups with weights less than 65% of standard (based on weights of captive pups at similar age) had a poor chance of survival.

Harassment. Aircraft use in a developed petroleum field is more intense than in either seismic or exploratory drilling phases. Impacts from harassment will be the same but the potential for harassment will increase as activity increases.

Access. Petroleum development will result in all weather roads and pipelines between well sites, well sites and the coast, and between ANWR and Prudhoe bay. A public airfield on ANWR may also be constructed and would contain facilities similar to those available at Prudhoe Bay. All weather roads would increase access for people from Barter Island which would include use of snowmobiles, ATV's, and possibly trucks. This would provide quick and easy access throughout the winter months and increase hunting pressure on foxes and wolves. If roads were open to the public, hunting pressure can be expected to increase with a corresponding increase in the harvest of wolves and foxes. At present there are about 10 locations on rivers in the mountains where light aircraft can land. In addition, in any given year, there are 2 - 3 three times that number of gravel bars that aircraft with short field landing and take off capabilities can use. Present use of these landing areas is limited due to lack of refueling, staging, and shipping points in the area, as the nearest facilities for these activities is Prudhoe Bay or Fort Yukon. Facilities at Barter Island are not open to public use. A public airfield and support facilities on the ANWR coastal plain would make such facilities readily available. An increase in the number of aircraft utilizing the area can be expected both by privately owned and charter aircraft. Ease of access and staging facilities can also be expected to increase use of the area by hikers, sightseers, tour groups and people floating rivers, which can increase disturbance of both foxes and wolves during the denning season. On ANWR, people floating rivers have actively searched for wolf dens, even after being told that they should not stop or camp in that area. Chapman (1977) and Eberhardt (1977) have documented desertion of den sites by foxes and wolves due to human disturbance.

Given adequate food resources, arctic foxes appear to be tolerant of disturbances and habituate quickly to development. Find (1980) found the highest density of arctic fox dens occurred near major oil fields in the Prudhoe Bay area. Results of past and present studies at Prudhoe Bay are difficult to classify into cause and effect relationships as far as impacts to the population due to the presence of artificial food sources which often tend to dampen or obscure some impacts or effects of development.

Little data are available on impacts of development in Alaska on red foxes. Tracy (1977) found that red foxes did not abandon dens that were near heavily used roads in McKinley Park. Allison (1971, as cited by Douglass et al. 1980) also did not observe desertion of dens which were subjected to disturbances. Activity and development at Prudhoe Bay (excluding the haul road) has had little impact on red foxes due to distance from the mountains and foothills where red foxes are more commonly found. Development on ANWR would be much closer to the mountains and in some areas would border the foothills. In general, red foxes are less tolerant of disturbance, especially around dens, than arctic foxes and would be slower to habituate to disturbances (E. Follmann, Univ. of Alaska, pers. comm.).

Wolves are less tolerant of disturbances than either arctic or red foxes. The presence of additional people with mechanized equipment on the coastal plain will result in more wolves being taken (Brooks et al. 1971). Known mortalities on ANWR, both human-induced and natural, was 7 animals in 1984 and 12 animals in 1985. Mortality in 1985 was 33% of the known 1984 fall population. Wolf packs successfully raised 7 pups in 1984 and 14 in 1985 (Weiler et al. 1986). Wolf densities on the north slope of ANWR are low and recruitment during the study period, was sufficient to offset known mortalities. Any activity which results in an increase in mortality of wolves, could result in a decrease in the population.

Wolverines

Recent observations of wolverine (Mauer 1985b), as well as information compiled from local trappers and hunters (Jacobson and Wentworth 1982), suggest that the coastal plain is used throughout the year by all segments of the wolverine population. Current data regarding wolverine use of specific areas are insufficient to adequately describe potential impact of specific oil and gas development scenarios, therefore, only general implications are discussed.

Throughout its circumpolar distribution, wolverines occur exclusively in remote regions where human activity is low (Myhre 1967, Van Zyll de Jong 1975). The wolverine has been displaced from southern portions of its historic range in Eurasia and North America (Allen 1942, Myhre 1967) and is known to be cautious and wary of man (Krott 1960). A paucity of wolverine observations near villages and industrial sites on the north slope suggests a general avoidance of centers of human activity (A. Magoun, Alaska Dep. Fish and Game, pers. comm.). It is likely that wolverine distributions and movements on the coastal plain would be altered by the presence of human activity associated with oil and gas development. Avoidance behavior and the wide-ranging nature of wolverines, may result in the displacement of wolverine from major portions of the coastal plain.

Since wolverines are primarily scavengers, their abundance is related to the biomass and turnover of large herbivore populations (van Zyll de Jong 1975). Apparently the abundance of wolverines is also influenced by the diversity of large herbivore populations as well (Hornocker and Hash 1981). Wolverine populations and abundance on the coastal plain will be affected if the numbers and diversity of caribou, moose, and muskox populations decline or are displaced due to the industrial development. Reduction in abundance of the primary predators (wolves and brown bears) could also influence the abundance of prey carcasses available for scavenging by wolverines.

Wolverines are vulnerable in the tundra environment to hunting from snowmobiles and aircraft during winter. Increased hunting and trapping of wolverines could occur on the coastal plain as a result of improved access to the area by roads, trails and airstrips associated with oil and gas developments, and due to increased human populations living in the region. The low incidence of recent wolverine observations on the coastal plain (Mauer 1985), relative to levels reported at some sites on the north slope (A. Magoun, Alaska Dep. Fish and Game, 1985), suggests the current wolverine population may be at a low level. The effects of habitat loss through displacement/avoidance, reduced food resources, and increased harvest pressure resulting from oil and gas development may be sufficient to cause removal of the wolverine from large areas of the ANWR coastal plain.

### Small Mammals

Little is known about the effects of development on small mammals. Lemmings (Lemmus and Dycrostonyx) are active under the snow all winter. In localized areas, tunnels and runways could be crushed by surface vehicles (Schmidt 1971, as cited in Bury 1978). Arctic ground squirrels (Spermophilus parryii) hibernate in winter and most would probably not be affected by winter activities. Local populations of small mammals could be temporarily affected by changes in habitat availability or quality.

## Fish

Should development and production of oil occur on the ANWR coastal plain, a variety of impacts could be expected affecting fishery resources. The large demand for gravel and water are perhaps the most threatening.

A prioritization of concerns for freshwater fish include:

1. water withdrawl in critical areas and/or critical time periods
2. gravel removal from fish bearing stream systems
3. stream barriers
4. stream channelization
5. improper culverting
6. increased angling pressure

7. oil spills
8. drill mud contamination
9. sewage and waste water disposal
10. other contaminants
11. blasting

For coastal fish a prioritization of concerns are:

1. physical and chemical barriers caused by docks and causeways
2. oil spills
3. water intake structures
4. drill muds and cuttings
5. other contaminants
6. blasting

The construction phase of development has other effects including those associated with initial gravel removal, bridged stream crossings, and culverting. Sustained effects include sedimentation from erosion, water withdrawl, increased regional fishing pressure, oil and other contaminant spills or improper disposal, barriers in streams and lagoons, and ongoing maintenance of facilities.

Oil Spills. Crude oil spilled on water can have two important biological effects. First, the oil contains high nutrient levels from the compressed prehistoric organisms that, considered alone, can act as a fertilizer to increase the biomass of tolerant microorganisms, and in turn increase the production of many species. However, because of the impurities in oil, the toxic metals, phenols, sulphur compounds, acids, and aromatics, many creatures that come in contact with an oil spill will be adversely affected (Milne et al. 1973).

Fish have mucous-coated gills which can repell small amounts of oil but they are not capable of cleaning their gills if they became coated and will die in such an event (Cole 1941). Besides interferring with respiration, oil can affect fish by reducing or eliminating food organisms, concentrate through the food chain to chronic toxic levels, cause gastric problems when ingested, and settle to the bottom interferring with spawning areas (McKee and Wolf 1963, Percy 1975).

There is no evidence to suggest that fish avoid oil (Percy 1975). Chipman and Galtsoff (1949) reported that crude oil in concentrations as low as 0.3 mg/l was extremely toxic to freshwater fish. Refined petroleum products can be much more toxic than crude oil (Environmental Protection Agency 1976). Even if ingestion of oil or petroleum products directly or indirectly does not cause mortality in a fish species, the flesh may be so tainted as to be inedible or may have concentrated dangerous levels of carcinogenic polycyclic aromatics so that it should not be eaten (Environmental Protection Agency 1976).

Periodic equipment design analysis and risk assessment can help ensure all practical technological advances are being employed in oil spill prevention. Siting oil transportation, storage, and processing facilities away from water bodies, preparation of adequate oil spill contingency plans, and the ready availability of clean-up equipment near all potential spill areas can help reduce the severity of an oil spill on fish.

Drilling Fluids. Many of the materials commonly used in drilling have been found to be toxic to fish. Logan et al. (1973) (as cited in Hrudey and Eng 1979) found that 13 of 27 common chemicals used in drilling operations were acutely toxic to rainbow trout at concentrations below 1000 mg/l. Falk and Lawrence (1973) also found acute toxicities with various drilling fluids when using rainbow trout and several species indigenous to the MacKenzie river area. Most samples of drilling fluids tested by B.C. Research Ltd. (1975) were toxic (96 h LC50) to seawater acclimated salmonid fishes and invertebrates at concentrations of less than 8 percent volume to volume.

On the basis of quantities used and long term harmful effects of drilling fluids used in northern Canada, Land (1974) reports that the alkaline sources, bactericides, barium sulphate, bentoniute, chromium salts, and potassium chloride compromise the major sources of aquatic toxicity. Lubricants and detergents can be toxic at much lower concentrations but are not used as extensively.

The overall effect of drilling muds, cuttings and fluids on fish depends largely on the disposal technique, location, concentration of individual constituents, water chemistry, duration of disposal, species present, and life stages involved.

The holding of muds and cuttings in impermeable pits, regulated disposal of only non-toxic fluids, and proper siting and timing of all disposal operations should help reduce potential impacts of drilling wastes on fish. A monitoring program for bioaccumulation of drilling associated contaminants in fish should also be undertaken to ensure handling and disposal practices are proving adequate.

Water Withdrawl. Water withdrawl from fish-bearing waters can cause detriment to fish populations in several manners. The pumping system can injure or kill small fish, eggs, and invertebrate prey organisms at the intake. Summer withdrawl in some locations can reduce flow sufficiently to prevent fish from migrating through to spawning or overwintering sites. Summer waters withdrawl can also reduce prime rearing habitat for juvenile fish along the edge of streams, and in some cases can leave rearing fish entrapped in pools above the dewatering site.

Water withdrawl conflicts have been reported in several areas in the Arctic in recent years. The most noteable example in Alaska occurred on the Sagavagrirktok River near Prudhoe Bay where isolated fish overwintering pools were dewatered resulting in fish kills (Bendock 1976). All known riverine fish overwintering sites in the ANWR study areas are comprised of pools completely separated from each other by frozen river. Water withdrawls from these isolated areas can kill all of the aquatic organisms in the pools. Even if the pools are not drained dry or to the point they will freeze, any decrease in existing water volume can cause die-offs by crowding organisms, decreasing available dissolved oxygen for respiration, and increasing concentrations of toxic waste metabolites in the pool (Wilson et al. 1977).

Perennial springs have been suggested as potential water sources but most seem to support fish populations and withdrawls from these areas could jeopardize their continued survival. Thirty-four of the 36 springs identified along the northern foothills of the Brooks Range between the Sagavanirktok River and Canada have been reported to support spawning and overwintering Arctic char (Ward and Peterson 1976, as cited by Wilson et al. 1977).

Wells tapping underground reservoirs and ground water in the thawed alluvium beneath large rivers are also potential sources of water for development in the Arctic. Removal of such stores, however, could result in drainage of water from nearby fish overwintering areas (Wilson et al. 1977).

Large reservoirs excavated in "dead arms" of rivers, perhaps in conjunction with gravel removal, may be the only viable option to provide the large quantities of water needed to develop oil reserves at the more inland areas of the ANWR coastal plain. These reservoirs could potentially be used to overwinter fish populations. Proper siting, timing of construction, and design of such reservoirs would be critical to ensure minimizing associated environmental impacts.

Timing and siting water withdrawls, screening of intakes, and conducting instream flow requirement studies for all fish-bearing waters prior to any water removal would also help reduce potential impacts.

Causeways. Construction of lengthy causeways to access offshore oil reserves or deep water for shipping and/or water intake structures can potentially have major effects on local fish habitat quality and movements. Impacts can include: impedence of normal fish and prey organism movements; alteration of water temperature, salinities, and current patterns; and changes in disposition of sediments.

The best studied existing causeway in the Beaufort Sea is the west dock causeway at Prudhoe Bay (Griffiths and Gallaway 1982, Savoie and Wilson 1983 and 1984, Biosonics 1984). Monitoring studies have demonstrated a pronounced effect of the causeway on water quality, specifically lower temperatures and higher salinities on the west side of the causeway. The single 50-foot breach in the west dock causeway proved inadequate to pass fish and provide normal water mixing. Researchers currently disagree on the effects of the habitat changes on fish use, but it appears that some fish maybe avoiding the area.

The potential threats of causeways were recognized in the preparation of the federal/state joint lease sale (BF) for the Beaufort Sea with a stipulation that prohibits continuous fill causeways (Bureau of Land Management 1979). Non-continuous fill causeways may be permitted only if absolutely necessary for the development of the oil field and if no other practical alternative exists.

A concern also exists involving potential cumulative effects of a series of causeways along the Beaufort Sea coast. Other than the west dock causeway, the Prudhoe development area also had the Endicott causeway constructed in 1985 and currently under study. The Lisbourne development will likely result in the construction of a 13,000 foot causeway in Prudhoe Bay as early as 1987. Future causeways to oil reserves off the Colville River delta are possible. Offshore development near ANWR would also likely require causeways. This area is currently under preparation for sale (State Lease Sale 55). Onshore development of oil resources on the ANWR may require causeway construction for a water flooding type project to assist in oil recovery, such as the case of the west dock extension at Prudhoe Bay.

Alternatives to causeways in the future may include use of sub-sea pipelines or structures built on pilings. The minimal mitigation standard for current causeway design should be adequate breaches to allow normal current patterns and fish movements to occur.

Gravel Removal. Gravel removal from streams can have a variety of effects on the surrounding aquatic habitat and on the organisms that live there. Woodward-Clyde Consultants (1980) in their study of gravel removal from arctic and subarctic floodplains in Alaska, found the following effects of scraping on riverine habitats:

1. the creation of braided channel areas which resulted in a reduction of diversity of the fish communities studied;
2. removal of bank and instream cover causing reduced population densities of species such as Arctic char and Arctic grayling which were strongly associated with the cover habitat type;
3. increased habitat diversity of primarily a temporary nature;
4. creation of potential migration blockages; and
5. creation of potential entrapment areas which resulted in a reduction of diversity of the fish communities studied.

Elliott (1982) noted several cases of loss of surface flow on streams where gravel was removed for the construction of the TAPS. The loss of flow resulted in a blockage of fish moving downstream to overwintering areas. Woodward-Clyde Consultants (1980) made recommendations to lessen damage to fisheries from gravel mining resulting from their studies in northern Alaska. These include:

1. avoid gravel mining from active stream channels and below the water table;
2. do not alter undercut and incised vegetated stream banks;
3. avoid critical habitats such as spawning and overwintering areas;
4. contour removal sites to provide adequate drainage and prevent formation of isolated pools which can entrap fish; and
5. excavate pits to an average depth of at least 2.5 m to avoid winter mortality of fish.

Sediments. Disturbance of stream beds, banks, runoff areas, and tributaries can cause increased siltation and sedimentation. Different measurements for the effects of the disturbances can include turbidity, suspended solids, dissolved solids, and settleable solids. Each of these parameters are estimated differently and each may have different effects.

In general, fine solids may harm freshwater fisheries in 5 ways (European Island Fisheries Advisory Commission 1965):

1. Acting directly on the fish swimming in water in which solids are suspended, and either killing them or reducing their growth rate, resistance to disease, etc.
2. Preventing the successful development of fish eggs and larvae.
3. Modifying natural movements and migrations.
4. Reducing the abundance of available food.
5. Affecting the efficiency of methods to catch fish.

Buch (1956) found in productivity studies of farm ponds that clear ponds produced 1.7 to 5.5 times the total weight of fish as in turbid ponds and interference with light penetration lowered plankton productivity 8 to 12.8 times in turbid waters as opposed to clear waters. LaPerriere et al. (1983) in work with human-induced turbidity in Alaska confirmed its effects on adversely affecting light penetration, primary production, and production of invertebrate fish prey.

The effects of turbidity and sedimentation on reducing stream production and ability for fish to feed (both by decreasing prey abundance and effectiveness of finding and catching prey) may be most critical under arctic conditions. In the Arctic, survival of most freshwater fish species is linked to a rapid build-up of energy stores during a very short productive season. The presence of turbidity and suspended sediments during the winter period could also be detrimental by physically stressing the fish under already extremely stressful conditions, affecting dissolved oxygen levels, and depositing sediment over fish eggs in the gravel.

Implementation of erosion control practices, creation of buffer zones adjacent to streams, and regulation of construction siting and timing can greatly reduce amounts and effects of sediments entering streams and lakes. State and federal water quality standards currently in place should be adequate for protection of fish and other aquatic resources if they are properly enforced.

Increased Angling. Easier access to arctic rivers and increased visitor use would increase pressure on individual stocks of fish. Arctic waters are often low in nutrients, cold, and provide a very short growing season. The results are that fish species generally grow more slowly and mature later than their cousins in more southern regions. Because of this, arctic fish populations may be easily affected by only slight increases in fishing pressure. Andrews and Lear (1956) provide several examples of significant Arctic char stock depletion after only a few years subjected to increased exploitation. Scott and Crossman (1973) recommend careful monitoring of Arctic char stocks to prevent overexploitation. The establishment of an index to estimate stock health, followed by review and implimentation of necessary harvest regulations, should reduce effects of increased fishing pressure on fish populations in the ANWR. Regulations to limit the take of spawning fish in freshwater would be likely to afford adequate protection in some areas.

## Human Culture and Lifestyle

### Archaeology and Human History

Development production and transportation of oil and gas resources on the ANWR study area have the potential of affecting cultural resources. Direct impacts may include burial of sites during construction of well pads, roads, or airstrips; destruction of sites by vehicle traffic or other activities; and destruction of sites in areas used to obtain gravel or rock material, specific impacts are summarized in Table 7. The magnitude of impacts will depend upon the size and location of development fields and transportation corridors. Development, production of petroleum resources will require large amounts of gravel for construction of well pads, pipelines, roads, airstrips, and field facilities. Cultural resource work done during previous construction activity

Table 7. Potential impacts on archaeological and historical resources by petroleum development and production (source: U.S. Geological Survey 1979).

| Source | Impacts |
|---|---|
| Excavation (borrow pits, quarries, trenches, pits, blasting) | Site obliteration<br>Destruction of artifacts or change in preservation<br>Exposure of new sites for scientific investigation |
| Construction | |
| snow and ice roads | Changes in artifact preservation<br>Alteration of erosional patterns |
| sand and gravel roads, pads, pipelines | Site burial<br>Changes in artifact preservation |
| Drilling | Destruction of artifacts or changes in preservation |
| Human activity | Changes in artifact preservation<br>Looting of sites<br>Discovery of new sites for scientific investigations |
| Waste disposal | Changes in artifact preservation<br>Strata disruption<br>Chemical contamination of artifacts |
| Accidents/emergency clean-up | Site obliteration or burial<br>Change in artifact preservation<br>Strata disruption<br>Chemical contamination of artifacts<br>Exposure of new sites for scientific investigation |
| Abandonment (stabilization, revegetation, contouring) | Site obliteration or burial<br>Change in artifact preservation<br>Strata disruption<br>Exposure of new sites for scientific investigation |

in Alaska has indicated that knobs, upland terraces and hilltops favored as gravel sources also were favored as activity areas by previous occupants of the area (Cook 1977, U.S. Geological Survey 1979).

Construction of either seasonal or permanent well pads, roads, airstrips, pipeline access pads, docks, or other facilities may bury archaeological sites within the construction zone. The extensive network of roads and facilities found in a developed oil field has a greater potential impact than do a few exploratory wells due to the amount of construction per unit of land surface. A special problem may be encountered in the ANWR study area if oil reservoir development is along the coastline or nearshore and well pads are concentrated along the shoreline, an area in which archaeological sites are concentrated (Hall 1982).

Indirect or secondary impacts from oil development activities include roadways altering the hydrological regime of a river causing bank erosion; docks, causeway or gravel borrow accelerating beach erosion; ponding behind improperly culverted roads leading to thermokarsting; or human destruction or looting of archaeological sites. Waste disposal and accidents resulting in emergency clean-up may contaminate artifacts with fuel or other chemicals, precluding the use of $C^{14}$ for site dating (Table 7).

Excavation for borrow sites, clean-up, or site rehabilitation may result in the discovery of previously unknown sites buried beneath the surface (Table 7). Such sites, if available for scientific investigations, could contribute to the knowledge of human occupancy in the Arctic.

Archaeological sites identified by Hall (1982) and historical sites identified by Libbey (1982) may be avoided or salvaged if they occur in areas of development. Site specific surveys for cultural remains would have to be done to avoid destruction of previously unidentified sites.

## Subsistence

Kaktovik. Development and production of petroleum resources in the ANWR may result in the same impacts described for continuing exploration. But the presence of permanent structures and facilities, the long term presence of a maintenance work force and the potential for increased revenues to political organizations and local government will result in additional impacts and impacts of a greater magnitude.

The Arctic Environmental Information and Data Center (1982) described socioeconomic impacts from petroleum development and production on the National Petroleum Reserve in Alaska (NPR-A) which is located 200 km west of the ANWR study area. Socioeconomic components likely to be affected by petroleum development and production in ANWR include the economy, containing both market (cash) and subsistence elements (Worl and McMillan 1982, Jacobson and Wentworth 1982), social structure and cultural values, political organizations, and facilities and services (Arctic Environmental Information and Data Center 1982). Potential socioeconomic and environmental changes are summarized in Table 8. Possible socioeconomic changes resulting from development and production of petroleum resources include increases in the number of available jobs, increases in local populations, and increases in

Table 8. Possible effects of petroleum development, in the Arctic National Wildlife Refuge on the subsistence economic system (source: U.S. Geological Survey 1979, Arctic Environmental Information and Data Center 1982).

| Affected components | Socio/economic changes: Employment opportunities | Socio/economic changes: Increased population | Socio/economic changes: Increased revenues | Environmental changes: Decreased populations of subsistence resources | Environmental changes: Increased access |
|---|---|---|---|---|---|
| Economy | | | | | |
| cash element | Less unemployment<br>More cash<br>Higher cost of living<br>Stabilized economy<br>Need for job training | Higher cost of living | Stabilized economy<br>Economic diversity<br>Opportunities for local investment | | |
| subsistence element | Less time for subsistence activities<br>Purchases of equipment for subsistence | Increased hunting by non-locals<br>Modified game regulations | | Less subsistence production<br>Modified game regulations | Change in land use patterns<br>Subsistence resources more available<br>Possible long-term depletion of subsistence resources |
| Social Structure | More competition for jobs<br>Isolation from family and community | Stress on kinship and social structures<br>Change in ethnic and/or sex ratios | | Competition for resources<br>Less sharing and cooperation<br>Loss of extended families,<br>Less socialization and training of children<br>More health problems | |
| Cultural values | Isolation from family and community | More interracial tension<br>More crime<br>Loss of regional isolation<br>Difficult to maintain traditional culture<br>Rapid cultural change | | Difficult to maintain traditional culture<br>Rapid cultural change<br>Loss of subsistence skills | |
| Government | Higher tax base | Higher tax base<br>Change in political control<br>Shift in public policies<br>More demands on local government | More jobs<br>More cash for capitol projects<br>Need for more government<br>More investment opportunities<br>Greater financial stability | | |
| Facilities | | More demands on housing, public health and safety, transportation, infrastructure<br>Local supply of fuel<br>Decreased fuel costs | | | |

revenues available to both government and the private sector. Changes in the availability of subsistence resources is potentially a major environmental effect of petroleum development.

Increased employment opportunities will affect several components of the subsistence economic system. The recruitment and training of local residents, paychecks and economic stability are potentially positive aspects (U.S. Geological Survey 1979). Although employment may peak during early development of petroleum fields, long term employment may result from jobs associated directly with petroleum production and indirectly from government and private-sector jobs created as a result of the stimulated economy. Many jobs may require special skills resulting in a need for area job training. Increased employment would stabilize the local economy and increase the tax base available to borough and local governments, provide economic diversity and opportunities for local investment by village and regional corporations. But increased employment would likely be accompanied by an increase in the cost of living (U.S. Geological Survey 1979).

Employment means less available time to spend on subsistence activities. Workers are likely to be the young and strong members of the community, who currently provide subsistence resources for old and very young members of the community (Worl and McMillan 1982). But the purchase of subsistence equipment with cash derived from employment can increase hunting efficiency: for example, the use of snowmachines, motor boats or airplanes will decrease the amount of time required for subsistence production by decreasing the time needed to get to hunting sites (Arctic Environmental Information and Data Center 1982).

Employment away from the village of Kaktovik may result in a disruption of family and social ties, (U.S. Geological Survey 1979), causing a change in the kinship system which is the basis for Inupiat culture (Worl and McMillan 1982). Workers leaving Kaktovik for petroleum-related jobs may suffer alienation and isolation from the community. But the relatively close proximity of Kaktovik to potential areas of development may reduce these problems as individuals may be able to commute from their home or return on a frequent basis.

The availability of cash from increased employment would intensify problems of alcohol and drug abuse as drugs would be more affordable and some individuals stressed by changing social and cultural values or feelings of isolation may increase their use. If drug and alcohol use did increase, a corresponding increase in crime, accidents, suicides, and health problems may also occur (U.S. Geological Survey 1979).

Development and production of petroleum resources in ANWR is likely to cause an increase to the population in the area. Immigration will create stress in the village of Kaktovik and put more demands on the existing infrastructures. Water, housing, public health and safety, transportation and communication facilities are all elements which may be in short supply. More demands will be made on local government, both at the village and borough level. An increasing population would cause the cost of living to increase (U.S. Geological Survey 1979).

If non-Natives make up the bulk of the population increase, the ethnic composition at the local and/or regional level will shift. Sex composition may also change as many workers coming into the area will be male. New residents may participate in local politics. The borough and village government would have to respond to a more diverse constituency. As the population increases, interethnic tensions may also increase due to competition for jobs, facilities and resources and resentments over social and cultural change (U.S. Geological Survey 1979).

Kaktovik, like much of the North Slope has lost much of its regional isolation during the past decade with the advent of frequent air service and the influx of borough capitol improvement projects. Development and production of petroleum resources in ANWR would continue this trend. Retention of cultural values is increasingly difficult as regional isolation is lost, according to U.S. Geological Survey (1979). But Worl and McMillan (1982) found that in spite of the political and economic forces impacting Kaktovik during the 1970's, the Inupiat culture and social organization showed a remarkable resiliency and tenacity. They attribute that to slower changes which occurred in earlier decades and the persistence of certain social and cultural elements: a small highly social community, functional extended families, a strong local government, and successful intermix of cash and subsistence elements.

Competition for subsistence resources will increase as the local populations increase. If pressures on species become too great, game regulations will probably have to be modified to protect animal or fish populations from over exploitation. Arctic Environmental Information and Data Center (1982) identified changes in hunting regulations as a source of impact on the subsistence economy.

Increased revenues resulting directly or indirectly from petroleum development and production will stabilize the market component of the Kaktovik economy and provide economic diversity. The borough tax base would increase, which would facilitate capital improvements and services. Small business opportunities and investment opportunities for native corporations would increase. Development of a tourist industry may occur. Attracting tourists to Kaktovik may be economically beneficial, but hunting and recreation in areas used primarily by local residents may cause interethnic tensions and may effect subsistence resources. The development of small businesses and a tourist industry may also stress the existing governmental infrastructure (U.S. Geological Survey 1979).

Local resource use may result from petroleum development on ANWR. The discovery and development of a natural gas field near Kaktovik may provide a source of relatively inexpensive fuel for house heating and generation of electricity. It costs up to $4000 per year to heat a house in Kaktovik (Worl and McMillan 1982). All fuel oil is currently imported by air or barge.

Environmental changes resulting from petroleum development on ANWR which affect the subsistence economic system of Kaktovik include those which influence the availability of subsistence resources. Changes in the distribution or numbers of wildlife or fish species may result from many aspects of development. Of particular concern are those which may affect caribou or fish (Arctic Environmental Information and Data Center 1982). Impacts to these species are discussed earlier in this chapter. Access to subsistence resources may be enhanced by the construction of roads and airfields, making subsistence harvest (production) more efficient. But increased access may increase hunting pressure by local residents and/or attract other hunters with a result of over harvest and population decline or strict game regulations designed to prevent over harvest. In either case, subsistence resource availability may then decline.

Access to subsistence resources may be denied in developed areas for security reasons. No hunting is permitted in the Prudhoe Bay complex. Loss of these areas would result in changing land use patterns and possibly a decline in subsistence production. Competition for limited resources may increase social tension. A decline in subsistence production would disrupt the cultural and social basis of the Inupiat community (Worl and McMillan 1982).

In summary, people in Kaktovik, in order to maintain the subsistence economic system with its social and cultural values intact, desire to continue subsistence activities. But subsistence requires time for pursuit and cash to purchase hunting equipment, fuel, snowmachines, and motor boats. Employment provides the necessary cash, but decreases the availability of time for subsistence activities. Increasing populations and revenues from petroleum development can bring economic diversity and stability to the community but social stress and cultural change may result.

Other Villages. Arctic Village, located 170 km south of the ANWR study area is relatively far from sites of potential development and is unlikely to be a staging area. As an Athabaskan village outside the boundaries of the North Slope Borough, it will probably not be affected by large increases in population or revenues. Some job opportunities may be available, but would require people to leave their homes and families for extended periods. But increased employment opportunities would be beneficial in Arctic Village which has a depressed capitol economy (Arctic Environmental Information and Data Center 1982). Petroleum development in ANWR will affect the subsistence economy of Arctic Village and Old Crow in the Northwest Territories, Canada, if caribou in the Porcupine herd become less available to residents in these villages. Potential impacts to caribou are described earlier in this chapter. If caribou distribution and movement patterns are altered or the caribou population declines, direct effects on the subsistence economy as well as social and cultural systems would occur in these villages, which depend on caribou as a major subsistence resource (Lonner and Beard 1982, Caufield 1983). A decrease in subsistence could affect the individuals and entire community as complex sharing patterns and social interactions would be disrupted. Diet and health, particularly of the elderly, could be adversely affected by a decreased consumption of subsistence foods, and decreased exercise. Efficiency of subsistence production may decrease if young hunters cannot acquire necessary hunting skills (Arctic Environmental Information and Data Center 1982).

Communities of the MacKenzie River delta (Inuvik, Aklavik, and Tuktoyaktak) and Amundsen Gulf (Sachs Harbour, Holman and Paulatuk) in northwest Canada are partially dependent on the use of beluga whales and polar bears. As land based development activities are not anticipated to cause major effects on marine mammal populations used by these village, effect on the subsistence economic of these communities is anticipated to be relatively minor.

Recreation

The effects of oil development on recreational activities in the study area would be similar to the effects of oil exploration but of greater magnitude in time and space. Development activities will largely destroy wilderness values and alter or destroy scenic values on a year-round basis. A change in the wilderness qualities would discourage wilderness-oriented recreation due to destruction of esthetic values. The overall effect may be to bring about a change in the type of recreationists who visit the area. Recreationists needing true wilderness to satisfy their recreational needs will be displaced to other areas where wilderness characteristics are still available. This phenomena of social succession has been noted by Hendee and Stanky (1973).

Development, even though limited to a relatively small area, would have impacts on the scenic resource as facilities associated with development would be difficult to hide on the treeless coastal plain. This visual impact would have a negative effect on scenic resources, an important wilderness component. Odors generated by machines or waste materials may decrease esthetic qualities of the area. The overall increase in activities and disturbance would remove the opportunity for experiencing solitude which are important components of a wilderness experience (Rossman and Ulehla 1977, Hendee et al. 1968). Water consumption or siltation caused by construction may adversely affect float-boating or fishing opportunities in the affected rivers. If too much water is removed from the river, recreational fishing may be negatively affected. Gravel removal could cause increased channel braiding resulting in shallower water which would inhibit river trips.

Roads and trails, especially if opened to the public, would have impact on recreational activities by providing improved access for recreationists. With increased access, recreation use may increase. If access is complete enough, for example, if the Dalton Highway is opened to the public to Prudhoe Bay and a spur road to Camden Bay or Kaktovik is also opened, the potential for overuse, at least in local areas, may exist. Facilities such as drilling pads, pipelines, pump stations, treatment stations, camps, and power plants may physically prohibit recreational activities from taking place, as these area will likely be closed to the public for safety and security reasons.

Increased aircraft flights will decrease the quality of the wilderness experience far from the development sites. Warren (1980) reported that more aircraft sightings by visitors contributed to a lower quality of experience. Airstrips or runways could have beneficial or adverse effects on recreationists. More airstrips would mean improved access for recreational uses of a given area, but a permanent or heavily used airstrip would reduce the wilderness qualities of an area. Increased access may also cause overharvesting of game which may reduce hunting success.

If an increase in recreational use is the result of oil related development, it is possible that there will be a demand for facilities on ANWR that are not now available. The construction of facilities such as visitor centers and public use cabins would further alter the wilderness characteristics which now exist in the refuge.

Wilderness and Natural Landmarks

Development of the ANWR coastal plain resulting in drill pads, pipelines, permanent camps, airstrips, and a general increase in air and ground activity would render the area ineligible for wilderness classification. The possibility exists for restoration when and if oil activity ceases; however, to return the area to its present wilderness condition would be an extremely slow process, if it can be accomplished at all. The loss of the wilderness status of the study area may effect not only people who use the area, but also may effect people who will never visit the area, but derive satisfaction merely from knowing that it is there.

Natural landmark eligibility will be negated in an area with permanent oil development. With complete clean-up and restoration, there is the possibility that these sites would again by eligible in the future.

Oil and gas development on the coastal plain would also negatively affect the wilderness quality of the adjacent wilderness area. Because of the relatively flat terrain in the area and lack of tall vegetation oil, field structures would be readily visible from long distances, and this scenic impact would extend into the adjacent wilderness area.

## Literature Cited

Abele, G., J. Brown, and M.C. Brewer. 1984. Long-term effects of off-road vehicle traffic on tundra terrain. J. Terramechanics 21:283-294.

Adam, K.M. 1981. Travel over snow. Pages 521-561 in D.M. Gray and D.H. Male, eds. Handbook of snow: principles, processes, management and uses. Permagon Press, Toronto, Canada.

Alaska Department Environmental Conservation. 1986. north slope district off-shore spills. North. Reg. Off., Fairbanks, Ak. Unpubl. comput. printout.

Albers, P.H. 1978. The effects of petroleum on different stages of incubation in bird eggs. Bull. Environ. Contam. Toxicol. 19:624-630.

Albers, P.H. 1980. Transfer of crude oil from contaminated water to bird eggs. Environ. Res. 22:307-314.

Albers, P.H., and G.H. Heinz. 1983. FLIT-MLO and No. 2 Fuel oil: effects of aerosol applications to mallard eggs on hatchability and behavior of ducklings. Environ. Res. 30:381-388.

Albers, P.H., and R.C. Szaro. 1978. Effect of No 2 fuel oil on common eider eggs. Mar. Pollut. Bull. 9:138-139.

Allen, G.M. 1942. Extinct and vanishing mammals of the western hemisphere with the marine species of all the oceans. Am. Comm. Int. Wildl. Protection, Spec. Publ. 11. 620pp.

Allison, L.M. 1971. Activity and behavior of red foxes in central Alaska. M.S. Thesis, Univ. Toronto, Ontario. 92pp.

Anderson, W.L. 1978. Waterfowl collisions with power lines at a coal-fired power plant. Wild. Soc. Bull. 6:77-83.

Andrews, C.W., and E. Lear. 1956. The biology of the Arctic char (Salvelinus alpinus L.) in northern Labrador. J. Fish. Res. Board Canada 13:843-860.

Ankney, C.D., and C.D. MacInnis. 1978. Nutrient reserve dynamics and reproductive performance of female lesser snow geese. Auk 95:459-471.

Arctic Environmental Information and Data Center. 1982. Sociocultural assessment of proposed Arctic National Wildlife Refuge Oil and Gas exploration Final Report. Univ. Alaska, Anchorage. 194pp.

B.C. Research Ltd. 1975. Marine toxicity studies on drilling fluid wastes. Rep. No. 6114. Vancouver, B.C. 28pp.

Babb, T.A., and L.C. Bliss. 1974. Effects of physical disturbance on arctic vegetation in the Queen Elizabeth Islands. Appl. Ecol. 11:549-562.

Banfield, A.W.F. 1954. Preliminary investigations of the barren-ground caribou. Can. Wild. Serv., Wild. Manage. Bull. Ser. 1, Nos. 10A and 10B.

Barrett, P., and R. Schulten. 1975. Disturbance and the successional response of the arctic plants on polar desert habitats. Arctic 28:70-73.

Barrett, R.T. 1979. Small oil spill kills 10-20,000 seabirds in North Norway. Mar. Pollut. Bull. 10:253-255.

Barry, S.J. 1976. Bird life response to oil well drilling during operations and five years later. 19pp.

Barry, T.C. 1962. Effect of late seasons on Atlantic brant reproduction. J. Wildl. Manage. 26:19-26.

Barry, T.W. 1976. The geese of the Anderson River Delta, NWT. Ph.D. Thesis Univ. Alberta, Edmonton. 212pp.

Barry, T.W., and R. Spencer. 1976. Wildlife response to oil well drilling. Can. Wildl. Serv. Prog. Notes No. 67. 15pp.

Barsdale, R.J., M.C. Miller, V. Alexander, J.R. Vestal, and J.E. Hobbie. 1980. Oil spill effects. Pages 388-406 in J.E. Hobbie, ed. Limnology of tundra ponds, Barrow, Alaska. U.S. Int. Biol. Program Synthesis Ser. 13. Dowden, Hutchinson and Ross, Stroudsburg, Pa.

Bart, J. 1977. Impact of human visitation on avian nesting success. Living Bird. 16:186-192.

Bartels, R.F., and T. Doyle. 1984. Migratory bird use of the coastal lagoon system of the Beaufort Sea coastline within the Arctic National Wildlife Refuge, Alaska. 1983. Pages 169-199 in G.W. Garner and P.E. Reynolds, eds. 1983 update report baseline study of fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. 379pp.

Bartels, R.F., T. Doyle, and T.J. Wilmers. 1984. Movement of molting oldsquaw within the Beaufort sea coastal lagoons of Arctic National Wildlife Refuge. Pages 156-168 in G.W. Garner and P.E. Reynolds, eds. 1983 update report baseline study of the fish, wildlife, and their habitat. U.S. Fish and Wildl. Serv., Anchorage, Ak. 379pp.

Beak Consultants Ltd. 1976. A study of the influence of seismic exploration on muskoxen and caribou on Banks Islands, N.W.T. Panarctic Oils Limited, Calgary, Alberta. 67pp.

Belikov, S.E. 1976. Behavioral aspects of the polar bear, Ursus maritimus. Pages 37-40 in M.R. Pelton, J.W. Lentfer, and G.E. Folk, Jr., eds. Bears their biology and management. IUCN Publ. New Ser. 40.

Bellamy, D., J. Radforth, and N.W. Radforth. 1971. Terrain, traffic and tundra. Nature 231:429-432.

Bellrose, F.C. 1980. Ducks, geese and swans of North America. Stockpile Books. Harrisburg, Pa. 540pp.

Bendock, T.N. 1976. Dewatering effects of industrial development on arctic fish stocks. Unpub. Rep. Alaska Board of Fish. Alaska Dep. Fish and Game. Fairbanks, 13pp.

Berger, T.R. 1977. Northern frontier, northern homeland; the report of the Mackenzie Valley pipeline inquiry, Vol. 1. Minist. Supply Serv., Queens Printer, Ottawa, Canada. 213pp.

Bergerud, A.T. 1974a. The role of the environment in the aggregation, movement and disturbance behavior of caribou. Pages 552-584 in V. Geist and F. Walter, eds. The behavior of ungulates and its relation to management. Vol. 1, Int. Union Conserv. Nat. Publ. 24, Morges, Switzerland

Bergerud, A.T. 1974b. Decline of caribou in North America following settlement. J. Wildl. Manage. 38:757-700.

Bergerud, A.T. 1976. Impact on the living environment. Transcripts, MacKenzie Valley Pipeline Inquiry. Vol. 106.

Bergerud, A.T. 1978. Caribou. Pages 83-101 in J.L. Schmidt and D.L. Gilbert, eds. Big game of North America. Stackpole Books, Harrisburg, Pa. 494pp.

Bergman, R.D., and D.V. Derksen. 1977. Observations on arctic and red-throated loons at Storkersen Point, Alaska. Arctic 30:41-51.

Bergman, R.D., R.L. Howard, K.F. Abraham, and M.W. Weller. 1977. Waterbirds and their wetland resources in relation to oil development at Storkersen Point, Alaska. U.S. Fish and Wildl. Serv. Resour. Publ. 129. 38pp.

Berridge, S.A., R.A. Dean, R.G. Fallows, and A. Fish. 1968. Properties of persistent oils at sea. J. Inst. Petrol. 54:300-309.

Berridge, S.A., M.T. Thew, and A.G. Lorriston-Clark. 1969. The formation and stability of emulsions of water in crude petroleum and similar stocks. J. Inst. Petrol. 54:333-357.

Biosonics, Inc. 1984. Prudhoe Bay water flood project fish monitoring program 1983, Chapter 3. in Prudhoe Bay water flood project environmental monitorying program 1983, Final Rep. U.S. Army Corps of Engineers, Alaska District. Anchorage, Alaska.

Birkhead, T.R., C. Lloyd, and P. Corkhill. 1973. Oil seabirds successfully cleaning their plumage. Brit. Birds. 66:537.

Bliss, L.C. 1970. Oil and the ecology of the arctic. Trans. R. Soc. Can. 8:361-372.

Bliss, L.C., and R.W. Wein. 1972. Plant community responses to disturbance in the western Canadian arctic. Can. J. Bot. 50:1097-1109.

Blumer, M., and J. Sass. 1972. Indigenous and petroleum derived hydrocarbons in a polluted sediment. Mar. Pollut. Bull. 3:92-94.

Bourne, W.R.P. 1968a. Oil pollution and bird populations. Pages 99-121 in J.D. Carthy and D.R. Arther, eds. The biological effects of oil pollution on littoral communities. Suppl. Vol. 2, Field Studies Council, London, England.

Bourne, W.R.P. 1968b. Observation of an encounter between birds and floating oil. Nature. 219:632.

Bourne, W.R.P. 1971. Atlantic Puffins decline. Smithsonian Inst. Center for Short-lived Phenomena Annual Rep. 83.71. Smithsonian Inst., Washington, DC.

Boussu, M.F. 1954. Relationship between trout populations and cover in a small stream. J. Wildl. Manage. 18: 229-239.

Brackney, A.W., and R.M. Platte. 1986. Habitat use and behavior of molting oldsquaw on the coast of the Arctic National Wildlife Refuge, Alaska 1985. Pages ____ - ____ in G.W. Garner and P.E. Reynolds, eds. 1985 update report baseline study of the fish and wildlife and their habitats. U.S. Fish and Wildlife Serv., Anchorage, Ak. ____pp.

Brackney, A.W., J. Morton, and J. Noll. 1985. Migratory bird use of the coastal lagoon system of the Beaufort sea coastline within the Arctic National Wildlife Refuge, Alaska, 1985. Pages 309-398 in G.W. Garner and P.E. Reynolds, eds. 1984 update report baseline study of the fish, wildlife, and their habitat. U.S. Fish and Wildl. Serv., Anchorage, Ak. 777pp.

Brackney, A.W., R.M. Platte, J.M. Morton, and D. Whiting. 1986. Ecology of lesser snow geese staging on the coastal plain of the Arctic National Wildlife Refuge, Alaska, fall 1985. Pages ____ - ____ in G.W. Garner and P.E. Reynolds, eds. 1985 update report, baseline study of the fish and wildlife and their habitats. U.S. Fish and Wildlife Service, Anchorage, Ak. __pp.

Brannon, A.C., and K.R. Rao. 1979. Barium, strontium and calcium levels in the exoskeleton, hepatopancreas and abdominal muscle of the grass shrimb Palaemonetes pugio: relation to molting and exposure to barite. Comp. Biochem. Physiol. 63A:261-274.

Brendel, J. 1985. Revegetation of arctic tundra after an oil spill: a case history. Pages 315-318 in Proceedings 1985 oil spill conference (prevention, behavior, control, cleanup). Feb. 25-28, 1985, Los Angeles, Ca.

Brink, K.L. 1978. The effects of the trans-Alaska pipeline on breeding bird and microtine rodent populations at Franklin Bluffs, Alaska. M.S. Thesis, Univ. Montana, Bozeman. 108pp.

Brooks, J.W., J.C. Bartonek, D.R. Klein, D.L. Spencer, and A.S. Thayer. 1971. Environmental influences of oil and gas development in the Arctic Slope and Beaufort Sea. Bur. of Sport Fish. and Wildl. Resour. Publ. 96. 24pp.

Brown, J., and R.L. Berg, eds. 1980. Environmental engineering and ecological baseline investigations along the Yukon River-Prudhoe Bay haul road. U.S. Army Cold Regions Research and Engineering Laboratory, Rep. 80-19. Hanover, NH

Brown, R.G.B. 1982. Birds, oil and the Canadian environment. Pages 105-112 in J.B. Sprague, J.H. Vandermeulen and P.G. Wells, eds. Oil and dispersants in Canadian seas--research appraisal and recommendations. Environmental Protection Service, Environment Canada, Ottawa.

Bryan, G.W. 1974. Adaption of an estuarine polychaete to sediments containing high concentrations of heavy metals in F.J. Vernburg and W.B. Vernberg, eds. Pollution and physiology of marine organisms. Academic Press. New York. __pp.

Buch, D.H. 1956. Effects of turbidity on fish and fishing. Trans. N. Amer. Wildl. Conf. 21:249-261.

Bureau of Land Management. 1979. Federal/state joint Beaufort Sea oil and gas lease sale BF. U.S. Dep. Interior, Bureau of Land Management and State of Alaska Dep. of Nat. Resour. Anchorage 38pp.

Bureau of Land Management. 1981. National Petroleum Reserve in Alaska, Draft Environ. Assess., Federal Oil and Gas Lease Sale. Alaska State Off., Anchorage. 148pp.

Bureau of Land Management. 1983. Final environmental impact statement on oil and gas leasing in the National Petroleum Reserve in Alaska. Alaska State Off., Anchorage. 115pp.

Burger, J. 1981. Behavioral responses of herring gulls (Larus argentatus) to aircraft noise. Environ. Pollut. Ser. A, 24:177-184.

Burgess, R.M. 1984. Investigations of patterns of vegetation, distrubution and abundance of small mammals and nesing birds, behavioral ecology of arctic foxes at Demarcation Bay, Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 191 pp.

Burns, J.J., L.H. Shapiro, and F.H. Fay. 1980. The relationships of marine mammals distributions, densities and activities to sea ice conditions. Final Rep. Outer Continental Shelf Environ. Assessment Program, RU 248/249, Contract No. 03-5-022-55. 172pp.

Bury, R.L., 1978. Snowmobile impacts on wildlife. Trans N. Am. Wildl. and Nat. Resour. Conf. 43:149-156.

Busdosh, M. 1981. Long-term effects of the water soluable fraction of Prudhoe Bay crude oil on survival, movement, and food search success of the Arctic Amphipod Boechosimus (=Onismus) affinis. Mar. Environ. Res. 5:167-180.

Butler, M., M.C. Miller, and S. Mozley. 1980. Macrobenthos. Pages 297-339 in J.E. Hobbie, ed. Limnology of tundra ponds, Barrow, Alaska. US/IBP Synthesis Ser. 13., Dowden, Hutchinson and Ross, Stroudsburg, Pa.

Butler, R.G., and P. Lukasiewicz. 1979. A field study of the effect of crude oil on Herring Gull (Larus argentatus) chick growth. Auk 96:809-812.

Calef, G.W. 1974. The predicted effect of the Canadian Arctic Gas Pipeline on the porcupine caribou herd. Pages 101-120. in Environmental impact assessment of the portion of the MacKenzie Gas Pipeline from Alaska to Alberta. Vol. IV. Res. Reps. Environ. Protect. Board. Winnipeg. 307pp.

Calef, G.W., and P.C. Lent. 1976. Impact on living environment. Transcripts, MacKenzie Valley Pipeline Inquiry. Vol. 106.

Calef, G.W., and G.M. Lortie. 1973. Observations of the porcupine caribou herd 1972. Interim. Rep. No. 3. Towards an environmental impact assessment of the portion of the MacKenzie Gas Pipeline from Alaska to Alberta. Environ. Protect. Board, Winnipeg. 127pp.

Calef, G.W., E.A. DeBock, and G.M. Lortie. 1976. The reaction of barren ground caribou to aircraft. Arctic 29:201-212.

Cameron, R.D. 1983. Issue: caribou and petroleum development in arctic Alaska. Arctic 36:227-231.

Cameron, R.D., and K.R. Whitten. 1979. Seasonal movements and sexual segregation of caribou determined by aerial survey. J. Wildl. Manage. 43:626-633.

Cameron, R.D., and K.R. Whitten. 1980. Influence of the Trans-Alaska Pipeline corridor on the local distribution of caribou. Pages 475-484 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proc. 2nd Int. Reindeer/Caribou Symp. Roros, Norway. 799pp.

Cameron, R.D., K.R. Whitten, W.T. Smith, and D.D. Roby. 1979. Caribou distribution and group composition of the Trans-Alaska Pipeline. Can. Field-Nat. 93:155-162.

Cameron, R.D., K.R. Whitten, and W.T. Smith. 1985. Occurrence of central arctic caribou herd in the Arctic National Wildlife Refuge during the spring and summer. Pages 725-728 in G.W. Garner and P.E. Reynolds, eds. 1984 Update report baseline study of fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv. Anchorage, AK. 777pp.

Campbell, J.M. 1978. Aboriginal human overkill of game populations: examples from interior north Alaska. Pages 179-208 in R.C. Dunnell and E.S. Hall Jr., eds. Archaeological essays in honor of Irving B. Rouse. Mouton publishers, New York.

Carr, R.S., W.L. McCulloch, and J.M. Neff. 1982. Bioavailability of chromium from a used chrome-lignosulfonate drilling fluids to five species of marine invertebrates. Mar. Environ. Res. 6:189-204.

Caufield, R.A. 1983. Subsistence land use in upper Yukon-Porcupine communities, Alaska. Div. of Subsistence, Alaska Dep. Fish and Game, Fairbanks. 231pp.

Cavanaugh, K.P., A.R. Goldsmith, W.N. Holmes, and B.K. Follett. 1983. Effects of ingested petroleum on the plasma proloctin levels during incubation and the breeding success of paired mallard ducks. Arch. Environ. Contam. and Toxicology. 12:334-341

Challinor, J.L., and P.L. Gersper. 1975. Vehicle perturbation effects upon a tundra soil-plant system: II. Effects on the chemical regime. Soil Sci. Soc. Amer. Proc. 39:689-695.

Chance, N.A. 1966. The eskimos of north Alaska. Holt, Rinehart and Winston, New York, N.Y. 107pp.

Chapin, F.S., and M.C. Chapin. 1980. Revegetation of an arctic disturbed site by native tundra species. J. Appl. Ecol. 17:449-456.

Chapin, F.S., and G.R. Shaver. 1981. Changes in soil properties and vegetation following disturbance of Alaskan arctic tundra. J. Appl. Ecol. 18:605-617.

Chapman, R.C. 1977. The effects of human disturbance on wolves (Canis lupus L.). M.S. Thesis, Univ. Alaska, Fairbanks. 209pp.

Chesemore, D.L. 1967. Ecology of the arctic fox in northern and western Alaska. M.S. thesis, Univ. Alaska, Fairbanks 59pp.

Chesemore, D.L. 1975. Ecology of the arctic fox (Alopex lagopex) in North America- a review. Pages 143-163 in M.W. Fox, ed. The wild canids, their systematics, behavioral ecology and evolution. Van Nostrand Reinhold Co., New York. 508pp.

Child, G.I. 1969. A study of non-fat weights in migrating Swainson's thrushes (Hylocichla ustulata). Auk 81:327-338.

Child, K.N. 1973. The reactions of barren-ground caribou (Rangifer tarandus granti) to simulated pipeline and pipeline crossings structures at Prudhoe Bay, Alaska. Completion Rep., Alaska Coop. Wildl. Res. Unit., Univ. Alaska, Fairbanks.

Chipman, W.A., and P.S. Galtsoff. 1949. Effects of oil mixed with carbonized sand on aquatic animals. Dep. of Interior, Special Sci. Rep. Fish No. 1.

Claridge, F.B., and A.M. Mirza. 1981. Erosion control along transportation routes in northern climates. Arctic 34:147-157.

Clark, R.B. 1969. Oil pollution and the conservation of seabirds. Pages 76-112 in Proc. Int. Conf. on Oil Pollution of the Sea, October 1968, Advisory Committee on Oil Pollution of the Sea, London.

Clark, R.B. 1984. Impact of oil pollution on seabirds. Environ. Pollut. (Ser. A.) 33:1-22.

Clausen, J., L. Braestrup, and O. Bery. 1974. Content of polychlorinated hedrocarbons in arctic animals. Bull. of Environ. Contamination and Toxicology. 12:529-534.

Clausen, J., and O. Bery 1975. The content of polyehlorinated hydrocarbons in arctic ecosystems. Pure and Applied Chem. 42:223-232.

Cole, A.E. 1941. The effect of pollutional waste on fish life. A Symposium on Hydrobiology. Univ. Wisconsin. Madison. 241pp.

Cole, G.F. 1971. Preservation and management of grizzly bears in Yellowstone National Park. Bioscience 21:858-864.

Connors, P.G., and R.W. Risebrough. 1977. Shorebird dependence on arctic littoral habitats. Ann. Rep. Prin. Invest. BLM/NOAA, OCSEAP. Boulder, Colorado. 121pp.

Conover, R.J. 1971. Some relations between zooplankton and bunker C oil in Chepdabucto Bay following the wreck of the tanker Arrow. J. Fish. Res. Board Can. 28:1327-1330.

Cooch, F.G. 1955. Observations on the autumn migration of blue geese. Wilson Bull. 67:171-174.

Cooch, F.G. 1958. The breeding biology and management of the blue goose (Chen caerulescens) Ph.D. Thesis, Cornell University, Ithaca, New York 235pp.

Cook, J.P. 1977. Pipeline archaeology. Unpub. Rep. Inst. Arctic Biol. Univ. Alaska, Fairbanks, Alaska.

Coon, N.C., and M.R. Dieter. 1981. Responses of adult mallard ducks to ingested south Louisiana crude oil. Environ. Res. 24:309-314.

Cordone, A.J., and D.W. Kelley. 1961. Influence of inorganic sediment on aquatic life of streams. Calif. Fish and Game. 42: 189-228.

Cornwell, G., and H.A. Hockbaum. 1971. Collisions with wires - a source of anatid mortality. Wilson Bull. 83:305-306.

Cowell, E.B. 1976. Oil pollution of the sea. Pages 353-401 in R. Johnston, ed. Marine pollution. Academic Press, London.

Craig, P.C., and P.J. McCart. 1974. Fall spawning and overwintering areas of fish populations along routes of proposed pipeline between Prudhoe Bay and Mackenzie Delta, 1972-73. Chapter III, 34pp. in P.J. McCart ed. Fisheries research associated with proposed gas pipeline routes in Alaska, Yukon and Northwest Territories. Arctic Gas. Biol. Rept. Ser. 15. 448pp.

Craig, P.C., and P.J. McCart. 1975. Fish utilization of nearshore coastal waters between the Colville and Mackenzie Rivers with an emphasis on anadromous species. Appendix, Chapter II, pages 172-219 in P.C. Craig, ed. Fisheries investigations in a coastal region of the Beaufort Sea. Arctic Gas Biol. Rept. Ser. 34. 387pp.

Craighead, J.J., and F.C. Craighead, Jr. 1971. Grizzly bear-man relationship in Yellowstone National Park. Bioscience 21:845-857.

Crawford, R.L. 1981. Weather, migration, and autumn bird kills at a north Florida TV tower. Wilson Bull. 93:189-195.

Crocker, A.D., J. Cronshaw, and W.N. Holmes. 1974. The effect of a crude oil on intestinal absorption in ducklings (Anas platyrhynchos). Environ. Pollut. 7:165-177.

Crocker, A.D., J. Cronshaw, and W.N. Holmes. 1975. The effects of several different curde oils and some petroleum distillation fractions on intestinal absorption in ducklings (Anas platyrhynchos). Environ. Physiol. Brochem. 5:91-106.

Croxall, J.P. 1977. The effects of oil on seabirds. Rapp. P. Reun. Cons. Int. Explor. Mer., 171, 191-5.

Cummings, H.G. 1975. Clumping behavior and predation with special reference to caribou. Pages 474-497 in J.R. Luick, P.C. Lent, D.R. Klein and R.G. White, eds. Biol. Pap. Univ. Alaska. Spec. Rep. No. 1. 551pp.

Curatolo, J.A. 1975. Factors influencing local movements and behavior of barren-ground caribou. M.S. Thesis, Univ. Alaska, Fairbanks. 145pp.

Curatolo, J.A. 1984. A study of caribou response to pipelines in and near the Eileen West End, 1983. Final Rep. for SOHIO Alaska Petroleum Co. Anchorage, Prepared by Alaska Biological Research, Fairbanks. 32pp.

Curatolo, J.A. 1985. Caribou response to the pipeline-road complex in the Kuparuk Oilfield, Alaska. Page 62 in A. Martell and D. Russell, eds. Proc. First N. Am. Caribou Workshop. Canad. Wildl. Serv. Spec. Publ. Ottawa. 68pp.

Curatolo, J.A., and S.M. Murphy. 1983. Caribou responses to the pipeline/road complex in the Kuparuk Oilfield, Alaska, 1982. Final Rep. for ARCO Alaska, Anchorage, Prepared by Alaska Biological Research, 81pp.

Custer, T.W., and F.A. Pitelka. 1978. Seasonal trends in summer diet of the Lapland Longspur near Barrow, Alaska. Condor 80:295-301.

Dau, J.R., and R.D. Cameron. in press. Effects of a road system on caribou distribution during calving. Proc. Fourth Int. Reindeer/Caribou Symp.

Dauphine, T.C. Jr. 1976. Biology of the Kaminuriak population of barren-ground caribou. Part 4: growth, reproduction, and energy reserves. Canad. Wildl. Serv. Rep. Ser. 38. 69pp.

Dauphine, T.C., and R.L. McClure. 1974. Synchronous mating in Canadian barren-ground caribou. J. Wildl. Manage. 38:54-66.

Davis, J.L., and P. Valkenburg. 1979. Caribou distribution, population characteristics, mortality, and responses to disturbance in northwest Alaska. Pages 13-52 in Studies of selected wildlife and fish and their use of habitats on and adjacent to National Petroleum Reserve in Alaska work group 3. 1977-1978. Field Study 3, Vol. 1 U.S. Dep. of Interiior Anchorage. 225pp.

Davis, R.A., and A.N. Wiseley. 1974. Normal behavior of snow geese on the Yukon-Alaska North Slope and the effects of aircraft-induced disturbance on this behavior, September, 1973. Chapter II, 35pp. in W.W.H. Gunn, W.J. Richardson, R.E. Schweinsburg, and T.D. Wright, eds. Studies on snow geese and waterfowl in the Northwest Territories Yukon Territory and Alaska. 1978. Arctic Gas Biol. Rep. Ser. 27, 203pp.

Dementyeff, N.E. 1958. Biology of the arctic fox in the Bolshezemelskaya tundra. Pages 166-181 in Translations of Russian game reports. Vol. 3. Can. Wildl. Serv., Ottawa. (Translation of: Dement'yev, N.I. 1955. K biologii pestsa Bol'shezemel'shoy tundry. Voprosy Biologii Pushnykh Zverey 14:123ff).

Deneke, F.J., B.H. McCown, P.I. Coyne, W. Rickard, and J. Brown. 1975. Biological aspects of terrestrial oil spills, U.S.A. CRREL Oil Research in Alaska, 1970-1974. U.S. Army Cold Regions Res. and Eng. Lab. Research Report 346 Hanover, NH. 66pp.

Densmore, R. 1982. Status of revegetation of areas disturbed by construction and mining in interior and northern Alaska. Unpub. Rep. State Pipeline Officer, Div. of Land and Water Manage., Anchorage, Alaska. 34pp.

Derksen, D.V., W.D. Eldridge, and T.C. Rothe. 1979. Waterbird and wetland habitat studies. Pages 229-311 in National Petroleum Reserve in Alaska Work Group 3, Studies of selected wildlife and fish and their use of habitats on and adjacent to the NPRA 1977-1978. Field Study 3, Vol. 2. US Dep. Interior, Anchorage. 423pp.

de Vos, A. 1960. Behavior of barren-ground caribou on their calving grounds. J. Wildl. Manage. 24:250-258.

Dick, M.H., and W. Donaldson. 1978. Fishing vessel endangered by crested auklet landings. Condor 80:235-236.

Doughtie, D.G., P.J. Conklin, and K.R. Rao. 1983. Cutcicular lesions induced in grass shrimp exposed to hexavalent chromium. J. Invert. Pathol. 42:249-258.

Douglass, R.J., J.M. Wright, S.G. Fancy, E.H. Follmann, and J.L. Hechtel. 1980. Assessment of the knowledge of potential effects of the Northwest Alaskan pipeline project on mammals: literature review and agency input. Final Rep. Prepared for Northwest Alaska Pipeline Company by LGL. Ecological Research Associates, Inc., Fairbanks. 150pp.

Duke, T., J. Willis, T. Price, and K. Fischer. 1969. Influence of environmental factors on the concentration of zinc-65 by an experimental community. Proc. Natl. Symp. Radioecol. 2(1967):355-362.

Eastin, K.E. 1984. Wilderness review for the Arctic National Wildlife Refuge coastal plain. Memorandum, U.S. Department of the Interior, Office of the Solicitor, Washington, D.C. 21pp.

Environmental Protection Agency. 1980. Ambient water quality criteria for zinc. PB81-117898. Washington, D.C.

Environmental Protection Agency. 1985a. Ambient water quality criteria for chromium - 1984. EPA 440/5-84-029. Washington, D.C.

Environmental Protection Agency. 1985b. Ambient water quality criteria for lead - 1984. Washington, D.C. PB85-227437.

Eberhardt, W.L. 1977. The biology of arctic and red foxes on the north slope. M.S. Thesis, Univ. Alaska, Fairbanks. 125pp.

Eberhardt, L.E., W.C. Hanson, J.L. Bengtson, R.A. Garrot, and E.E. Hanson. 1982. Arctic fox home range characteristics in an oil development area. J. Wildl. Manage. 46:183-190.

Eberhardt, L.E., R.A. Garrot, and W.C. Hanson. 1983. Den use by arctic foxes in northern Alaska. J. Mammal. 64:97-102.

Ebersole, J.J. 1985. Vegetation disturbance and recovery at the Oumalik oil well, Arctic Coastal Plain, Alaska. PhD. Thesis, Univ. Colorado, Boulder 408pp.

Eisler, R. 1986. Chromium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildl. Serv. Biol. Rep. 85(1.6). 60pp.

Elliott, G.V. 1982. Final report on the evaluation of stream crossings and effects of channel modifications on fishery resources along the route of the trans-Alaska pipeline. U.S. Fish and Wildl. Serv. Anchorage. 110pp.

Environmental Protection Agency. 1976. Quaility criteria for water. U.S. Environmental Protection Agency. Washington, D.C. 256pp.

Envirosphere Company. 1985. Effects of dynamite and vibrator seismic exploration on visual quality, soils, and vegetation of the Alaskan North Slope. Final Rep. Prepared for Geophysical Services, Inc., Anchorage, Ak. 82pp. + appendices.

Epsmark, Y. 1972. Behavior reactions of reindeer exposed to sonic booms. Deer. 2(7): 800-802.

Erasmus, T., R.M. Randall, and B.M. Randall. 1981. Oil pollution, insulation and body temperatures in the jackass penguin Spheniscus Demersus. Comp. Biochem. Physiol. 69A:169-171.

Esprey, Huston & Associates, Inc. 1981. Bioassay and depuration studies on two types of barite. Document No. 81123. Rep. prepared for Magcobar Group, Dresser Industries, Inc., Houston, Tex. 256pp.

European Island Fisheries Advisory Commission. 1965. Water quality criteria for European freshwater fish, report on finely divided solids and inland fisheries. European Island Fisheries Advisory Commission. Tech. Paper 1. Int. J. Air Wat. Pollut. 9:151-168.

Everett, K.R. 1979. Distribution and properties of road dust along the northern portion of the Haul Road. Pages 101-128 in J. Brown and R. Berg eds. Environmental engineering and ecological baseline investigations along the Yukon River - Prudhoe Bay Haul Road. U.S. Army Cold Regions Res. and Eng. Lab., Rep. 80-19, Hanover, N.H.

Everett, K.R. 1980. Distribution and properties of road dust along the northern portion of the Haul Road. Pages 101-128 in J. Brown and R.L. Berg, eds. Environmental engineering and ecological baseline investigations along the Yukon River-Prudhoe Bay Haul Road. U.S. Army Cold Regions Res. and Eng. Lab., Hanover, N.H. Rep. 80-19.

Everett, K.R. 1981. Inigok ice road - re-evaluation of disturbance 1981. Report to U.S. Army Cold Regions Res. and Eng. Lab., Hanover, N.H. 14pp.

Everett, K.R., B.M. Murray, D.F. Murray, A.W. Johnson, A.E. Linkins, and P.J. Webber. 1985. Reconnaissance observations of long-term natural vegetation recovery in the Cape Thompson region, Alaska, and additions to the checklist of flora. U.S. Army Cold Regions Res. and Eng. Lab., Rep. 85-11 Hanover, N.H.

Everhart, W.H., and R.M. Duchow. 1970. Effects of suspended sediment on the aquatic environment. Completion Report. U.S. Bureau of Reclamation Rep. P13 196 641. 107pp.

F.F. Slaney & Company Limited. 1973. Environmental effects assessment Voyageur air cushion vehicle, Mackenzie Delta, N.W.T. Vol II Field Studies. Rep. to Environ. Protect. Serv., Environment Canada. 46pp.

Falk, M.R. , and M. J. Lawrence. 1973. Acute toxicity of petrochemical drilling fluid components and wastes to fish. Fish. Mar. Serv. Rep. CEN-T-73-1. Environment Canada.

Fancy, S.G., and R.G. White. 1985. The incremental cost of activity. Pages 143-159 in R.J. Hudson and R.G. White, eds. Bioenergetics of wild herbivores. Boca Raton, CRC Press. 314pp.

Farrar, R.B. 1966. Lean dry weight and water balance in slate-coloured juncos. Auk. 83:616-622.

Felix, N.A, and M.T. Jorgenson. 1985. Effects of winter seismic exploration on the coastal plain of the Arctic National Wildlife Refuge, Alaska. Pages 622-699 in G.W. Garner and P.E. Reynolds, eds. 1984 update report: baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. 777pp.

Felix, N.A., M.T. Jorgenson, M.K. Raynolds, R. Lipkin, D.L. Blank, and B.K. Lance. 1986a. Effects of winter seismic trails on visual resources, vegetation, and surface stability of the coastal plain of the Arctic National Wildlife Refuge, Alaska. Pages ____ - ____ in Garner and P.E. Reynolds eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv. Anchorage Ak. ____pp.

Felix, N.A., M.T. Jorgenson, M.K. Raynolds, R. Lipkin, D.L. Blank, and B.K. Lance. 1986b. Air-photo analysis of winter seismic trails on the coastal plain of the Arctic National Wildlife Refuge, Alaska. Pages ____ - ____ in Garner and P.E. Reynolds eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv. Anchorage Ak. ____pp.

Felix, N.A., M.T. Jorgenson, M.K. Raynolds, R. Lipkin, D.L. Blank, and B.K. Lance. 1986c. Snow distribution on the arctic coastal plain and its relationship to disturbance caused by winter seismic exploration, Arctic National Wildlife Refuge, Alaska. Pages ____ - ____ in Garner and P.E. Reynolds eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildlife Service, Anchorage, Ak. ____pp.

Fimreite, N. 1979. Accumulation and effects of mercury on birds. Pages 601-627 in J.O. Nriagu, ed. The biogeochemistry of mercury in the environment. Elsevier/North-Holland Biomedical Press, New York, NY.

Finley, M.T., and R.C. Stendell. 1978. Survival and reproductive success of black ducks fed methyl mercury. Environ. Pollut. 16:51-64.

Fine, H. 1980. Ecology of arctic foxes at Prudhoe Bay, Alaska. M.S. Thesis Univ. Alaska, Fairbanks. 76pp.

Follman, E.H., and J.L. Hechtel. In press. Bears and pipeline construction in the far north. Sixth Int. Conf. Bear Res. and Manage. Bear Biol. Assoc.

Follman, E.H., R.A. Dieterich, and J.L. Hechtel. 1980. Recommended carnivore control program for the Northwest Alaska pipeline project including a review of human carnivore encounter problems and animal deterent methodology. Final rep. Inst. Arctic Biol., Univ. Alaska, for Northwest Alaska Pipeline Company, Fairbanks. 113pp.

Fraker, M.A., D.E. Sergeant, and W. Hoek. 1978. Bowhead and white whales in the southern Beaufort Sea. Beaufort Sea Project, Tech. Rep. No. 4. 114pp.

Fraker, M.A., C.R. Green, and B. Wursig. 1981. Disturbance responses of bowheads and characteristics of waterborne noise. Pages 91-195 in W.J. Richardson, ed. Behavior, disturbance responses and feeding of bowhead whales in the Beaufort Sea, 1981. Unpubl. Rep. by LGL Ecological Research Associates, Inc., Bryan, TX, for U.S. Bureau of Land Manage., Washington. 273pp.

Freedman, W., and T.C. Hutchinson. 1976. Physical and biological effects of experimental crude oil spills on low arctic tundra in the vicinity of Tuktoyaktuk, N.W.T., Canada. Can. J. Bot. 54:2219-2230.

French, H.M. 1980. Terrain, land use and waste drilling fluid disposal problems, arctic Canada. Arctic 33:794-806.

French, H.M., and M.W. Smith. 1980. Geothermal disturbance resulting from sump construction and use in permafrost terrain, arctic Canada. Pages 139-165 in Symposium/research on environmental fate and effects of drilling fluids and cuttings. Lake Buena Vista, Florida. 1122pp.

Garner, G.W., G.J. Weiler, and L.D. Martin. 1983. Ecology of brown bears inhabiting the coastal plain and adjacent foothills and mountains of the northeastern portion of the Arctic National Wildlife Refuge. Pages 275-290 in G.W. Garner and P.E. Reynolds, eds. 1982 Update report. baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildlife Serv., Anchorage, Alaska. 379pp.

Garner, G.W., H.V. Reynolds, L.D. Martin, T.J. Wilmers, and T.J. Doyle. 1984. Ecology of brown bears inhabiting the coastal plain and adjacent foothills and mountains of the northeastern portion of the Arctic National Wildlife Refuge. Pages 330-358 in G.W. Garner and P.E. Reynolds, eds. 1983 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Alaska. 614pp.

Garner, G.W., H.V. Reynolds, L.D. Martin, G.J. Weiler, J.M. Morton, and J.M. Noll. 1985. Ecology of brown bears inhabiting the coastal plain and adjacent foothills and mountains of the northeastern portion of the Arctic National Wildlife Refuge. Pages 268-296 in G.W. Garner and P.E. Reynolds, eds. 1984 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Alaska. 777pp.

Garner, G.W., H.V. Reynolds, M.K. Phillips, G.E. Muehlenhardt, and M.A. Masteller. 1986. Ecology of brown bears inhabiting the coastal plain and adjacent foothills and mountains of the northeastern portion of the Arctic National Wildlife Refuge. Pages __-__. in G.W. Garner and P.E. Reynolds, eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. ____pp.

Gartner, B.L., F.S. Chapin III, and G.R. Shaver. 1983. Demographic patterns of seedling establishment and growth of native graminoids in an Alaskan tundra disturbance. J. Appl. Ecol. 20:965-980.

Gavin, A. 1945. Notes on mammals observed in the Perry River District, Queen Maud Sea. J. Mammal. 26:226-230.

Geist, V. 1975. Harassment of large mammals and birds. Unpubl. Rep. to the Berger Comm. Univ. Calgary, Alberta. 62pp.

Geist, V. 1981. On the reproductive strategies in ungulates and some problems of adaptation. Pages 111-132 in G.G.E. Scudder and J.L. Reveal, eds. Evolution today. Proc. Second Int. Congress of Systematic and Evolutionary Biology. Hunt Institute for Botanical Documentation. Carnegie Mellon University, Pittsburgh.

Gerber, R.P., E.S. Gilfillan, J.R. Hotham, L.J. Galletto, and S.A. Hanson. 1981. Further studies on the short and long-term effect of used drilling fluids on marine organisms. Year II Unpub. Final Report to the American Petroleum Institute, Washington, D.C. 30pp.

Gibbs, P.E., W.J. Lanston, G.R. Burt, and P.L. Pascoe. 1983. Tharyx marioni (Polychaeta): a remarkable accumulator of arsenic. Mar. Biol. Ass. U.K. 63:313-325.

Gillett, W.H., J.L. Hayward Jr., and J.F. Stout. 1975. Effect of human activity on egg and chick mortality in a glaucous-winged gull colony. Condor 77:492-495.

Gilliam, J.K., and P.C. Lent. 1982. Proc. of the National Petroleum Reserve in Alaska caribou/waterbird impact analysis workshop. U.S. Dep. of Interior, Bureau of Land Management. Anchorage. 61pp.

Goede, A.A. 1985. Mercury, selenium, arsenic, and zinc in waders from the Dutch Wadden Sea. Environ. Pollut. (Ser. A) 37:287-309

Goede, A.A., and P. deVoogt. 1985. Lead and cadmium in waders from the Dutch Wadden Sea. Environ. Pollut. (Ser. A) 37:311-322

Gollop, M.A., and R.A. Davis. 1974. Gas compressor noise simulator disturbance of snow geese, Komakuk Beach, Yukon Territory, September 1972. Pages 280-304 in W.W.H. Gunn and J.A. Livingston, eds. Disturbance to birds by gas compressor noise simulation, aircraft, and human activity in the Mackenzie valley and the north slope, 1972. Arctic Gas Biol. Rep. Ser. 14. 304pp.

Gollop, M.A., J.R. Goldsberry, and R.A. Davis. 1974a. Effects of gas compressor noise simulator disturbance to terrestrial breeding birds, Babbage River, Yukon Territory, June 1972. Pages 49-96 in W.W.H. Gunn and J.A. Livingston, eds. Disturbance to birds by gas compressor noise simulation, aircraft, and human activity in the MacKenzie valley and the north slope 1972. Arctic Gas Biol. Rep. Ser. 14. 304pp.

Gollop, M.A., R.A. Davis, J.P. Prevett, and B.E. Felske. 1974b. Disturbance studies of terrestrial breeding bird populations: Firth River, Yukon Territory, June 1972. Pages 97-152 in W.W.H. Gunn and J.A. Livingston, eds. Disturbance to birds by gas compressor noise simulation, aircraft, and human activity in the MacKenzie valley and the north slope 1972. Arctic Gas Biol. Rep. Ser. 14. 304pp.

Gollop, M.A, J.E. Black, B.E. Felske, and R.A. Davis. 1974c. Disturbance studies on breeding black brant, common eider, glaucous gulls, and arctic terns at Nunaluk Spit and Phillips Bay, Yukon Territory July 1972. Pages 153-200 in W.W.H. Gunn and J.A. Livingston, eds. Disturbance to birds by gas compressor noise simulation, aircraft, and human activity in the MacKenzie valley and the north slope 1972. Arctic Gas Biol. Rep. Ser. 14. 304pp.

Gollop, M.A., T.R. Goldsberry, and R.A. Davis. 1974d. Aircraft disturbance to molting sea ducks, Herchel Island, Yukon Territory. August, 1972. Pages 202-231 in W.W.H. Gunn and J.A. Livingston, eds. Disturbance to birds by gas compressor noise simulation, aircraft, and human activity in the MacKenzie valley and the north slope, 1972. Arctic Gas Biol. Rep. Ser. 14. 304pp.

Gorsline, J., and W.N. Holmes. 1981. Effects of petroleum on adrenocortical activity in mallard ducks. Arch. Environment. Contam. Toxical. 10:765-777.

Gorsline, J., and W.N. Holmes. 1982a. Suppression of adrenocortical activity in mallard ducks exposed to petroleum-contaminated food. Arch. Environ. Contam. Toxicology. 11:497-502.

Gorsline, J., and W.N. Holmes. 1982b. Variations with age in the adrenocortical responses of mallard ducks (Anas platyrhynchos) consuming petroleum- contaminated food. Bull. Environ. Contam. Toxicology. 29:146-152.

Gorsline, J., and W.N. Holmes. 1982c. Adrenocortical function and hepatic naphthalene metabolism in mallard ducks (Anas platyrhynchos) consuming petroleum distillates. Environ. Res. 28:139-146.

Gorsline, J., W.N. Holmes, and J. Cronshaw. 1981. The effects of ingested petroleum on the napthalene metabolizing properties of liver tissue in seawater adapted mallard ducks (Anas platyrhynchos) Environ. Res. 224: 377-390.

Gotmark, F., and M. Ahlund. 1984. Do field observers attract nest predators and influence nesting success of common eiders? J. Wildl. Manage. 48:381-387.

Grace, E.S. 1976. Interactions between man and wolves at an arctic outpost on Ellesmere island. Can. Field-Nat. 90:149-156.

Grau, C.R., T. Roudybush, J. Dobbs, and J. Wathen. 1977. Altered yolk structure and reduced hatchability of eggs from birds fed single doses of petroleum oils. Science 195:779-781.

Gray, D.R. 1973. Social organization and behavior of muskoxen (obibos moschatus) on Bathurst Island, N.W.T. PhD thesis. Univ. Alberta, Edmonton. 212pp.

Gray, D.R. 1984. Dominance fighting in muskoxen of different social status. Pages 118-122. in D.R. Klein, R.G. White, and S. Keller, eds. Biol. Pap. Univ. Alaska Spec. Rep. No. 4 Fairbanks. 218pp.

Griffiths, W.B., and B. Gallaway. 1982. Prudhoe Bay Waterflood Project, fish monitoring program. Report by LGL Alaska Research for Woodward-Clyde Consultants, Anchorage, Alaska and the United States Army Corps of Engineers, Anchorage, Alaska, USA.

Griffiths, W.B., D.R. Schmidth, R.G. Fechelm, and B.J. Gallaway. 1983. Fish ecology. Pages 1-342 in Environmental summer studies (1982) of the Endicott development. Vol.III. Prepared by LGL Alaska Res. Assoc. Inc. for Sohio Alaska Petroleum Co., Anchorage, Ak.

Gundlach, E.R., and M.O. Hayes. 1978. Vulnerability of coastal environments to oil spills impacts. Marine Tech. Soc. J. 12:18-27.

Gunn, A. 1984. Aspects of the management of muskoxen in the Northwest Territories. Pages 33-40 in D.R.Klien, R.G. White, and S. Keller, eds. Biol. Pap. Univ. Alaska Spec. Rep. No. 4. Fairbanks. 218pp.

Haag, R.W. and L.C. Bliss. 1974. Energy budget changes following surface disturbance to upland tundra. J. Appl. Ecol. 11:355-374.

Hachmeister, L.E., and J.B. Vinelli. 1983. Environmental characteristics and biological use of lagoons in the coastal Beaufort Sea. Chapter 7. Pages 501-5704 in Physical oceangraphy. Final Rep. OSCEAP; NOAA, Office of Marine Pollut. Asses.

Haines, T.A., and R.L. Butler. 1969. Responses of yearling smallmouth bass to artificial shelter in a stream aquarium. J. Fish Res. Board Canada. 26: 21-31.

Hall, E.S. Jr. 1982. Preliminary archaeological and historical resource reconnaissance of the coastal plain of the Arctic National Wildlife Refuge, Alaska. Tech. Rep. No. 1. Edwin Hall and Associates, Brockport, New York. 162pp.

Hampton, P.D., and M.R. Joyce. 1985. Birds. in Lisburne development environmental studies: 1984 Rep. prepared by Woodward-Clyde Consultants, to Arco Alaska, Inc. Anchorage, Ak.

Hand, J.L. 1980. Human disturbance in western gull *Larus occidentalis* livens colonies and possible amplification by intraspecific predation. Biol. Cons. 18:59-63.

Hanley, P.T., J.E. Hemming, J.W. Morsell, T.A. Morehouse, L.E. Leask, and G.S. Harrison. 1980. Natural resource protection and petroleum development in Alaska. Office Biol. Serv., U.S. Fish and Wildl. Serv. 318pp.

Harrison, C. 1978. A field guide to the nests, eggs, and nestlings of North American birds. Collins, Cleveland. 416pp.

Hartung, R. 1965. Some effects of oiling on reproduction of ducks. J. Wildl. Manage. 29:872-874.

Hartung, R. 1967. Energy metabalism in oil-covered ducks. J. Wildl. Manage. 31:798-804.

Hartung, R., and G.S. Hunt. 1966. Toxicity of some oils to waterfowl. J. Wildl. Manage. 30:564-570.

Harvey, S., P.J. Sharp, and J.G. Phillips. 1982. Influence of ingested petroleum on the reproductive performance and pituitary-gonadal axis of domestic ducks (Anas platyrhynchos). Comp. Biochem. Physiol. 72C:83-89.

Haugen, H.S. 1985. Prey utilization by wolves in two drainages within the Arctic National Wildlife Refuge, and a preliminary description of wolf pack behavior around the den in the Kongakut River drainage. Pages 145-172 in G.W. Garner and P.E. Reynolds, eds. 1984 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak 777pp.

Haukioja, E., and R. Salovaara. 1978. Summer weight of reindeer (Rangifer tarandus) calves and its importance for their future survival. Rep. Kevo Subarctic Res. Stat. 14:1-4.

Heinz, G.H. 1976. Methylmercury: second-year feeding effects on mallard reproduction and duckling behavior. J. Wildl. Manage. 40:82-90.

Heinz, G.H. 1979. Methylmercury: reproductive and behavioral effects on three generations of mallard ducks. J. Wildl. Manage. 43:394-401.

Helle, T., and J. Aspi. 1983. Does herd formation reduce insect harassment among reindeer? A field experiment with animal traps. Acta Zool. Fenn. 175:129-132.

Helle, T., and L. Tarvanien. 1984. Effects of insect harassment on weight gain and survival in reindeer calves. Rangifer. 4(1):24-27

Hendee, J.C., and G.H. Stanky. 1973. Biocentricity in wilderness management. Bioscience. 23(9). 4pp.

Hendee, J.C., W.R. Catton, L.D. Marlow, and C.F. Brockman. 1968. Wilderness users in the Pacific Northwest - their characteristics, values and management preferences. Oreg. Res. Pap. PNW-61. 92pp.

Hernandez, H. 1972. Surficial disturbance and natural plant recolonization in the Tuktoyaktuk Peninsula Region, N.W.T., M.S. Thesis, Univ. Alberta, Edmonton. 99pp.

Hernandez, H. 1973a. Natural plant recolonization of surficial disturbances, Tuktoyaktuk Peninsula region, Northwest Territories. Can. J. Bot. 51: 2177-2196.

Hernandez, H. 1973b. Revegetation studies - Norman Wells, Inuvik, and Tuktoyaktuk, N.W.T. and Prudhoe Bay, Alaska. Pages 77-149 in L.C. Bliss, ed. Botanical studies of natural and man-modified habitats in the MacKenzie Valley, Eastern MacKenzie Delta Region, and the Arctic Islands. Report no. 73-43. Arctic Land Use Res. Program, Dept. of Indian Affairs and North. Dev., Canada.

Hinman, R. 1974. The impact of oil development on wildlife populations in Northern Alaska. Proc. Western Assoc. State Game and Fish Comm. 54: 156-164.

Hobbs, D.R. 1947. Trout fisheries in New Zealand, their development and management. Fish Bull. New Zealand. 9: 159pp.

Hoffman, D.J. 1979a. Embryotoxic and teratogenic effects of petroleum hydrocarbons in mallards. J. Toxical. Environ. Health. 5:835-844.

Hoffman, D.J. 1979b. Embryotoxic and teratogenic effects of crude oil on mallard embryos on day one of development. Bull. Environment. Contam. Toxicol. 22:632-637.

Hoffman, W.A. 1974. Observations on the influence of seismic activity on wintering caribou in the Fish River area. Northwest Territories Game Manage. Rept. Aklavik, Northwest Territories 4pp.

Hollis, E.H. 1964. A literature review of the effects of turbidity and siltation in aquatic life. Staff Rep. Dep. of Chesapeake Bay Affairs, Annapolis, Maryland. 20pp.

Holmes, R.T. 1966. Feeding ecology of the red-backed Sandpiper (Calidris alpina) in arctic Alaska. Ecology 47:32-45.

Holmes, R.T., and F.A. Pitelka. 1968. Food overlap among coexisting sandpipers on northern Alaskan tundra. Syst. Zool. 17:305-318

Holmes, W.N., and J. Cronshaw, 1977. Biological effects of petroleum on marine birds. Pages 359-398 in D.C. Malins, ed. Effects of petroleum on arctic and subarctic marine environments and organisms, Vol. II. Academic Press, New York.

Holmes, W.N., J. Cronshaw, and J. Gorsline. 1978. Some effects of ingested petroleum on seawater-adapted ducks (Anas platyrhynchos). Environ. Res. 17:177-190.

Holmes, W.N., J. Gorsline, and J. Cronshaw. 1979. Effects of mild cold stress on the survival of seawater-adapted mallard ducks (Anas platyrhynchos) maintained on food contaminated with petroleum. Environ. Res. 20:425-444.

Hone, E. 1934. The present status of the muskox. Am. Comm. Int. Wildl. Protection Spec. Publ. No. 5. 87pp.

Hope-Jones, P., J.Y. Monnat, C.J. Cadbury, and T.J. Stowe. 1978. Birds oiled during the AMOCO CADIZ incident-an interim report. Mar. Pollut. Bull. 9:307-310.

Hopkins, D.M., ed. 1978. Effects of gravel mining and construction of gravel islands and causeways. Pages 321-334 in Outer continental shelf environmental assessment program. Interim Synthesis Report, Beaufort/Chukchi. Boulder, Colorado.

Horeijsi, B. 1981. Behavioral response of barren ground caribou to a moving vehicle. Arctic 34:180-185.

Hornocker, M.G., and H.S. Hash. 1981. Ecology of the wolverine in northwestern Montana. Can. J. Zool. 59:1286-1301

How, G.T., and H. Hernandez. 1975. Terrain and vegetation response to disturbance in the Yukon Coastal Plain and Mackenzie Delta region and relevance to the proposed gas pipeline. Environ. Protect. Board. Canada. 62pp.

Hunt, G.L. 1984. Offshore oil development and seabirds: the present status of knowledge and long-term research needs. Unpubl. Rep., Dep. Ecol. and Environ. Biol. Irvine, Ca. 91pp.

Hunt, R.L. 1968. Effects of habitat alteration on production, standing crop and yield of brook trout in Lawerence Creek, Wisconsin. Wis. Dep. Nat. Res., Waupaca, 32pp.

Hurst, R.J., N.A. Oritsland, and P.D. Watts. 1982. Metabolic and temperature responses of polar bears to crude oil. Pages 263-280 in P.J. Rand, ed. Land and water issues related to energy development. Ann Arbor Science Publishers, Ann Arbor MI 469pp.

Hurdey, S.E., and P. Eng. 1979. Source and characteristics of liquid process wastes from arctic offshore hydrocarbon exploration. Arctic 32:3-21.

Jacobson, M.J., and C. Wentworth. 1982. Kaktovik subsistence - land use values through time in the Arctic National Wildlife Refuge area. U.S. Fish and Wildl. Serv., Northern Alaska Ecological Services, Fairbanks, Ak 147pp.

Jakimchuk, R.D. 1980. Disturbance to barren-ground caribou: a review of the effects and implications of human developments and activities. in A.W. Banfield and R.D. Jakimchuk, eds. Analyses of the characteristics and behavior of barren-ground caribou in Canada. Rep. prepared by Rangifer Associates Environmental Consultants and R.D. Jakimchuk Mange. Associates for Polar Gas Project. 281pp + appendix.

Jenssen, B.M., M. Ekker, and C. Bech. 1985. Thermoregulation in a naturally oil-contaminated black-billed murre Uria aalge. Bull. Environ. Contam. Toxicol. 35:9-14.

Jewett, S.C., H.M. Feder, and W.B. Griffiths. 1983. Chapter 4: The invertebrates. Pages 223-287 in Environmental characterization and biological use of lagoons in the eastern Beaufort Sea. Final rep. prepared by LGL. Ecol. Res. Assoc. Inc., Bryan TX for outer coastal shelf environmental assessment program NOAA. 434pp.

Jingfors, K.T. 1980. Habitat relationships and activity patterns of a reintroduced muskoxen population. M.S. Thesis, Univ. Alaska, Fairbanks. 166pp.

Jingfors, K.T. 1982. Seasonal activity budgets and movements of a reintroduced Alaskan muskox herd. J. Wildlife Manage. 46:344-350.

Jingfors, K.T. 1984. Home range affinity on a recently established muskox herd in Arctic Alaska. Pages 89-92 in D.R. Klein, R.G. White, and S. Keller, eds., Biol. Pap. Univ. of Alaska Spec. Rep. No. 4. Fairbanks, Ak. 218pp.

Jingfors, K.T., and P. Lassen. 1984. Muskox responses to a seismic test operation:preliminary observations. Page 127 in D.R. Klein, R.G. White and S. Keller, eds. Biol. Pap. Univ. Alaska Spec. Rep. No. 4., Fairbanks, Ak. 218pp. (Abstract).

Johnson, D.R., and M.C. Todd. 1977. Summer use of a highway crossing by mountain caribou. Can. Field-Nat. 91:312-314.

Johnson, L., and K. VanCleve. 1976. Revegetation in arctic and subarctic North America: a literature review. U.S. Army Cold Regions Res. and Eng. Lab., Rep. 76-15, Hanover, N.H. 32pp.

Johnson, L.A. 1981. Revegetation and selected terrain disturbance along the Trans-Alaska Pipeline, 1975-1978. U.S. Army Cold Regions Res. and Eng. Lab., Rep. 81-12. Hanover, N.H. 115pp.

Johnson, L.A., E.B. Sparrow, T.F. Jenkins, C.M. Collins, C.V. Davenport, and T.T. McFadden. 1980. The fate and effects of crude oil spilled on subarctic permafrost terrain in interior Alaska. U.S. Army Cold Regions Res. and Eng. Lab., Rep. 80-29. Hanover, N.H. 67pp.

Johnson, L.A., S.D. Rindge, and D.A. Gaskin. 1981. Chena River Lakes Project revegetation study--three year summary. U.S. Army Cold Regions Res. and Eng. Lab., Rep. 81-18. Hanover, NH. 59pp.

Johnson, P.R., and C.M. Collins. 1980. Snow pads used for pipeline construction in Alaska, 1976. U.S. Army Cold Regions Res. and Eng. Lab., Rep. 80-17. Hanover, N.H. 28pp.

Jonkel, C.J. 1970. The behavior of captired North American bears (with comments on bear management and research). Bioscience 20:1145-1147.

Jones, P.H. 1980. The effect on birds of a North Sea gas flare. Brit. Birds 73:547-555.

Jordan, R.E., and J.R. Payne. 1980. Fate and weathering of petroleum spills in the marine environment. Ann Arbor Science Pub., Ann Arbor, Mi.

Jorgenson, M.T. 1986. Biophysical factors influencing the geographic variability of soil heat flux near Toolik Lake, Alaska; implications for terrain sensitivity. M.S. Thesis. Univ. Alaska, Fairbanks. 109pp.

Kavanagh, N., and A. Townsend. 1977. Construction-related oil spills along Trans-Alaska Pipeline, Special Report No. 15. Joint State/Fed. Fish and Wildl. Advisory Team. Alaska Dept. Fish and Game, U.S. Dept. of Interior. 16pp.

Kay, S.H. 1985. Biomagnification of contaminants within aquatic food webs not dramatic. U.S. Army Corps of Engineers Information Exchange Bull. Environ. Effects of Dredging D 85-1:1-7. Waterways Exp. Station, Vicksburg, MS.

Kelsall, J.P. 1968. The migratory barren-ground caribou of Canada. Can. Wildl. Serv., Monograph No. 3, Queen's Printer, Ottawa. 364pp.

Kerfoot, D.E. 1972. Tundra disturbance studies in the western Canadian Arctic. Arctic Land Use Research Program, Dep. of Indian Affairs and Northern Development, Ottawa. 115pp.

Kevan, P.G. 1970. The caribou of the northern Yukon Territory: A history of man's interest in them with special interest to wildlife biology. Canad. Wildl. Serv. Rep. 47pp.

King, J.C., and G.A. Sanger. 1979. Oil vulnerability index for marine oriented birds. Pages 227-240 in J.C. Bartonek and D.N. Nettleship, eds. Conservation of marine birds of northern North America. U.S. Fish and Wildlife Service, Washington, DC.

King, J.R. 1963. Autumnal migratory-fat deposition in the white-crowned sparrow. Proc. Int. Ornithol. Congr. 13:940-949.

Klein, D.R. 1970. Tundra ranges north of the boreal forest. J. Range. Manage. 23:08-14.

Klein, D.R. 1971. The reaction of some northern mammals to aircraft disturbance. Proc. International Cong. Game Biologists. Stockholm, Sweden. 11:377-383.

Klein, D.R. 1972. Problems in conservation of mammals in the north. Biol. Conserv. 4:97-101.

Klein, D.R. 1973. The impact of oil development in the northern environment. Proc. Interpetrol Congress. 3:109-121.

Klein, D.R. 1979. The Alaska oil pipeline in restrospect. Trans of North Am. Wildl. and Nat. Resour. Conf. 44:235-246.

Klein, D.R. 1980. Reaction of caribou and reindeer to obstructions - a reassessment. Pages 519-527 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proc. 2nd Int. Reindeer/Caribou Symp., Roros, Norway. 799pp.

Klein, D.R., and J.E. Hemming. 1976. Resource development and related environmental problems in arctic Alaska - impact on fish and wildlife. Pages 15-22 in Symposium: Geography of polar countries, Leningrad. Spec. Rep. 77-6. Cold Regions Res. and Eng. Lab., Hanover, N.H.

Klinger, L.F., D.A. Walker, M.D. Walker, and P.J. Webber. 1983. The effects of a gravel road on adjacent tundra vegetation. Chapter 6. Pages 1-162 in Prudhoe Bay waterflood project environmental monitoring program. Final report prepared for the Alaska District, Corps of Engineers, Anchorage, Ak.

Knapman, L. 1982. Fire reclamation on two fire sites in interior Alaska. Resour. Manage. Note 1. U.S. Bureau of Land Management, Fairbanks, Ak. 23pp.

Kopischke, E.D. 1972. The effect of 2, 4, D and diesel fuel on egg hatchability. J. Wildl. Manage. 36:1353-1354.

Korschgen, C.E. 1977. Breeding stress in female eiders in Maine. J. Wildl. Manage. 41:360-373.

Krott, P. 1960. Ways of the wolverine. Natural History Vol. LXIX., No.2. p. 16-29.

Kubanis, S.A. 1982. Revegetation techniques in Arctic and Subarctic environments. Office of the Federal Inspector, Alaska Natural Gas Transportation Systems, Anchorage, Ak. 40pp.

Kubanis, S.A. 1985. Natural and induced revegetation along the Yukon River-Prudhoe Bay Haul Road, 1977-1981. Paper presented at the International Society of Petroleum Industry Biologists Conference on Northern Hydrocarbon Development Environmental Problem Solving, Sept. 24-26, 1985, Banff, Alberta, Canada.

Kucera, E. 1974. Potential effects of the Canadian Arctic Gas pipeline project on the mammals of western Arctic. Pages 69-100 in Research reports, Volume IV environmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta. Environ. Protect. Board, Winnipeg, Manitoba. 307pp.

Kuropat, P., and J.P. Bryant. 1980. Foraging behavior of cow caribou on the Utukok calving grounds in northwestern Alaska. Pages 64-70 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proc. 2nd Int. Reindeer/Caribou Symp., Roros Norway. 799pp.

LGL Limited. 1972. Effects of gas compressor noise simulator disturbance to terrestrial breeding brids, Babbage River, Yukon Territory. Rept. to Northern Engineering Services, Ltd. 45pp.

LGL Limited. 1981. Alaskan Beaufort Sea coastal sensitivity analysis, phase one. Report for Alaska Beaufort Sea Oilspill Response Body. Anchorage, Alaska. 661pp.

LaPerriere, J.D. , D. M. Bjerklie, R.C. Simmons, E. Van Nieuwenhuyse, S.M. Wagener, and J.B. Reynolds. 1983. Effects of gold placer mining on interior Alaskan stream ecosystems. in Proc. of First Annual Meet. of Alaska Chap. Am. Wat. Res. Assoc., Nov. Fairbanks. 34pp.

Lambert, G., D.B. Peakall, B.J.R. Philogene, and F.R. Engelhardt. 1982. Effect of oil and oil dispersant mixtures on the basal metabolic rate of ducks. Bull. Environ. Contam. Toxicol. 29:520-524.

Lambert, J.D.H. 1972. Botanical changes resulting from seismic and drilling operation, Mackenzie Delta area. Arctic Land Use Research Program, Dep. of Indian Affairs and Northern Development, Ottawa. 55pp.

Land, B. 1974. The toxicity of drilling fluid components to aquatic biological systems, a literature review. Environment Canada. Fish. Mar. Serv. Res. Dev. Tech. Rep. 487. 33pp.

Larrison, E.L. 1977. Increases in a population of nesting glaucous winged gulls disturbed by humans. Murrelet 58:18-20.

Lawson, D.E., J. Brown, K.R. Everett, A.W. Johnson, V. Komarkova, B.M. Murray, D.F. Murray, and P.J. Webber. 1978. Tundra disturbances and recovery following the 1949 exploratory drilling, Fish Creek, northern Alaska. Report 78-28U.S. Army Cold Regions Res. and Eng. Lab., Hanover, N.H. 81pp.

Leighton, F.A., D.B. Peakall, and R.G. Butler. 1983. Heinz-body hemolytic anemia from the ingestion of crude oil: a primary toxic effect in marine birds. Science 220:871-872.

Lent, P.C. 1964. Calving and related social behavior in the barren-ground caribou. Ph.D. Thesis, Univ. Alberta, Edmonton. 220pp.

Lent, P.C. 1974. Mother - infant relationships in ungulates. Pages 14-55 in V. Geist and F. Walter, eds. The behavior of ungulates and its relation to management. Vol. 1. Int. Union Conserv. Nat. Publ. 24, Morges, Switzerland. 941pp.

Lent, P.C. 1980. Synoptic snowmelt patterns in arctic Alaska in relation to caribou habitat use. Pages 71-77 in E. Reimers, E. Gaare and S. Skjenneberg, eds. Proc. 2nd Int. Reindeer/Caribou Symp., Roros, Norway. 799pp.

Lentfer, J.W. 1974. Polar bear reproduction biology and denning. Alaska Dept. Fish and Game. Final Rep. Fed. Aid in Wildl. Rest. Projects W-17-3 and W-17-4, Job VG-5.4. 32pp.

Lentfer, J.W., and R.J. Hensel. 1980. Alaskan polar bear denning. Pages 101-109 in C.J. Martinka, and K.L. McArthur, eds. Bears - their biology and management. U.S. Government Printing Office. Washington, D.C.

Libbey, D. 1982. Kaktovik area cultural resource survey. Unpub. Rep. for North Slope Borough and State Office of History and Archaeology, Anchorage. 124pp.

Liss, R.G., F. Knox, D. Wayne, and T.R. Gilbert. 1980. Availability of trace elements in drilling fluids to the marine environment. Pages 691-722 in Proc. Symp. Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Washington, D.C.: Courtesy Associates.

Lonner, T.D., and S.W. Beard. 1982. Part II Arctic Village. Pages 94-179 in Sociocultural assessment of proposed Arctic National Wildlife Refuge oil and gas exploration final report. Arctic Environmental Information and Data Center. Anchorage. 194pp.

MacInnes, C.D., and R.J. Misra. 1972. Predation on Canada goose nests at McConnell River, Northwest Territories. J. Wildl. Manage. 36:414-422.

Mackay, D., T.W. Ng, W.Y. Shiu, and B. Reuber. 1980. The degradation of crude oil in northern soils. Environmental Studies No. 18, Northern Affairs Program, Canada. 39pp.

Macko, S.A., and S.M. King. 1980. Weathered oil effect on hatchability of heron and gull eggs. Bull. Environm. Contam. Toxicol. 25:316-320.

Magoun, A.J. 1985. Ecology of the wolverine in northwest Alaska. Ph.D. Thesis, Univ. Alaska, Fairbanks. 197pp.

Malcolm, J.M. 1982. Bird collisions with a power transmission line and their relation to botulism at a Montana wetland. Wildl. Soc. Bull. 10:297-304.

Marler, P., and W.J. Hamilton. 1967. Mechanisms of animal behavior. John Wiley and Sons, Inc. New York. 771pp.

Marsh, J.S. 1972. Bears and man in Glacier National Park, British Columbia, 1880-1980 Pages 289-296 in S. Herrero, ed. Bears-their biology and management. IUCN Publ. New Ser. No. 23. 371pp.

Martin, P.D., and C.S. Moitoret. 1981. Bird populations and habitat use, Canning River Delta, Alaska. Report in files of U.S. Fish and Wildlife Service, Fairbanks, Alaska. pp.

Mauer, F.J. 1985a. Distribution and relative abundance of golden eagles in relation to the Porcupine caribou herd during calving and post-calving periods, 1984. Pages 114-144 in G.W. Garner and P.E. Reynolds, eds. 1984 update report baseline study of fish, wildlife, and their habitats. U.S. Fish and Wildlife Serv., Anchorage, Ak. 777pp.

Mauer, F.J. 1985b. Distribution and abundance of wolverines in the northern portion of the Arctic National Wildlife Refuge, Pages 501-514 in G.W. Garner and P.E. Reynolds, eds. 1984 update report baseline study of fish, wildlife, and their habitats, U.S. Fish and Wildlife Serv., Anchorage, Ak. 777pp.

Mauer, R.J. 1986. Distribution and relative abundance of golden eagles in relation to the Porcupine caribou herd during calving and post-calving periods, 1985. Pages ____ - ____ in G.W. Garner and P.E. Reynolds, eds. 1985 update report baseline study of the fish, wildlife and their habitats. U.S. Fish and Wildlife Serv., Anchorage, Ak. ____pp.

McCourt, K.H., J.D. Feist, D. Doll, and J.J. Russell. 1974. Disturbance studies of caribou and other mammals in the Yukon and Alaska, 1972. Arctic Gas Biol. Rep. Ser. 5. 246pp.

McCulloch, W.L., J.M. Neff, and R.S. Carr. 1980. Bioavailability of heavy metals from used offshore drilling fluids to the clam Rangia cuneata and the oyster Crassostrea gigas. Pages 984-996 in Proceedings symposium research on environmental fate and effects of drilling fluids and cuttings. Washington, D.C.: Courtesy Associates.

McEwan, E.H., and A.F.C. Koelink. 1973. The heat production of oiled mallards and scaup. Can. J. Zool. 51:27-31.

McEwan, E.H., and P.M. Whitehead. 1978. Influence of weathered crude oil on liver enzyme metabolism of testosterone in gulls. Can. J. Zool. 56:1922-1924.

McFadden, T., T. Jenkins, C. Collins, L. Johnson, B. McCown, and E. Sparrow. 1977. Fate and effects of crude oil spilled on permafrost terrain. Special Report 77-44. U.S. Army Cold Regions Res. and Eng. Lab., Hanover, N.H. 28pp.

McGill, P.A., and M.E. Richmond. 1979. Hatching success of great black-backed gull eggs treated with oil. Bird Banding 50:108-113.

McGrogan, J.F., A.C. Condo, and J. Neubauer. 1971. Tundra restoration: two-year response study of generic related grass types introduced onto disturbed Prudhoe Bay area tundra. Pres. Southwest Alaska Sec. Reg. Meeting of the Soc. of Petrol. Eng., Anchorage, Alaska, May 5-7, 1971. 5pp.

McKee, J.E., and H.W. Wolf. 1963. Water quality criteria. The Resources Agency of California State Water Resour. Control Board. Pub. No. 3-A, 2nd ed. 548pp.

McKendrick, J.D., and W.W. Mitchell. 1978a. Effects of burning crude oil spilled onto six habitat types in Alaska. Arctic 31:277-295.

McKendrick, J.D., and W.W. Mitchell. 1978b. Fertilizing and seeding oil-damaged arctic tundra to effect vegetation recovery Prudhoe Bay, Alaska. Arctic 31:296-304.

McNeil, R., J.R. Rodriguez, and H. Ouellet. 1985. Bird mortality at a power transmission line in northeastern Venezuela. Biol. Cons. 31:153-165.

McWhorter, M., R.M. Oates, D.C. Douglas, C. Babcock, R. Field, S. Gehman, T. Maxwell, and J.M. Morton. 1986b. Species accounts of birds at eight study areas on the coastal plain of the Arctic National Wildlife Refuge, Alaska, 1985. Pages ____ - ____ in G.W. Garner and P.E. Reynolds, eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, AK. ____pp.

Meehan, R. 1985. Guidance manual for evaluating and mitigating oil development impacts on coastal tundra wetlands of the Alaskan north slope. Draft rept. to U.S. Environmental Protection Agency, Cold Climate Environmental Research Program. U.S. Fish and Wildl. Serv., Anchorage, Alaska.

Metz, M.C., T.G. Krzewinski, and E.S. Clarke. 1982. The Trans-Alaska Pipeline System workpad - an evaluation of present conditions. Pages 523-534 in Proc. Fourth Int. Permafrost Conference, Canada.

Milke, G. 1977. Animal feeding: problems and solutions. Joint State/Federal Fish and Wildl. Advisory Team Spec. Rep. No. 14. 11pp.

Miller, D.S., D.B. Peakall, and W.B. Kinter. 1978. Ingestion of crude oil: sublethal effects in Herring Gull chicks. Science 199:315-317.

Miller, F.L. 1974. Biology of the Kaminuriak population of barren-ground caribou. Part 2: Dentition as an indicator of age and sex; composition and socialization of the population. Can. Wildl. Serv. Rep. Ser. No. 31 Queen's Printer, Ottawa 88pp.

Miller, F.L. 1982. Caribou. Pages 923-954 in G. Chapman, and G. Feldhamer, eds. Wild mammals of No. Am. John Hopkins Univ. Press, Baltimore. 1147pp.

Miller F.L., and A. Gunn. 1979. Responses of Peary caribou and muskoxen to turbo-helicopter harrassment, Prince of Wales Island, N.W.T. 1976-1977. Can. Wildl. Serv. Occ. Pap. No. 40. 90pp.

Miller, F. L., and A. Gunn. 1980. Behavioral responses of muskox herds to simulation of cargo slinging by helicopter, N.W.T. Can. Field-Nat. 94(1):52-60.

Miller, F.L., and A. Gunnn. 1984. Muskox defense formations in response to helicopters in the Canadian high arctic. Pages 123-126 in D.R. Klein, R.G. White, and S. Keller, eds. Proc. 1st Int. Muskox Symp. Biol. Pap. Univ. Alaska. Spec. Rep. No. 4. Fairbanks, Ak. 218pp.

Milne, A.R., and R.H. Herlinveaux. 1973. Crude oil in cold water. in R.J. Childerhose, ed. Minister of Supply and Services. Canada, Ottawa. 118pp.

Mitchell, W.W. 1970. Revegetation problems and progress. Agroborealis 2:18-22.

Mitchell, W.W. 1981. Alaskan-developed grass varieties coming into use. Agroborealis 13:56-58.

Mitchell, W.W., and T.E. Loynachan. 1977. 1976 Progress report to Alaskan Arctic Gas Study Company on revegetation research at Prudhoe Bay, Kavik, and Palmer, Alaska. Univ. Ak. Agr. Exp. Sta., Palmer, Ak. 38pp.

Moiteret, C.S., P.A. Miller, R.M. Oates, and M.A. Masteller. 1985. Terrestrial bird populations and habitat use on coastal plain tundra of the Arctic National Wildlife Refuge, Alaska. Pages 362-446 in G.W. Garner and P.E. Reynolds, eds. 1984 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, AK. 777pp.

Moles, A., S.D. Rice, and S. Korn. 1979. Sensitivity of Alaskan freshwater and anadromous fishes to Prudhoe Bay crude oil and benzene. Trans. Amer. Fish. Soc. 108:408-414.

Monnat, J.Y. 1969. Status actual des oiseaux marins nicheurs en Bretagne. Ar. Von. 2:1-24.

Moore, G.D., and R. Quimby. 1975. Environmental considerations for the Polar Bear (Ursus maritimus, Phipps) of the Beaufort Sea. in R.D. Jakimchuk, ed. Studies of large mammals along the proposed Mackenzie Valley gas pipeline route from Alaska to British Columbia. Arctic Gas Biol. Rep. Ser., Vol. 32.

Moore, J.W., and S. Ramamorthy. 1984. Heavy Metals in Natural Waters: Applied Monitoring and Impact Assessment. Springer-Verlag, NY.

Morehouse, T.A., R.A. Childers, and L.E. Leask. 1978. Fish and wildlife protection in the planning and construction of the trans-Alaska oil pipeline. Off. Biol. Serv. Rep. 78/70. U.S. Fish and Wildl. Serv., Anchorage. 131pp.

Mundy, K.R.D., and D.R. Flook. 1973. Background for managing grizzly bear in the national parks of Canada. Can. Wildl. Serv. Rep. Ser. 22:35pp.

Munoz, R.U., C.S. Hacker, and T.F. Gessell. 1976. Environmentally acquired lead in the laughing gull. J. Wildl. Dis. 12:139-142.

Murphy, S.M. 1984. Caribou use of ramps for crossing pipe/road complexes, Kuparuk oil field, Alaska, 1984. Final Rep. to ARCO Alaska by Alaska Biological Research, Fairbanks. 61pp.

Myers, K.C., and M.H. Barker. 1984. Examination of drilling reserve pit fluids and effects of tundra disposal at Prudhoe Bay, Alaska, 1982-1983. ARCO Alaska, Inc.

Myhre, R. 1967. The wolverine. Fauna. 20-2:51-63.

National Research Council. (Subcommittee on Zinc). 1979. University Park Press, Baltimore, MD.

National Petroleum Reserve in Alaska Task Force. 1978. Ecological Profile Study Report 4. U.S. Department of the Interior, Anchorage, Alaska. 118pp.

National Research Council. 1983. Drilling discharges in the marine environment. Panel on assessment of fates and effects of drilling fluids and cuttings in the marine environment. Marine Board Comm. of Eng. and Tech. Sys. National Academy Press, Washington D.C. 180pp.

Native Plants, Inc. 1981. Phase II: Revegetation studies in disturbed habitats adjacent to the proposed Alaska Natural Gas Transportaiton System. Final report to Northwest Alaskan Pipeline Company and Fluor, Inc. by Native Plants, Inc., Utah. 94pp.

Nelson, F., and S.F. Outcalt. 1982. Anthropogenic geomorphology in northern Alaska. Phys. Geogr. 3(1):17-48.

Niethammer, K.R., R.D. Atkinson, T.S. Baskett, and F.B. Samson. 1985. Metals in riparian wildlife of the lead mining district of southeastern Missouri. Arch. Environ. Contam. Toxicol. 14:213-223.

Nisbet, I.C.T., W. II. Drury, and J. Baird. 1963. Weight loss during migration. Part I deposition and consumption of fat by the blackpoll warbler (Dendroica stirata). Bird Banding. 34:107-138.

Norheim, G. 1978. The composition and distribution of PCB in arctic fox (Alopex lagopus) caught near long year byen on Svalbard. Acta Pharmacologica et Tocological 42:7-13

Northern Technical Services. 1981. Beaufort Sea drilling effluent study. Prepared for the Reindeer Island stratigraphic test well participants under the direction of SOHIO Alaska Petroleum Company, Anchorage, Ak. 329pp.

Northern Technical Services. 1982. Above ice drilling effluent disposal tests: Jago Delta No. 7. Sag delta No. 8 and challenge Island No. 1 wells. Beaufort Sea, Alaska. Prepared for SOHIO Alaska Petroleum Company, Anchorage, Ak.

Oakley, K.L. 1984. Revegetation in arctic and subarctic North America - a literature review relevant to the rehabilitation of abandoned oil and gas fields in Alaska. Alaska Dep. of Fish and Game, Anchorage, Alaska. Unpublished report. 37pp.

Oates, R.M., A.W. Brackney, M. McWhorter, R.M. Platte, J.M. Morton, G. Muehlenhardt, and C. Bitler. 1986. Distribution, abundance and productivity of fall staging lesser snow geese on coastal habitats of northeast Alaska and northwest Canada. Pages ____ - ____ in G.W. Garner and P.E. Reynolds, eds. 1985 update report, baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildlife Service, Anchorage, Ak. ____pp.

Odum, E.P., C.E. Connell, and H.L. Stoddard. 1961. Flight energy and estimated ranges of migratory birds. Auk. 78:515-527.

Odum, E.P., and J.O. Perkinson. 1951. Relation of lipid metabolism to migration in birds: seasonal variation in body lipids of the migratory white-throated sparrow. Physiol. Zool. 24:216-230.

Olson, S.T. 1958. Caribou management studies, movements, distribution and numbers - arctic caribou. Fed. Aid in Wildl. Rest. Job Completion Rep. 2c Alaska Game Commission, Juneau.

Page, D.S., B.T. Page, J.R. Hotham, E.S. Gilfillan, and R.P. Gerber. 1980. Bioavailability of toxic constituents of used drilling fluids. Pages 984-996 in Proceedings symposium research on environmental fate and effects of drilling fluids and cuttings. Washington, D.C.: Courtesy Associates.

Palazzo, A.J., S.D. Rindge, and D.A. Gaskin. 1980. Revegetation at two construction sites in New Hampshire and Alaska. Rep. 80-3.U.S. Army Cold Regions Res. and Eng. Lab., Hanover, N.H. 20pp.

Pamplin, W.L. 1979. Construction related impact of the trans-Alaska pipeline system on terrestial wildlife habitats. Joint State/Federal Fish and Wildlife Advisory Team, Special Rep. No. 24. U.S. Fish and Wildl. Serv. Anchorage.

Pank, L.F., E. Friedman, C. Curby, and A. Jones. 1984. Probe: spatial and temporal distribution of biting and parasitic insects on the coastal plain and adjoining foothills of the ANWR. Pages 570-590 in G.W. Garner, and P.E. Reynolds, eds. 1983 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, AK. 614pp.

Pank, L.F., C. Curby, B. Nankivell, C. Simon, and R. Wright. 1985. Probe: spatial and temporal distribution of biting and parasitic insects on the coastal plain and adjoining foothills of the ANWR. Pages 695-724 in G.W. Garner and P.E. Reynolds, eds. 1984 update report. baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. 777pp.

Pattee, O.H., and J.C. Franson. 1982. Short-term effects of oil ingestion on American Kestrels (Falco sparverius). J. Wildl. Dis. 18:235-141.

Patterson, L.A. 1974. An assessment of the energetic importance of the north slope to snow geese (Chen caerulescens) during the staging period in September, 1973. Chapter 4, 67pp. in W.W.H. Gunn, W.J. Richardson, R.E. Schweinburg and T.D. Wright. eds. Studies on snow geese and waterfowl in the Northwest Territories, Yukon Territory and Alaska 1973. Arctic Gas Biol. Rep. Ser. 27. 203pp.

Peakall, D.B., D.Hallett, D.S. Miller, R.G. Butler, and W.B. Kinter. 1980. Effects of ingested crude oil on Black Guillemots: a combined field and laboratory study. Ambio. 9:28-30.

Peakall, D.B., J. Tremblay, W.B. Kinter, and D.S. Miller. 1981. Endocrine dysfunction in seabirds caused by ingested oil. Environment. Res. 24:6-14.

Peake, E., and G.W. Hodgson. 1966. Alkanes in aqueous systems. I. Exploratory investigation on the accommodation of C-20 - C-33 n-alkalines in distilled water and occurrence in natural water systems. J. Am. Oil. Chem. Soc. 43(4):215-222.

Pedersen, S., and M. Coffing. 1984. Caribou hunting: land use dimensions and recent harvest patterns in Kaktovik, northeast Alaska. Alaska Dept. of Fish and Game, Division of Subsistence. Tech. Pap. No. 92. Fairbanks, Alaska. 57pp.

Percy, J.A. 1974. Report to environmental-social program, northern pipelines, on project no. 11, marine ecology of the Mackenzie delta and Tuktoyaktuk Peninsula region part II. Effects of crude oil on arctic marine invertebrates. 94pp.

Percy, R. 1975. Fish of the outer Mackenzie Delta. Dep. Environ., Beaufort Sea Technical Rep. 8, Victoria, Canada.

Percy, J.A., and T.C. Mullin. 1975. Effects of crude oil on Arctic marine invertebrates. Beaufort Sea Technical Report #11. Beaufort Sea Project, Can. Dep. Environ., Quebec, Canada. 167pp.

Peterson, S.R., and R.S. Ellarson. 1979. Changes in oldsquaw carcass weight. Wilson Bull. 91:288-300.

Platt, J.B., and C.E. Tull. 1977. A study of wintering and nesting gyrfalcons on the Yukon north slope during 1975 with emphasis on their behavior during experimental overflights by helicopters. Chapter 1, 90pp. in W.W.H. Gunn, C.E. Tull and T.D. Wright, eds. Ornithological studies conducted in the area of the proposed gas pipeline route: northern Alberta, Northwest Territories, Yukon Territories, and Alaska, 1975. Arctic Gas Biol. Rep. Ser. 35. 348pp.

Plattee, O.H., and J.C. Franson. 1982. Short-term effects of oil ingestion on American Kestrels (Falco sporverius). J. Wildl. Dis. 18:235-241.

Pope, P.R., S.O. Hillman, and L. Safford. 1982. Arctic coastal plains tundra restoration: a new application. Pages 93-109 in Proceedings of the arctic marine oil spill program technical seminar, June 15-17, 1982, Edmonton, Alberta, Canada.

Pruitt, W.O., Jr. 1959. Snow as a factor in the winter ecology of barren-ground caribou in northern Saskatchewan. Arctic 12:159-179.

Quimby, R. 1974. Wolf, wolverine, and red fox. Chapter III. 27pp. in R.D. Jakimchuk, ed. Mammal studies in northeastern Alaska with emphasis within the Canning River Drainage. Arctic Gas Biol. Rept. Ser. Vol. 24. 267pp.

Rattner, B.A., and W.C. Eastin Jr. 1981. Plasma corticosterone and thyroxine concentrations during chronic ingestion of crude oil in Mallard ducks (Anas platyrhynchos). Comp. Biochem. Physiol. 68C:103-107.

Raveling, D.G. 1978. The timing of egg laying by northern geese. Auk 95:294-303.

Ream, C.H., 1976. Loon productivity, human disturbance, and pesticide residues in northern Minnesota. Wilson Bull. 88:427-432.

Reimers, E., D.R. Klein, and R. Sorumgard. 1983. Calving time, growth rate, and body size of Norweigian reindeer on different ranges. Arctic and Alpine Res. 15:107-118.

Reimnitz, E., and D.K. Maurer. 1979. Effects of storm surges on the Beaufort Sea coast, northern Alaska. Arctic 32:329-344.

Reynolds, H.V. 1979. Population biology, movements, distribution and habitat utilization of a grizzly bear population in NPR-A. Pages 129-182 in NPR-A Work Group 3, Studies of selected wildlife and fish and their use of habitats on and adjacent to the National Petroleum Reserve in Alaska 1977-1978. Bur. Land Manage. 105(c) Land Use Study, Field Study 3, Vol.1.

Reynolds, P.E. 1982. Some effects of oil and gas exploration activities on tundra vegetation in northern Alaska. Pages 403-417 in P.J. Rand, ed. Land and water issues related to energy development. Ann Arbor Science, Ann Arbor, Michigan.

Reynolds, P.E. 1986a. Effects of winter seismic exploration activities on muskoxen in the Arctic National Wildlife Refuge, January - May 1984 and 1985. Pages ____ - ____ in G.W. Garner and P.E. Reynolds, eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. ____pp.

Reynolds, P.E. 1986b. Movements and activity patterns of satellite-collared muskox on the Arctic National Wildlife Refuge, 1984-1985. Pages ____ - ____ in G.W. Garner and P.E. Reynolds, eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. ____pp.

Reynolds, P.E. 1986c. Effects of aircraft overflights on muskoxen in the Arctic National Wildlife Refuge, 1982-1985. Pages ____ - ____ in G.W. Garner and P.E. Reynolds, eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. ____pp.

Reynolds, P.E, and D.J. LaPlant. 1985. Effects of winter seismic exploration activities on muskoxen in the Arctic National Wildlife Refuge, January - May 1984. Pages 96-113 in G.W. Garner and P.E. Reynolds, eds. 1984 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wild. Serv. Anchorage, Ak. 777pp.

Reynolds, P.E., L.D. Martin, and G.J. Weiler. 1983. Population size, productivity and distribution of muskoxen in the Arctic National Wildlife Refuge, Alaska. Pages 248-274 in G.W. Garner and P.E. Reynolds, eds. 1982 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. 379pp.

Reynolds, P.E., J. Herrige, and M. Masteller. 1986. Muskox ecology on the Arctic National Wildlife Refuge, 1982-1985. Pages ____ - ____ in G.W. Garner and P.E. Reynolds, eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. ____pp.

Rice, S.D., J.W. Short, and J.F. Karinen. 1977. Comparative oil toxicity and comparative animal sensitivity. Pages 78-94 in D.A. Wolfe, ed. Fate and effects of petroleum hydrocarbons in marine organisms and ecosystems. New York, NY. Pergamon Press. 478pp.

Robert, H.C., and C.J. Ralph. 1975. Effect of human disturbance on the breeding success of gull. Condor. 77:495-499.

Robus, M.A. 1984. Summer food habits of muskoxen in northeastern Alaska. Pages 81-85 in D.R. Klein, R.G. White, and S. Keller, eds. Proc. 1st int. muskox symp. Bio. Pap. Univ. Alaska Spec. Rep. No 4, Fairbanks Ak. 218pp.

Roby, D.D. 1978. Behavioral patterns of barren ground caribou of the central arctic herd adjacent to the Trans-Alaska Pipeline. M.S. Thesis, Univ. Alaska, Fairbanks. 200pp.

Rocke, T.E., T.M. Yuill, and R.D. Hinsdill. 1984. Oil and related toxicant effects on mallard immune defenses. Environment. Res. 33:343-352

Rognmo, A., K.A. Markussen, E. Jacobson, and A.S. Blix. 1983. Effects of improved nutrition in pregnant reindeer on milk quality, calf birth weight, growth and mortality. Rangifer. 3:10-18.

Roseneau, D.G., and P. Stern. 1974. Distribution and movements of the porcupine caribou herd in northeastern Alaska, 1972. Arctic Gas Biol. Rep. Ser., Vol. 7. 209pp.

Roseneau, D.G., and J.A. Curatolo. 1976. The distribution and movements of the porcupine caribou herd in northeastern Alaska and the Yukon Territory, 1975. in R.D. Jakimchuk, ed. Studies of mammals along the proposed MacKenzie Valley Gas Pipeline route, 1975. Arctic Gas Biol. Rep. Ser. Vol. 36. 1976.

Roseneau, D.G., P.M. Stern, and C. Warbelow. 1974. Distribution and movements of the porcupine caribou herd in northeastern Alaska. in K.H. McCourt and L.P. Horstman, eds. Studies of large mammal populations in northern Alaska, Yukon and Northwest Territories, 1973. Arctic Gas Biol. Rep. Ser., Vol. 22, Chap. 4.

Roseneau, D.G., J. Curatolo, and G. Moore. 1975. The distribution and movements of the porcupine caribou herd in northeastern Alaska and the Yukon Territory, 1974. in R.D. Jakimchuk, ed. Studies of large mammals along the proposed MacKenzie Valley Gas Pipeline route from Alaska to British Columbia. Arctic Gas Biol. Rep. Ser. Vol. 32.

Rossman, B.B., and Z.J. Ulehla. 1977. Psychological reward values associated with wilderness use. Environ. and Behav. 9:41-66.

Rubinstein, N.I., R. Rigby, and C.N. D'Asaro. 1980. Acute and sublethal effects of whole used drilling fluids on representative estuarine organisms. Pages 828-846 in Procedings symposium on research on environmental fate and effects of drilling fluids and cuttings. Washington, D.C.: Courtesy Associates.

Russell, D.E., and W.A. Nixon. 1986. Distribution, movements and juvenile mortality of the porcupine caribou herd in northern Yukon, June 1982 - January 1986. Pages ____ - ____ in G.W. Garner and P.E. Reynolds, eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildlife Service, Anchorage, Ak. ____pp.

Russell, J. 1977. Some overt responses of muskox and caribou to seismic activities, northeastern Banks Island. Northwest Terr. Wildl. Serv. Yellowknife. 85pp.

Savile, D.B.O. 1972. Arctic adaptions in plants. Research Branch, Canada Dep. of Agriculture. Monograph No. 6. 81pp.

Savoie, M.A., and D.E. Wilson. 1983. Prodhoe Bay water flood project physical processes monitoring program 1982, Chapter 3. in Prudhoe Bay water flood project environmental monitoring program 1982, Final Rep. U.S. Army Corps of Engineers, Alaska District. Anchorage, Alaska.

Savoie, M.A., and D.E. Wilson. 1984. Prudhoe Bay water flood project physical processes, Chapter 2. in Prodhoe Bay water flood project environmental monitoring program 1983, Final Rep. U.S. Army Corps of engineers, Alaska District. Anchorage, Alaska.

Schallock, E.W. 1976. Implications of resource development on the north slope of Alaska with regard to water quality on the Sagavanirktok River Pages 174-184 in Proceedings symposium marine, estuarine and freshwater quality. 26th Annual Meeting. Am. Inst. of Biol. Sci., 1975. Rep. EPA-600/3-76--079.

Schmid, W.D. 1971. Modifications of the subnivean microclimate by snowmobiles. Pages 251-257 in Proceedings of the snow and ice symposium. Coop. Wildl. Res. Unit., Iowa State Univ., Ames.

Schmidt, W.T. 1970. A field survey of burd use at Beaufort Lagoon, June-September 1970. Unpublished Rep. on file, U.S. Fish and Wildlife Service, Arctic National Wildlife Range, Fairbanks, Alaska. 36pp.

Schofield, E. 1975. Some considerations on the possible effects of local and global sources of air pollution on lichens grazed by reindeer and caribou. Pages 90-94 in J.R. Luick, P.C. Lent, D.R. Klein and R.G. White, eds. Proceedings first international reindeer and caribou symposium, Biol. Pap. Univ. Alaska Spec. Rep. No.1. 551pp.

Schweinsburg, R.E. 1974a. Disturbance effects of aircraft on waterfowl on north slope lakes, June 1972. Pages 1-48 in W.W.H. Gunn and J.A. Livingston, eds. Disturbance to birds by gas compressor noise stimulators, aircraft and human activity. Arctic Gas Biol. Rep. Ser. 14 304pp.

Schweinsburg, R.E. 1974b. Snow geese disturbance by aircraft on the north slope, September 1972. Pages 258-279 in W.W.H. Gunn and J.A. Livingston, eds. Disturbance to birds by gas compressor noise stimulators, aircraft and human activity in the MacKenzie Valley and the north slope, 1972. Arctic Gas Bio. Rep. Ser. Vol. 14. 304pp.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Resour. Board of Canada Bull. 1984. Ottawa. 966pp.

Seelye, J.G., R.J. Hesselberg, and M.J. Mac. 1982. Accumulation by fish of contaminants released from dredged sediments. Environ. Sci. Technol. 16:459-464.

Sellers, R. 1979. Waterbird use of and management considerations for Cook Inlet state game refuges. Draft Rep. Alaska Dep. Fish and Game, Anchorage, Ak. 42pp.

Sexstone, A., K. Everett, T. Jenkins, and R.M. Atlas. 1978. Fate of crude and refined oil in north slope soils. Arctic 31:339-347.

Shaver, G.R. and F.S. Chapin. 1980. Response to fertilization by various plant growth forms in an Alaskan tundra: Nutrient accumulation and growth. Ecology 61:662-675.

Shaver, G.R., B.L. Gartner, F.S. Chapin, and A.E. Linkins. 1983. Revegetation of arctic disturbed sites by native tundra plants. Pages 1133-1137 in Proc. Fourth Int. Conf. on Permafrost. National Academy Press, Wash., D.C.

Shaw, D.G., L.E. Clement, D.J. McIntosh, and M.S. Steks. 1981. Some effects of petroleum on nearshore Alaskan marine organisms. U.S. Environment Protection Agency Special Topic P.B. 81-157:147.

Shideler, R.T. 1986. Impacts of human developments and land use on caribou: literature review, Vol. II. Impacts of oil and gas development on the central arctic herd. Tech. Rep. No. 86-3. Alaska Dep. of Fish and Game. Habitat Division, Juneau, Ak. 128pp.

Simmons, C.L., K.R. Everett., D.A. Walker, A.E. Linkins, and P.J. Webber. 1983. Sensitivity of plant communities and soil flora to seawater spills, Prudhoe Bay, Alaska. Rep. 83-24. U.S. Army Cold Regions Res. and Eng. Lab., Hanover, N.H. 35pp.

Skoglund, T. 1984. The effects of food and maternal conditions on fetal growth and size in wild reindeer. Rangifer. 4:39-46.

Skoog, R.O. 1968. Ecology of the caribou (Rangifer tarandus granti) in Alaska. Ph.D. Dissert, Univ. California, Berkeley. 699pp.

Slaney and Company Ltd. 1973. Enviromental effects assessment, Voyager air cushion vehicle, Mackenzie Delta Northwest Territories. Vol II Field Studies. Enviromental Protection Service. Canada

Smith, D.W., and T.D.W. James. 1980. Sump studies III - biological changes in permafrost terrain adjacent to high arctic oil and gas wellsites. Environmental Studies No. 16, Northern Affairs Program, Canada. 150pp.

Smith, W.T., and R.D. Cameron. 1985. Factors affecting pipeline crossing success of caribou. Pages 40-46 in A. Martell and D. Russell, eds. Proc. First N. Am. Caribou Workshop. Whitehorse, 1983. Canad. Wildl. Serv. Spec. Publ. Ottawa. 68pp.

Smith, W.T., R.D. Cameron, and K.R. Whitten. 1985. Reactions of large groups of caribou to a pipeline corridor on the arctic coastal plain of Alaska. Arctic 38:53-57.

Snyder-Conn E., C. Moitoret, and J. Stroebele. 1986. Heavy metal pollution by drilling muds from oil exploration in low-energy, shallow-water Arctic environments. Unpubl. Rep., U.S. Fish and Wildlife Service, North. Ecol. Serv. Fairbanks, Ak. 17pp.

Spann, J.W., R.G. Heath, J.F. Kreitzer, and L.N. Locke. 1972. Ethyl mercury p-toluene sulfonanilide: lethal and reproductive effects on pheasants. Science 175:328-331.

Spatt, P.D. and M.C. Miller. 1981. Growth conditions and vitality of Sphagnum in a tundra community along the Alaska Pipeline Haul Road. Arctic 34:48-54.

Starr, S.J., M.N. Kuwada, and L.L. Trasky. 1981. Recommendations for minimizing the impacts of hydrocarbon development on the fish, wildlife and aquatic plant resources of the Northern Bering Sea and Norton Sound. Alaska Dep. Fish and Game, Anchorage. 525pp.

Stowe, T.J., and L.A. Underwood. 1984. Oil spillages affecting seabirds in the United Kingdom, 1966-1983. Mar. Pollut. Bull. 15:147-152.

Strang, C.A. 1980. Incidence of avian predators near people searching for waterfowl nests. J. Wildl. Manage. 44:220-221.

Surrendi, D.C., and E.A. DeBock. 1976. Seasonal distribution, population status and behavior of the porcupine caribou herd. Canad. Wildl. Serv. Ottawa. 144pp.

Szaro, R.C. 1977. Effects of petroleum on birds. Trans. N. Amer. Wildl. Nat. Resour. Conf. 42:374-381.

Szaro, R.C. 1978. Petroleum: effects on mallard egg hatchability. J. Wildl. Manage. 42:404-406.

Szaro, R.C. 1979. Bunker C fuel oil reduces mallard egg hatchability. Bull. Environ. Contam. Toxicol. 22:731-732.

Szaro, R.C., M.P. Dieter, and G.H. Heinz. 1978. Effects of chronic ingestion of south Louisiana crude oil on mallard ducklings. Environ. Res. 17:426-436.

Szaro, R.C., N.C. Coon, and W. Stout. 1980. Weathered petroleum: effects on mallard egg hatchability. J. Wildl. Manage. 44:709-713.

Taylor, E.J. 1986. Foods and foraging ecology of oldsquaw ducks (Clangula hymenalis L.) on the arctic coastal plain, Alaska. M.S. Thesis. Univ. Alaska, Fairbanks. 130pp.

Tchirkova, A.F. 1958. A preliminary method of forcasting changes in numbers of arctic foxes. Pages 29-49 in Translations of Russian game reports. Vol. 3. Can. Wildl. Serv., Ottawa. (Translations of Tchirkova, A.F. 1951. Predvaritel'naya metodika prognosou izmeneniy chislennosti pestsov. Voprosy Biologii Pushnykh Zverey i Tekhnike Okhothich'vego Promysla 11:56 ff)

Teal, J.M., and R.W. Howarth. 1984. Oil spill studies: A review of ecological effects. Environ. Manage. 8:27-44.

Tener, J.S. 1965. Muskoxen in Canada: a biological and taxonomic review. Can. Wildl. Serv. Monogr. 2. 166pp.

Thompson, D.C., and D.G. Roseneau. 1978. Winter distribution of the Porcupine caribou herd in relation to the proposed Dempster Lateral Pipeline Route. Prepared for Foothills Pipelines (Yukon) Ltd. by Renewable Resources Consulting Services Ltd. Edmonton. 70pp.

Tracy, D.M. 1977. Reactions of wildlife to human activity along Mount McKinley National Park road. M.S. Thesis, Univ. Alaska, Fairbanks. 260pp.

Treisman, M. 1975. Predation and the evolution of gregariousness. I. Models for concealment and evasion. Anim. Behav. 23:777-800.

Trivelpiece, W.Z., R.G. Butler, D.S. Miller, and D.B. Peakall. 1984. Reduced survival of chicks of oil-dosed adult Leach's Storm-Petrels. Condor 86:81-82.

Troy, D.M. 1985. Prudhoe Bay waterflood project environmetnal monitoring program terrestrial studies - 1984. Draft Rep. prepared for Envirosphere Company, Anchorage, Alaska. 126pp.

Troy, D.M., D.R. Herter,and R.M. Burgess. 1982. Tundra bird monitoring program. in Prudhoe Bay waterflood environmental monitoring project 1982. Rep. to U.S. Army Corps of Engineers, Alaska District by LGL Research Associates, Inc., Fairbanks, Ak.

Truett, J.C. 1980. Synthesis, impact analysis, and a monitoring strategy. Part 7. Pages 259-359m. Beaufort Sea barrier island-lagoon ecological process studies: Final Rep. Simpson Lagoon. Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. BLM/NOAA, OCSEAP. Boulder, Colorado. 359pp.

U.S. Army Corps of Engineers. 1980. Final environmental impact statement, Prudhoe Bay oilfield waterflood project. Vol. I. Alaska District, Anchorage.

U.S. Department of Interior. 1976. Alaska natural gas transportation system final environmental impact statement. 635pp.

U.S. Fish and Wildlife Service. 1970. A reconnaissance report on the impact on fish and wildlife resources of the north slope oil development, the Trans-Alaska pipeline system, and the marine terminal sites. Bur. of Com. Fish. Juneau, Alaska and Bur. of Sport Fish and Wildl., Portland, Oregon.

U.S. Fish and Wildlife Service. 1982. Initial report baseline study of the fish, wildlife, and their habitats. Arctic National Wildlife Refuge coastal plain resource assessment. U.S. Fish and Wildl. Serv. Anchorage, Alaska. 507pp.

U.S. Geological Survey. 1979. An environmental evaluation of potential petroleum development on the National Petroleum Reserve in Alaska. U.S. Geol. Sur., Anchorage, Alaska. 238p.

U.S. Geological Survey. 1981. Arctic summary report. USGS Open-File Report 81-62. Reston, Virginia. 72pp.

Urquhart, D.R. 1973. Oil exploration and Banks Island wildlife: A guide for the preservation of caribou, muskox, and arctic fox populations on Banks Island, Northwest Territories. Game Manage. Div. Rep., Gov. Northwest Territories. 105pp.

Uspenskii, S.M. 1969. Life in high latitudes: a study of bird life. Translated from Russian 1984. Amerind Publishing Co. Pvt. Ltd. New Delhi. 385pp.

Utter, J.M., and E.A. LeFebvre. 1973. Daily energy expenditure of purple martins (Progne subis) during the breeding season: estimates using $D_2O^{18}$ and time budget methods. Ecology 54:597-604.

Valkenburg, P., and J.L. Davis. 1985. The reaction of caribou to aircraft: a comparison of two herds. Pages 7-9 in A. Martell and D. Russell, eds. Proc. First North Am. Caribou Workshop 1983. Whitehorse Y.T. Canad. Wildl. Serv. Spec. Publ. Ottawa. 68pp.

Van Ballenberghe, V., and L.D. Mech. 1975. Weights, growth, and survival of timber wolf pups in Minnesota. J. Mammal. 56:44-63

Van Cleve, K. 1972. Revegetation of disturbed tundra and taiga surfaces by introduced and native plant species. Pages 7-11 in Proceedings symposium on the impact of oil resource develoment on northern plant communities. Occ. Publ on Northern Life, No. 1., Univ. Alaska, Fairbanks.

Van Cleve, K. 1977. Recovery of disturbed tundra and taiga surfaces in Alaska. Pages 422-455 in J. Cairns, Jr., K.L. Dickson and E.E. Herricks, eds. The recovery process in damaged ecosystems. Univ. Virginia, Charlottesville.

Van der Molen, E.J., A.A. Blok, and G.J. DeGraaf. 1982. Winter starvation and mercury intoxication in grey herons (*Ardea cinerea*) in The Netherlands. Ardea. 70:173-184.

Van der Zande, W.J. ter Keurs, and W.J. Van der Weyden. 1980. The impacts of roads on the densities of four bird species in an open field habitat - evidence of a long-distance effect. Biol. Cons. 18:299-321.

Vander Valk, A.G., R.F. Nuss, and S.D. Swanson. 1980. Impact of sediment deposition on Alaskan wetlands. Preliminary draft for the U.S. Environmental Protection Agency. Project #805837010. 84pp.

Vangilder, L.D., and T.J. Peterle. 1980. South Louisiana crude oil and DDE in the diet of mallard hens: effects on reproduction and duckling survival. Bull. Environment. Contam. Toxical. 25:23-28.

Vangilder, L.D., and T.J. Peterle. 1981. South Louisiana crude oil and DDE in the diet of mallard hens: effects on egg quality. Bull. Environment. Contam. Toxical. 26:328-336.

Van Zyll de Jong, G.G. 1975. Distribution and abundance of the wolverine (*Gulo gulo*) in Canada. Can. Field-Nat. 89:431-437.

Verheijen, F.J. 1981. Bird kills at tall lighted structures in the USA in the period 1935-1973 and kills at a Dutch lighthouse in the period 1924-1928 show similar lunar periodicity. Ardea 69:199-203.

Vermeer, K. 1971. A survey of mercury residues in aquatic bird eggs in the Canadian prairie provinces. Trans. North Am. Wildl. Nat. Resour. Conf. 36:138-152.

Vermeer, K., and F.A.J. Armstrong. 1972. Mercury in Canadian prairie ducks. J. Wildl. Manage. 36:179-182.

Vermeer, K., and G.G. Anweiler. 1975. Oil threat to aquatic birds along the Yukon coast. Wilson Bull. 87:467-480.

Vermeer, K., and R. Vermeer. 1975. Oil threat to birds on the Canadian west coast. Can. Field-Nat. 89:278-298.

Villmo, L. 1975. Potential impact of accelerated northern development on caribou and reindeer populations and ecology: The Scandanavian viewpoint. in J.R. Luick, P.C. Lent, D.R. Klein, and R.G. White, eds. Proceedings first international reindeer and caribou symposium, Biol. Pop. Univ. Alaska, Spec. Rep. No. 1 Fairbanks. 551pp.

Walker, D.A. 1981. The vegetation and enviromental gradients of the Prudhoe Bay region, Alaska. Ph. D. Thesis, University Colorado, Boulder, Co. 484pp.

Walker, D.A., P.J. Webber, K.R. Everett, and J. Brown. 1978. Effects of crude and diesel oil spills on plant communities at Prudhoe Bay, Alaska, and the derivation of oil sensitivity maps. Arctic 31:242-259.

Walker, D.A., K.R. Everett, P.J. Webber, and J. Brown. 1980. Geobotanical atlas of the Prudhoe Bay region, Alaska. CRREL Report 80-14. U.S. Army Corps of Eng., Cold Regions Res. and Eng. Lab., Hanover, N.H. 69pp.

Walker, D.A., W. Acevedo, K.R. Everett, L. Gaydos, J. Brown, and P.J. Webber. 1982. Landsat-assisted environmental mapping in the Arctic National Wildlife Refuge, Alaska. Rep. 82-37. U.S. Army Cold Regions Res. and Eng. Laboratory, Havoner, N.H. 59pp.

Walker, D.A., M.A. Walker, N.D. Lederer, and P.J. Webber. 1984. The use of geobotanical maps and automated mapping techniques to study the historical changes in the Prudhoe Bay oilfield, Alaska. Inst. of Arctic and Alpine Research, Univ. of Colorado, Boulder, Colo. 63pp.

Warbelow, C., D. Roseneau, and P. Stern. 1975. The Kutchin caribou fences of northeastern Alaska and the northern Yukon. Chapter IV. 129pp. in R.D. Jakimchuk, ed. Studies of large mammals along the Mackenzie Valley Pipeline from Alaska to British Columbia. Arctic Gas Biol. Rep. Ser. 32, Chap. 4.
418pp.

Ward, D.L., and L.A. Peterson. 1975. A summary of water use problems related to north slope petroleum development. Proc. of 27th Alaska Science Conf. Univ. Alaska, Fairbanks. 5pp.

Warren, G.A. 1980. Activities, attitudes and management preferences of visitors of the Arctic National Wildlife Refuge, Alaska. M.S. Thesis, Univ. Idaho, Moscow. 51pp.

Weathers, W.W., W.A. Buttemer, A.M. Hayworth, and K.A. Nagy. 1984. An evaluation of time budget estimates of daily energy expenditure in birds. Auk. 101:459-472.

Weeden R.B., and D.R. Klein. 1971. Wildlife and oil: a survey of critical issues in Alaska. Polar Record 15:479-494.

Weiler, G.J., G.W. Garner, L.D. Martin, and W. Regelin. 1985. Wolves of the Arctic National Wildlife Refuge: their seasonal movements and prey relationships. Pages 173-200 in G.W. Garner and P.E. Reynolds, eds. 1984 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wild. Serv., Anchorage, Alaska. 777pp.

Weiler, G.W., G.W. Garner, and W. Reglin. 1986. Wolves of the Arctic National Wildlife Refuge: their seasonal movements and prey relationships. Pages___-___ in G.W. Garner and P.E. Reynolds, eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Ak. ___pp.

Wein, R.W., and L.C. Bliss. 1973. Experimental crude oil spills on arctic plant communities. J. Appl. Ecol. 10:671-682.

Wentworth, C. 1980. National Petroleum Reserve in Alaska: preliminary subsistence economy analysis, literature evaluation, and socio-economic impact mitigation measures. U.S. FWS and BLM Memorandum-of-Understanding. FWS 14-16-0007-80-5509. July 1. 47pp.

West, G.C., and M.S. Meng. 1968. Seasonal changes in body weight and fat and the relation of fatty acid composition to diet in willow ptarmigan. Wilson Bull. 80:426-441.

West, R.L., and E. Snyder-Conn. 1985. The effects of Prudhoe Bay reserve pit fluids on the water quality and micro invertebrates of tundra ponds. Unpubl. Rep., U.S. Fish and Wildl. Serv., North. Ecol. Serv. Office, Fairbanks, Ak. 60pp.

White, D.H., K.A. King, and N.C. Coon. 1979. Effect of No. 2 Fuel oil on hatchability of marine and estaurine bird eggs. Bull. Environm. Contam. Toxical 21:7-10.

White, R.G. D.F. Holleman, P. Wheat, P.G. Tallas, M. Jourdan, and P. Henrichsen.1984. Seasonal changes in voluntary intake and digestibility of diets by captive muskoxen. Pages 193-194 in D.R. Klein, R.G. White, and S. Keller, eds. Proc. 1st int. muskox symp. Biol. Pap. Univ. Alaska Spec. Rep. No. 4. Fairbanks, Ak. 218pp.

Whitten, K.R. 1986. Population status and trend of the Porcupine caribou herd, 1982-1985. Pages___-___ in G.W. Garner and P.E. Reynolds, eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Alaska. ___pp.

Whitten, K.R., and R.D. Cameron. 1985. Distribution of caribou calving in relation to the Prudhoe Bay oilfield. Pages 35-39 in A.M. Martell and D.E. Russell, eds. Caribou and human activity. Proc. 1st North Am. Caribou Workshop, Whitehorse, Yukon. Canad. Wildl. Serv. Publ. Ottawa. 68pp.

Whitten K.R., R.D. Cameron, and W.T. Smith. 1981. Calving distribution of the Central Arctic Caribou Herd, 1981. Alaska Dep. of Fish and Game Report. in press.

Whitten, K.R., G.W. Garner, and F.J. Mauer. 1984. Calving distribution, initial productivity and neonatal mortality of the porcupine caribou herd, 1983. Pages 359-420. in G.W. Garner and P.E. Reynolds, eds. 1983 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv., Anchorage, Alaska. 614pp.

Whitten, K.R., F.J. Mauer, and G.W. Garner. 1985a. Calving distribution, initial productivity and neonatal mortality of the porcupine caribou herd, 1984. Pages 527-621 in G.W. Garner and P.E. Reynolds, eds. 1984 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Ser., Anchorage, Alaska. 777pp.

Whitten, K.R., F.J. Mauer, G.W. Garner, and D.E. Russell. 1985b. Fall, and winter movements and distribution and annual mortality patterns of the Porcupine caribou herd 1983-1984. Pages 515-526. in G.W. Garner and P.E. Reynolds, eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildl. Serv. Anchorage, Alaska. 777pp.

Whitten, K.R., F.J. Mauer, and G.W. Garner. 1986. Calving distribution, initial productivity and neonatal calf mortality of the Porcupine caribou herd. Pages ___-___ in G.W. Garner and P.E. Reynolds, eds. 1985 update report baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildlife Ser. Anchorage, Ak. ___pp.

Wilkenson, P.E. 1972. Oommgmak: a model for man-animal relationships in pre-history. Current Anthropology 13:23-36.

Will, R.T. 1984. Muskox procurement and use on Banks Island by nineteenth century Copper Inuit. Pages 1153-161 in D.R. Klein, R.G. White, and S. Keller, eds. Proc. 1st int. muskox symp. Bio. Pap. Univ. Alaska Spec. Rep. No. 4, Fairbanks, Ak. 218pp.

Williams, J.B., and K.A. Nagy. 1984. Daily energy expenditure of savannah sparrows: comparison of time-energy budget and doubly-labeled water estimates. Auk 101:221-229.

Wilson, W.J. , E.H. Buck, G.F. Player, and L.D. Dreyer. 1977. Winter water availability and use conflicts as related to fish and wildlife in arctic Alaska - a synthesis of information. U.S. Fish and Wildl. Serv. FWS/OBS - 77/06. Anchorage. 222pp.

Wiseley, A.N. 1974. Disturbance to snow geese and other large waterfowl species by gas compressor sound simulation, Komakuk, Yukon Territory, August-Sept. 1973. Chapter III, 35pp. in W.W.H. Gunn, W.J. Richardson, R.E. Schweinburg and T.D. Wright, eds. Studies on snowgeese and waterfowl in the Northwest Territories, Yukon Territory and Alaska, 1973. Arctic Gas Biol. Rep. Ser. 27. 203pp.

Woodward-Clyde Consultants. 1980. Gravel removal studies in arctic and subarctic floodplains in Alaska. U.S. Fish and Wildl. Serv. FWS/OBS-80/08. Wash., D.C. 403pp.

Worl, R.F., and P.O. McMillan. 1982. Part I. Kaktovik. Pages 11-93 in Sociocultural assessment of proposed Arctic National Wildlife Refuge oil and gas exploration final report. Arctic Environ. Information and Data Center., Univ. Alaska, Anchorage. 194pp.

Wotton, T.A., C.R. Grau, T.E. Roudybush, M.E. Kahs, and K.V. Hirsch. 1979. Reproductive responses of quail to Bunker C oil fractions. Arch. Environ. Contam. Toxical. 8:457-463.

Wright, J.M., and S.G. Fancy. 1980. The response of birds and caribou to the 1980 drilling operation at the Pt. Thomson #4 Well. Final Rep. by LGL Alaska Ecological Research Assoc. Inc., Fairbanks, to EXXON Company USA.

Wrigley, R.E., and D.R.M. Hatch. 1976. Arctic fox migrations in Manitoba. Arctic 29:147-158.

Wypkema, R.C.P., and C.D. Ankney. 1979. Nutrient reserve dynamics of lesser snow geese staging at James Bay, Ontario. Can. J. Zool. 57:213-219.

Younkin, W.E., and W. Friesen. 1976. San Sault revegetation trials. Chapter 2. Pages 1-28 in W.E. Younkin, ed. Revegetation studies in the northern Mackenzie Valley region. Canadian Arctic Gas Study Ltd. and Alaskan Arctic Gas Study Co. Biol. Rep. Ser. Volume 38. 119pp.

Younkin, W.E., and H. Martens. 1976. Progress report on rig site seeding tests in the Mackenzie delta region, N.W.T. Chapter III, 64pp. in W.E. Younkin, ed. Revegetation studies in the northern Mackenzie Valley region. Arctic Gas Biol. Rep. Ser. 38. 119pp.

Younkin, W.E. and D.L. Johnson. 1980. The impact of waste drilling fluids on soils and vegetation in Alberta. Abstract/Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings, Lake Buena Vista, Florida.

Zasada, J.C., B.J. Neiland, R. Densmore, M.A. Masters, and N. Moore. 1981. Investigations of techniques for large-scale reintroduction of willows in arctic Alaska. Final report submitted to Alyeska Pipeline Service Co. by Univ. of Alaska Agricultural Experiment Station, Fairbanks, Alaska. 448pp.

Zhigunov. P. 1968. Reindeer husbandry. Israel Program for Scientific Translations. 2nd edn., Jerusalem. 343pp.

Zozell, C.E. 1973. Microbial degradation of oil: present status, problems and perspectives. Pages 3-16 in D.G. Ahearn and S.P. Meyers eds. The Microbial Degradation of Oil Pollutants. La. State Univ. Publ. LSU-SG-73-01.

APPENDICES

APPENDIX I.

Appendix I, Table 1. Descriptions of Landsat land cover categories for the coastal plain study area, Arctic NWR (Walker et al. 1982)

| | Land Cover Class | Vegetation | Landform and Soil |
|---|---|---|---|
| I. | WATER | I. WATER. Water bodies generally larger than 0.5 ha: oceans, lakes, and rivers. | Ia. No soil identified. |
| II. | POND/SEDGE TUNDRA COMPLEX OR AQUATIC TUNDRA OR SHALLOW WATER | IIa. POND/SEDGE TUNDRA COMPLEX. Very wet tundra areas that have numerous small bodies of water, such as drained lake basins with small ponds, polygons and strangmoor. Relatively well drained tundra of varying character may cover up to 50% of the unit. Low-centered polygon complexes with standing water in their centers are usually included in this unit. | IIa. Principal landforms of the pond complex are numerous shallow ponds of less than 1 ha, low-centered polygons (often with standing water in their centers), and string bogs (stangmoor). The very wet elements of the unit have, in order of abundance, Histic Pergelic Cryaquepts, usually with 20 cm or more of fibrous organic materials over gleyed (reduced) mineral soil; Pergelic Cryaquepts with less than 20 cm of fibrous organic over gleyed mineral material; or Cryofibrists/Cryohemists with over 40 cm of fibrous organic over gleyed mineral soil. Positive-microrelief elements, especially well-developed (over 20 cm) rims of the low-centered polygons, have Pergelic Cryaquolls, occasionally Pergelic Cryaquepts with 5-10 cm of highly decomposed organic matter overlying gleyed mineral soil. Pergelic Cryosaprists are rare and are the organically oxidized extensions of the Cryofibrists or Cryohemists. |
| | | IIb. AQUATIC TUNDRA. Emergent communities that cover areas greater than 0.5 ha. The primary taxon in deeper water, up to 1 m deep, is Arctophila fulva (pendant grass). In water less than 30 cm deep, the main taxa are Carex aquatilis (aquatic sedge), Eriophorum scheuchzeri (arctic cottongrass) and E. angustifolium (common cottongrass). | IIb. Normally soils have not been described in areas where Arctophila fulva is mapped. The substrate in such environments consists commonly of a suspension of detrital organic materials, often with a significant component of mineral materials held in a matrix of plant roots. The underlying mineral soils may be uniformly gleyed, or on occasion, mottled, the result of oxidation around aerenchymous roots. Such soils are placed provisionally with the Pergelic Cryaquepts. Similar soils with increasing amounts of fibrous biomass occur within the shallowest (less than 30 cm) water depths. |
| III. | WET SEDGE TUNDRA | IIIa. WET SEDGE TUNDRA (NONCOMPLEX). Relatively wet tundra with little or no standing water and only a few well-drained microsites associated with polygon rims, strangmoor, hummocks, etc. Much of this tundra is flooded in early summer, but it generally drains of standing water by midsummer and remains saturated throughout the summer. Relatively large areas of noncomplex wet tundra occur in the deltas of the larger rivers, particularly the Canning River, and in drained lake basins and along some river channels. | IIIa. These areas have seasonal standing water (after snow melt) but by midsummer the thickening active layer, together with evapotranspiration, removes the the standing water, leaving a saturated soil. Free water is encountered within a very few centimeters of the surface. Patterned ground features are poorly developed and consist of large disjunct polygons, hummocks and strangmoor; the strangs are often coextensive with the low polygon rims. There is not much |

Appendix I, Table 1. Continued

| Land Cover Class | Vegetation | Landform and Soil |
|---|---|---|
| | The primary taxa are numerous sedges, including Carex aquatilis (aquatic sedge), Eriophorum angustifolium (common cottongrass), E. russeolum (russett cottongrass), C. rotundata (round-fruited sedge), C. saxatilis (rocky sedge) and a few herbs, including Pedicularis sudetica ssp. albolabiata (sudetan lousewort), Saxifraga hirculis (bog saxifrage), Melandrium apetalum (nodding lychnis), Caltha palustris (marsh marigold) and Potentilla palustris (marsh five-fingers). Mosses are mainly Drepanocladus spp., Scorpidium scorpioides, Campylium stellatum, Calliergon spp. and Sphagnum spp. | positive microrelief. The soils are wet, predominantly Pergelic Cryaquepts or Histic Pergelic Cryaquepts, both of which have fibrous organic horizons. In certain cases where organic and neutral to alkaline mineral substrate is present, Histic Pergelic Cryaquolls occur. |
| | IIIb. WET SEDGE TUNDRA (VERY WET COMPLEXES). Complexes of wet tundra with up to 50% water or emergent vegetation. Low-centered polygon complexes with extensive thermokarst pits, or complex thermokarst areas in the Foothills commonly have this vegetation subunit. Nonaquatic portions of the complex may be tundra of varying character. | IIIb. In contrast to IIIa these areas have more strongly expressed surface patterns and microrelief but contain significant amounts of standing water in the form of thermokarst pools or the centers of low-centered polygons. Such areas are typical of broad crests in the Foothills and portions of the Hilly Coastal Plain. Moist tussock and tussock frost-scar slopes in this subregion have Pergelic Cryaquolls and/or Ruptic-Entic Cryaquolls. Pergelic Cryaquolls commonly form associations with Pergelic and Histic Pergelic Cryquepts where low-centered polygons are well expressed. Histic Pergelic Cryaquolls are the principal soils of low, flat-centered polygons, a form common to Unit IIIb. Complexes of Pergelic Cryaquepts, Pergelic Cryaquolls, and Histic Pergelic Cryaquepts characterize the unit generally. |
| | IIIc. WET SEDGE TUNDRA (MOIST COMPLEXES). Complexes of wet tundra with up to 40% moist tundra of varying character. Low-centered polygon complexes with well-developed polygon rims, and string bogs with closely spaced strangs commonly have this kind of vegetation. | IIIc. This subunit differs from the others principally in terms of its better drainage. It includes extensive areas of well-developed low-centered polygons and areas of string bogs in which the strangs are more closely spaced, reflecting a more clearly defined hydraulic gradient. Pergelic and Histic Pergelic Cryaquepts are common in the strangs. Complexes and associations of Pergelic Cryaquolls and Pergelic and Histic Pergelic Cryaquepts are common to the rest of the subunit. |
| | IIId. WET SEDGE TUNDRA (SALINE FACIES). Areas near the coast that are periodically inundated with salt water. The primary taxa are Carex subspathacea (Hoppner sedge), Puccinellia phryganodes (creeping | IIId. These near-coast areas may display any of the landform subunits of Classes II or III. The soils in recently flooded ares are morphologically little different from those of |

| Land Cover Class | Vegetation | Landform and Soil |
|---|---|---|
| | alkali grass), *C. ursina* (bear sedge), *Stellaria humifusa* (low chickweed), and *Cochlearia officinalis* (common scurvy grass). Some saline areas have numerous ponds and are likely to be classed as Pond/Sedge Tundra Complex (IIa). | the unflooded parts. Chemically, however, they may have conductivities that range from 12,000 to over 18,000 micro-mho/cm and should probably be considered as Halic Pergelic Cryaquepts. Where saline conditions have prevailed for a protracted period of time and salt-tolerant plants such as *Puccinellia phryganodes* and *Carex subspathacea* are established on the dead *Carex aquatilis*, there is a pronounced change in the texture of the accumulating organic matter. |
| IV. MOIST/WET SEDGE TUNDRA COMPLEX OR DRY PROSTRATE SHRUB, FORB TUNDRA (DRYAS RIVER TERRACES) | IVa. MOIST/WET SEDGE TUNDRA COMPLEX. Areas of moist sedge tundra mixed with up to 40% wet sedge tundra. Flat areas with low- or flat-centered polygon complexes (common in drained lake basins) or strangmoor (more common in river delta systems and on gentle slopes) usually have a large percentage of wet tundra in the polygon troughs, basins, thermokarst pits and interstrang areas. The spectral signature of these areas is likely to vary depending on the percentage of moist tundra, the season, and the summer rainfall. Moist areas may or may not have cottongrass tussocks, depending on the proximity to the coast. Common taxa in moist tundra areas include the sedges *Eriophorum triste* (common cottongrass), *E. vaginatum* (sheathed cottongrass), *Carex bigelowii* (Bigelow's sedge), *C. membranacea* (fragile sedge); the prostrate shrubs *Dryas integrifolia* (arctic avens), *Salix reticulata* (net-veined willow), *S. lanata* (woolly willow); and the forbs *Pedicularis lanata* (woolly lousewort), *Polygonum bistorta* (bistort), *Stellaria laeta* (long-stalked stitchwort) and *Senecio atropurpureus* ssp. *frigidus* (arctic senecio). Common bryophytes include *Tomenthypnum nitens*, *Hylocomium splendens*, *Ptilidium ciliare*, *Orthothecium chryseum* and *Ditrichum flexicaule*. Common lichens are *Thamnolia subuliformis*, *Cetraria* spp., *Dactylina arctica*, *Cladonia* spp. and *Cladina* spp. | IVa. Occurs on flat upland areas or in old, drained lake basins where flat-centered polygons form complexes with thermokarst pits or strangmoor. Wet areas may compose up to 40% of any given area. The moist/wet sedge tundra is also common on gentle slopes with flat-centered polygons. The IVa subunit is most extensive east of the Hulahula River. Soils of the moist areas (polygon centers especially) are Pergelic Cryaquolls. Those of the wet sites are Histic Pergelic Cryaquolls or Histic Pergelic Cryaquepts. In areas where frost scars are common, the soil complex is best described as consisting of Ruptic-Entic Pergelic Cryaquolls. |
| | IVb. DRY PROSTRATE SHRUB, FORB TUNDRA (DRYAS RIVER TERRACES). River terraces that have a dense prostrate mat of *Dryas integrifolia* with numerous small forbs and prostrate shrubs. This unit is quite dark on aerial photographs and Landsat data and has a spectral signature similar to either Wet Sedge Tundra (III) or Moist/Wet Sedge Tundra Complex (IVa), although this unit is physiognomically very different from either of these other units. This is an extensive unit along | IVb. These terraces are generally components of the riverine complex. Exept under unusual circumstances they are not flooded, being a meter or more above the active terraces or river island complex. Surfaces of these terraces still display the river island and channel features. The former commonly displays polygonal cracks and has soils resembling Fluvents with 15-50 cm of interlayered silts, sands, and organic materials |

| | Land Cover Class | Vegetation | Landform and Soil |
|---|---|---|---|
| | | rivers, particularly along the Canning River, and is used heavily by ground squirrels, lemmings, and bears. It may be possible to distinguish these terraces in some other phenological stage on Landsat scenes taken later in the summer. The primary taxa are the prostrate shrubs Dryas integrifolia (arctic avens), Salix reticulata (net-veined willow), S. rotundifolia (round-leaved willow), and Salix ovalifolia (oval-leaved willow); the herbs Astragalus alpinus (alpine milk-vetch), Oxytropis nigrescens (blackish oxytrope), Equisetum arvense (common horsetail), Artemisia arctica (arctic wormwood), Silene acaulis (moss campion), Chrysanthemum integrifolium (entire-leaved chrysanthemum), Saxifraga oppositifolia (purple mountain saxifrage), Carex membranacea (fragile sedge) and Eriophorum triste (common cottongrass); and the mosses Distichium capillaceum and Ditrichum flexicaule. | overlying river-wash sands and gravels. The depth of thaw is greater than 1 m and no water-table occurs. Former channels are wet to moist and have Pergelic Cryaquept soils. |
| V. | MOIST SEDGE, PROSTRATE SHRUB TUNDRA<br>OR<br>MOIST SEDGE/BARREN TUNDRA COMPLEX (FROST-SCAR TUNDRA) | Va. MOIST SEDGE, PROSTRATE SHRUB TUNDRA. Moderately well drained areas, located primarily along the northern part of the Foothills and in drainages. The principal taxa are similar to those described for Moist/Wet Sedge Tundra Complex (IVa). These areas may have up to 20% cover of cottongrass tussocks. Wetter facies near streams are likely to have no tussocks and high percentages of prostrate shrubs, including Salix arctica (arctic willow) and S. pulchra (diamond-leaved willow), and herbs such as Petasites frigidus (Lapland butterbur), Saxifraga punctata (cordate-leaved saxifrage), Carex aquatilis (aquatic sedge), Saxifraga hirculus (bog saxifrage), and Valeriana capitata (capitate valerian).<br>Near the coast on slightly elevated microsites, moist tundra areas are likely to contain large components of a prostrate shrub, crustose lichen type. This type is a rather sparse community, including Dryas integrifolia (arctic avens), Salix pulchra (diamond-leaved willow), Carex bigelowii (Bigelow's sedge), S. phlebophylla (veiny-leaved willow), Luzula arctica (arctic wood-rush), with considerable ground cover of small hummocks with the moss Dicranum elongatum covered by white crustose lichens (mainly Ochrolechia frigida and Lecanora epibryon). | V. This cover class is mostly in the northern or rolling foothills of the wildlife refuge and is often difficult to separate from Unit IVa in that it occupies broad sloping interfluves with flat-centered polygons. The soils are Pergelic Cryaquolls with a small percentage of Pergelic Cryaquepts. Portions of the slopes have a very high percentage of frost scars, in some cases 80-90%. These areas are especially common on crests with bedrock outcrops at or close to the surface and areas low on the slopes near drainages. Soils of the frost scars are Pergelic Cryaquepts (or Entisols). More stable areas between the frost scars (10-50% of the surface) have Pergelic Cryaquolls. The active layer thickness ranges from near a meter in the scars to between 40 and 60 cm beneath the Cryaquolls. Portions of the long, low slopes are characterized by Moist Sedge Tussock, Dwarf Shrub/Wet Dwarf Shrub Tundra Complex (water track complex) (VIIc). |

Appendix I, Table 1. Continued

| Land Cover Class | | Vegetation | Landform and Soil |
|---|---|---|---|
| | | Vb. MOIST SEDGE/BARREN TUNDRA COMPLEX (FROST-SCAR TUNDRA). Primarily well-drained areas with as much as 90% of the surface covered by frostboils or frost rings. Vegetation on the frost scars is generally sparse, with such taxa as Juncus biglumis (two-flowered rush), Petasites frigidus (Lapland butterbur), Dryas integrifolia (arctic avens), Chrysanthemum integrifolium (entire-leaved chrysanthemum) and Saxifraga oppositifolia (purple mountain saxifrage), and the mosses Rhacomitrium lanuginosum, Bryum spp., Distichium capillaceum, Drepanocladus uncinatus, etc. Inter-frost-scar areas near the coast are usually Moist Sedge, Prostrate Shrub Tundra (Va) dominated by Carex bigelowii (Bigelow's sedge), Dryas integrifolia (arctic avens), Arctagrostis latifolia (wide-leaved arctagrostis) and Equisetum arvense (common horsetail), and the moss Tomenthypnum nitens. In the Foothills, frost-scar tundra occurs mainly on slopes and ridge tops and is likely to have scattered Salix lanata (woolly willow) or S. glauca (northern willow) 10-40 cm tall. This unit is extensive but is difficult to separate on the Landsat data. On the Flaxman scene, it is more often classified as Unit V (sand), while on the Canadian scene it often appears as Unit IV (light green). | |
| VI. | MOIST SEDGE TUSSOCK, DWARF SHRUB TUNDRA | VIa. MOIST SEDGE TUSSOCK, DWARF SHRUB TUNDRA (UPLAND TUSSOCK TUNDRA ACIDIC FACIES). Relatively well drained upland tussock tundra primarily in the Foothills, with a high percentage cover of cottongrass tussocks and dwarf or prostrate shrubs. In this unit the tussocks are usually dominant, with 20-70% cover. On acidic soils the dwarf shrubs include Salix pulchra (diamond-leaved willow), Betula nana (dwarf birch), Ledum decumbens (narrow-leaved Labrador tea), Vaccinium uliginosum (bog blueberry), V. vitis-idaea (mountain cranberry), Empetrum nigrum (crowberry) and Arctostaphylos rubra (bearberry), and the bryophytes are mainly Hylocomium splendens, Sphagnum spp., Aulacomnium palustre and Ptilidium ciliare. Lichens are dominated by Cladonia spp. and Cladina spp.<br><br>VIb. MOIST SEDGE TUSSOCK, DWARF SHRUB TUNDRA (UPLAND TUSSOCK TUNDRA, ALKALINE FACIES). On more neutral or basic soils, important taxa associated with the cottongrass tussocks include Dryas integrifolia (arctic avens), Carex bigelowii (Bigelow's sedge), Salix arctica (arctic willow), S. reticulata | VI. Two facies, acid and alkaline, are recognized in this Foothills unit. Landforms are principally long slopes dominated by cottongrass tussocks that obsure flat-centered polygons. The acidic facies of this unit occur in association with deeper organic layers or with sandy and gravel conglomerate units of the underlying Cretaceous and/or Tertiary bedrock and are particularly common in the area east of the Sadlerochit River. The soils are Pergelic Cryaquepts and form a complex with numerous frost scars (Ruptic-Entic Pergelic Cryaquepts). Histic Pergelic Cryaquepts are common where watertrack units occur. Alkaline facies of this cover class are most common west of the Katakturuk River, and the soil complex is Ruptic-Entic Pergelic Cryaquolls. Water tables are generally absent in the moist portions of both facies except in water tracks and near the foot and crest of the slope. Pergelic Cryochrepts are present on the few well-drained areas within this unit. |

| Land Cover Class | Vegetation | Landform and Soil |
|---|---|---|
| | (net-leaved willow), S. lanata (woolly willow) and Arctagrostis latifolia (wide-leaved arctagrostis); the chief moss is Tomenthypnum nitens, and the lichens are mainly Cetraria spp. The alkaline soils are most often a result of the frost stirring of basic parent materials, and barren frost scars can cover a large percentage of this unit. It is unclear whether this type is more commonly classed as Unit V (sand) or VI (light brown).<br><br>Both VIa and VIb may have up to 30% coverage of other vegetation types, mainly Moist/Wet Sedge Tundra Complex (IVa) or Wet Sedge Tundra (III). | |
| VII. MOIST DWARF SHRUB, SEDGE TUSSOCK TUNDRA OR MOIST SEDGE TUSSOCK, DWARF SHRUB/WET DWARF SHRUB COMPLEX (WATER TRACK COMPLEX) | VIIa. MOIST DWARF SHRUB, SEDGE TUSSOCK TUNRA (UPLAND DWARF SHRUB, TUSSOCK TUNDRA). Similar to VIa except here the shrubs, mainly Salix pulchra (diamond-leaved willow) and Betula nana (dwarf birch), are dominant and may reach heights of up to 50 cm. | VIIa. The soils of this subunit are generally similar to those of Unit VI. |
| | VIIb. MOIST DWARF SHRUB, SEDGE TUSSOCK TUNDRA (BIRCH TUNDRA). High-centered polygons and palsas with dwarf shrub communities dominated by Betula nana (dwarf birch) and Eriophorum vaginatum (sheathed cottongrass). These areas occur on high-centered polygons toward the southern end of the coastal plain and in low thermokarst drainage area in the Foothills. In some communities the birch is completely dominant and the cottongrass is absent. Other typical taxa in these sites are Rubus chamaemorus (cloudberry), Ledum decumbens (narrow-leaved Labrador tea), Pedicularis labradorica (Labrador lousewort), and Vaccinium vitis-idaea (mountain cranberry). Sphagnum mosses dominate the ground layer with numerous Cladonia and Cladina lichens. | VIIb. This subunit occurs principally in the headwater areas of many small, often beaded drainages in the Foothills area. In such areas thermal erosion combines with natural thermokarst to produce high-centered polygons, which may have a meter or more of microrelief. Soils that in uneroded portions of the headwater basins are Histic Pergelic Cryohemists are converted to (Sapric) Histic Pergelic Cryaquolls or Pergelic Cryosaprists because of the better drainage afforded by the microrelief. A feature of headwater basins and some broad interfluves (Unit III), especially in the southern part of the Foothills, are birch-covered peat plateaus (generally palsas) that stand 0.5-1 m above the surrounding wet sedge tundra. The soils of these features are fibrous Histic Pergelic Cryaquepts in which large volumes of segregation ice occur. Ice volumes increase with depth, and individual layers may be a meter or more thick. |
| | VIIc. MOIST SEDGE TUSSOCK, DWARF SHRUB/WET DWARF SHRUB TUNDRA COMPLEX (water track complex). Slopes in the Foothills with water tracks. In these areas the sedge tussock, dwarf shrub tundra forms a complex with shrub communities in the water tracks. The height and density of the water track shrubs vary, but the dominant taxon is generally Salix pulchra | VIIc. This unit differs from Unit VI primarily because of the increased abundance of water tracks, up to 30% of some slopes. These drainage channels run downslope, curving toward small streams. Soils in the tracks are primarily (Fibric) Histic Pergelic Cryaquepts. Intertrack areas are drier, with Pergelic Cryaquepts or |

| Land Cover Class | Vegetation | Landform and Soil |
| --- | --- | --- |
| | (diamond-leaved willow). Other important taxa in water tracks include Salix arctica (arctic willow), Betula nana (dwarf birch), Carex aquatilis (aquatic sedge), Eriophorum angustifolium (common cottongrass) and other taxa typically found in Wet Sedge Tundra (IIIa). | Pergelic Cryaquolls. A shallow water table is present in the tracks. Thaw in the tracks is somewhat greater than on intertrack areas. |
| VIII. SHRUB TUNDRA | VIIIa. SHRUB TUNDRA (NONCOMPLEX). South-facing slopes in the Foothills with communities dominated by dwarf and medium-height (up to 2 m) willows, birches and/or alders. These sites are relatively warm and often rocky with a variety of microsites, which contribute to great species diversity. Typical taxa include Salix spp. (willows), Betula glandulosa (shrub birch), Alnus crispa (mountain alder), Lupinus arcticus (arctic lupine), Artemisia tilesii (Tilesius' wormwood), A. arctica (arctic wormwood), Aconitum delphinifolium (delphinium-leaved monkshood), Delphinium brachycentrum (northern dwarf larkspur), Potentilla fruticosa (shrubby cinquefoil), Bromus pumpellianus (arctic brome-grass), Equisetum arvense (common horsetail), Festuca altaica (rough fescue), Senecio lugens (black-tipped grounsel), Castilleja caudata (pale paintbrush), Carex microchaeta (small-bristled sedge), Arnica frigida (nodding arnica) A. alpina (alpine arnica), Petasites frigidus (Lapland butterbur), Saxifraga tricuspidata (three-toothed saxifrage), Vaccinium uliginosum (bog blueberry), V. vitis-idaea (mountain cranberry, Aster siberica (Siberian aster), Ledum decumbens (narrow-leaved Labrador tea), and Empetrum nigrum (crowberry). | VIIIa. This unit is common on steep (25-65%) slopes in the southern part of the Foothills and on vegetation-covered slopes in the alpine areas of the wildlife refuge. Such slopes are characterized by one or more forms of mass wasting, most commonly solifluction. Non-soil and different kinds of soil are often juxtaposed, forming a mosaic composed of Pergelic Cryorthents, Pergelic Histic Pergelic Cryaquolls (Pergelic and Histic Pergelic Cryaquepts where ice bedrock types are near the surface), and in some cases Pergelic Cryosaprists. |
| | VIIIb. SHRUB TUNDRA (WATER TRACK COMPLEX). This unit is very similar to VIIc, except here the water track shrub communities dominate. The unit also appears in some stream drainages, with abundant medium-height and tall willows. | VIIIb. This subunit is similar to VIIc except the water track portion of the complex is dominant. In stream drainages the soils are formed on alluvium and may be Pergelic Cryaquepts, Pergelic Cryorthents or soils similar to those of IVb. |
| IX. PARTIALLY VEGETATED AREAS | IXa. RIVER BARS. Partially vegetated river bars have a wide diversity of taxa that include Epilobium latifolium (river beauty), Artemisia spp. (wormwoods), Salix spp. (willows), Castilleja caudata (pale paintbrush), Hedysarum alpinum (alpine hedysarum), H. mackenzii (Mackenzie's hedysarum), Arctostaphylos rubra (bearberry), Oxytropis campestris (yellow | IXa. River bars are included in river island complexes. Those that lack vegetation or soils are treated as river-wash deposits. Some bars or river islands, although subject to seasonal flooding and scouring, receive mostly silts and sands. Those that are partly vegetated have soils that are similar to those of unit IVb and |

| Land Cover Class | Vegetation | Landform and Soil |
|---|---|---|
| | oxytrope), Anemone parviflora (small-flowered anemone), Equisetum arvense (common horsetail), Trisetum spicatum (spiked trisetum), Deschampsia caespitosa (tufted hairgrass) and Astragalus alpinus (alpine milk-vetch). | are Pergelic Cryorthents. The principal difference is that the silt and/or sand upper horizon is generally less than 10 cm thick and lacks zones of organic materials. |
| | IXb. ALPINE TUNDRA. Many alpine tundra areas appear to be partially vegetated because of the large amount of barren talus and rocks. The character of alpine tundra varies considerably, but the more completely vegetated areas have extensive moss mats (mainly Hylocomium splendens) with numerous prostrate shrubs, such as Dryas octopetala (mountain avens), Salix phlebophylla (veiny-leaved willow) and S. chamissonis (Chamisso's willow), and herbs such as Carex microchaeta (small-bristled sedge), Geum glaciale (glacier avens), Saxifraga bronchialis (spotted saxifrage), S. davurica (davurian saxifrage), S. tricuspidata (three-toothed saxifrage), S. serpyllifolia (thyme-leaved saxifrage); and many lichens including Cladina spp., Nephroma expallidum, Cetraria spp., Dactylina arctica and Sphaerophorus globosus. | IXb. Alpine areas, above the solifluction slopes that are often shrub covered (Unit VIII), are composed of partially vegetated, steep (over 50%) talus slopes and narrow crests; the flatter ones have sorted and unsorted stone nets and/or frost scars. The stable areas that support most of the vegetation have Pergelic Cryorthent soils and if sufficient fines are present, Pergelic Cryochrepts. The soil pattern is Ruptic-Entic Pergelic Cryorthents and/or Cryochrepts, both with a Sapric organic surface horizon up to 5 cm thick. |
| | IXc. SORTED STONE NETS. Some extensive sorted polygons occur in the Jago and Okpilak drainages. These contain rocks covered by lichens such as Umbilicaria spp., Lecanora spp., Lecidea spp., Rhizocarpon spp., and Alectoria minuscula. | IXc. Large block-bordered polygons and block fields are noted in the southern parts of the Jago and Okpilak drainages. In some cases Ruptic-Entic Pergelic Cryochrepts and/or Cryaquepts are developed on the finer-textured materials in the polygon centers. |
| | IXd. BEACHES. Some coastal beaches and mud flats are sparsely vegetated with Carex subspathacea (Hoppner sedge) and Puccinellia phryganodes (creeping alkali-grass) and other taxa similar to wet saline tundra (IIId). | IXd. Beaches generally do not have sufficient stability to develop soils. In the few cases when they are developed under sedges, they are Cryorthents. |
| | IXe. SAND DUNES. Dune communities occur in the delta of the Canning River. Species are similar to those ocurring on river bars (IXa). The most sparsely vegetated dunes are dominated by Elymus arenarius (dune grass). More stable dunes have communities similar to the Dryas river terrace community (IVb). | IXe. Sand dunes are not abundant in the wildlife refuge, occurring mostly in the delta regions of the Canning and Jago rivers. Where sufficient vegetation exists to stabilize or partially stabilize them, the soils are Pergelic Cryopsamments. The active layer is greater than |

Appendix I, Table 1. Continued

| | Land Cover Class | Vegetation | Landform and Soil |
|---|---|---|---|
| | | | 1 m thick. Wet sandy materials between the dunes have Pergelic Cryaquept soils. No soil is recongized on active dunes lacking vegetation. |
| X. | BARREN GRAVEL OR ROCK | X. BARREN GRAVEL OR ROCK. Light-colored barren gravel or rock occurs in a variety of places that include bare river gravels, gravel and sand spits, alpine barrens and cultural barrens such as the runway and roads at Barter Island. Some gravelly ridge tops in the Foothills are in this unit. These areas actually have a rich but sparse flora that includes *Potentilla biflora* (two-flowered cinquefoil), *Dryas octopetala* (mountain avens), *Artemisia arctica* (arctic wormwood), *Castilleja caudata* (pale paintbrush), *Pedicularis verticillata* (whorled lousewort) and other taxa similar to gravel river bars (IXa). | X. Barren gravel areas are mostly included in the river island complex and do not have soils (river wash deposits, subunit IVb). The water tables reflect river water level, and permafrost is deep or absent. Some gravel barrens and rock outcrop areas occur, especially on uplands. Here a water table is absent and ice-rich permafrost, if present at all, lies at depths greater than 1 m. |
| XI. | WET GRAVEL OR MUD | XI. BARREN MUD OR WET GRAVEL. This unit has a somewhat darker spectral signature than Unit X. It includes extensive areas of barren mud in the deltas of rivers and wet gravels in the rivers and beaches. Some dark-colored barren rocks in the mountains are also in this unit. | XI. These areas are within the riverine system and occur mostly in the deltas areas, although wet gravels may occasionally be formed on flat uplands and beaches. In most cases shallow water tables and a thick active layer occur. No soils are recognized. |
| XII. | ICE | XII. ICE. River icings (aufeis) occur in the braided stream channels of most of the larger rivers. | XII. No soils are designated for aufeis areas. |

APPENDIX II.

Appendix II, Table 1. Hierarchical classification scheme for tundra on the coastal plain and foothills of the Arctic National Wildlife Refuge, Alaska (Walker et al. 1933).

| Level A | Level B | Level C | Level D |
|---|---|---|---|
| VERY SMALL-SCALE UNITS | LANDSAT LAND COVER UNITS (suggested map colors) | PHOTO-INTERPRETED MAP UNITS | TYPICAL PLANT COMMUNITIES |
| A. Water | I. Water (light blue) | Ia. Water | No vegetation |
| B. Wet Tundra | II. Very Wet Tundra (dark blue) | IIa. Shallow water (pond margins) | No vegetation |
| | | Non complex subunits:<br>IIb. Aquatic grass tundra | Aquatic *Arctophila fulva* grass tundra |
| | | IIc. Aquatic sedge tundra | Aquatic *Carex aquatilis* sedge tundra |
| | | IId. Aquatic forb tundra | Aquatic *Hippuris vulgaris*, *Caltha palustris*, *Menyanthes trifoliate* forb tundra (aquatic tundra, inland areas) |
| | | Common complex subunits:<br>IIe. Water/tundra complex: (pond complex) | Typical communities listed under Ia, IIa, IIIa, IIb, IIIc, and Va |
| | III. Wet Tundra (dark green) | Non complex subunits:<br>IIIa. Wet graminoid tundra | Wet *Carex aquatilis*, *Scorpidium scorpiodes* sedge tundra (wettest facies of wet alkaline tundra)<br>Wet *Carex Chordorrhiza*, *Eriophorum scheuchzeri*, *Potentilla palustris* sedge tundra (wet acidic tundra - inland areas)<br>Wet *Carex aquatilis*, *Eriphorum angustifolium*, *Pedicularis sudetica* ssp. *albolabiata*, *Drepanocladus brevifolius* sedge tundra (wet alkaline tundra)<br>Wet *Eriophorum angustifolium*, *Dupontia fisheri*, *Campyulium stellatum* graminoid tundra (wet acidic tundra, coastal areas) |
| | | IIIb. Wet low shrub, graminoid tundra | Wet *Salix planifolia* ssp. *pulchra*; *Carex aquatilis*, *Sphagnum* spp. low shrub, sedge tundra |
| | | IIIc. Wet graminoid tudnra (saline areas) | Wet *Carex*, *subspathacea*, *Punccinellina phryganodes*, *Stellaria humifusa*, *Cochlearia officinalis* sedge tundra |
| | | Common Complex Subunits:<br>IIId. Wet sedge tundra/water complex (pond complex) | Typical communities listed under Ia, IIa, and IIIa |
| | | IIIe. Wet sedge/moist sedge, dwarf shrub tundra complex (wet patterned-ground complex) | Typical communities listed under IIIa and Va |

Appendix II, Table 1. Continued.

| Level A<br>VERY SMALL-SCALE UNITS | Level B<br>LANDSAT LAND COVER UNITS (suggested map colors) | Level C<br>PHOTO-INTERPRETED MAP UNITS | Level D<br>TYPICAL PLANT COMMUNITIES |
|---|---|---|---|
| C. Moist Tundra | IV. Moist/Wet Tundra Complex (light green) | Common Complex Subunits:<br>IVa. Moist sedge, dwarf shrub/ wet graminoid tundra complex (moist patterned-ground complex) | Typical communities listed under Va and IIa. |
| | V. Moist or Dry Tundra (tan) | Non Complex Subunits:<br>Va. Moist sedge, dwarf shrub tundra | Moist Carex bigelowii, Eriophorum angustifolium ssp. triste, Dryas integrifolia, Salix reticulata, Tomenthypnum nitens, Thamnolia subuliformis sedge, dwarf shrub tundra (moist alkaline tundra)<br><br>Moist Luzula arctica, Poa arctica, Saxifraga cernua, Salix planifolia ssp. pulchra, Dicranum elongatum, Ochrolechia frigida graminoid, dwarf shrub, crustose lichen tundra (moist coastal acidic tundra)<br><br>Moist Carex aquatilis, Eriophorum angustifolium ssp. triste, Salix planifolia ssp. pulchra, Campylium stellatum sedge, dwarf shrub tundra (moist acidic tundra, wetter facies)<br><br>Moist Carex bigelowii, Dryas integrifolia, Lupinus arcticus, Salix lanata, ssp. richardsonii, Arctagrostis latifolia, Equisetum arvense, Tomenthypmum nitens, sedge, dwarf shrub, forb tundra (moist non-tussock alkaline tundra) |
| | | Vb. Moist tussock sedge, dwarf shrub tundra | Moist Eriophorum vaginatum Dryas integrifolia, Salix reticulata, S. arctica, Tomenthypnum nitens, Thamnolia subuliformis, tussock sedge, dwarf shrub tundra (alkaline tussock tundra)<br><br>Moist Eriophorum vaginatum, Dryas integrifolia, Salix planifolia ssp. pulchra, Salix reticulata, Hylocomium splendens, Ptilidium ciliare, Cetraria cucullata tussock sedge, dwarf shrub tundra (neutral to slightly acidic tussock tundra) |
| | | Vc. Dry dwarf shrub, crustose lichen tundra (Dryas tundra) | Dry Dryas integrifolia, Carex rupestris, Oxytropis nigrescens, Salix reticulata, Ditrichum flexicaule, Lecanora epibryon dwarf shrub, forb, crustose lichen tundra (Dryas river terraces)<br><br>Dry Dryas integrifolia, Astragalus alpinus, Oxytropis borealis, Salix reticulata, Distichium capillaceum, Lecanora epibryon dwarf shrub, forb, crustose lichen tundra (Dryas river terraces) |

Appendix II, Table 1. Continued.

| Level A<br>VERY SMALL-SCALE UNITS | Level B<br>LANDSAT LAND COVER UNITS (suggested map colors) | Level C<br>PHOTO-INTERPRETED MAP UNITS | Level D<br>TYPICAL PLANT COMMUNITIES |
|---|---|---|---|
| | | Vd. Dry dwarf shrub, fruticose lichen tundra (Dry acidic tundra) | Dry Dryas octopetala, Arctostaphylos alpina, Empetrum nigrum, Salix phlebophylla, Rhytidium rugosum, Alectoria nigricans dwarf shrub, fruticose lichen tundra (dry acidic tundra on kames and moraines in foothills)<br><br>Dry Salix rotundifolia, Pedicularis kanei, Luzula arctica, Polytrichum sp., Alectoria nigricans, Cetraria islandica dwarf shrub, fruticose lichen tundra (dry acidic tundra near coast) |
| | | Common Complex Subunit:<br>Ve. Moist graminoid, dwarf shrub tundra/barren complex (frost-scar complex) | Typical communities listed under Va and Vb plus either completely barren, frost-scars or communities such as: Dry Saxifraga oppositifolia, Dryas integrifolia, Chrysanthemum integrifolium, Juncus biglumis, Arctagrostis latifolia, Ochrolechia frigida barren (alkaline frost scars) |
| | VI. Moist Tussock Sedge, Low Shrub Tundra (brown) | Non complex Subunit:<br>VIa. Moist tussock sedge, low shrub tundra (acidic tussock tundra) | Moist Eriophorum vaginatum, Salix planifolia ssp. pulchra, Betula nana ssp. exilis, Ledum palustre ssp. decumbens, Vaccinium spp., Sphagnum spp., Cladonia spp. tussock sedge, low shrub tundra |
| | | Complex Subunits:<br>VIb. Moist tussock sedge, low shrub tundra/tall shrub complex (alder tundra savanna) | Typical communities listed under Vb and VIa plus widely spaced Alnus crispa |
| | | VIc. Moist tussock sedge, low shrub/wet low shrub tundra complex (water track complex) Note: This complex may appear as sub-unit of VI or VII depending on the density of water tracks. | Typical communities listed under VIa and VIIIa |
| | VII. Moist Shrub-rich Tundra (dark brown) | Non-Complex Subunits:<br>VIIa. Moist low shrub, tussock sedge tundra (shrubby tussock tundra) | Moist Salix planifolia ssp. pulchra, Betula nana ssp. exilis, Eriophorum vaginatum, Ledum palustre ssp. decumbens, Vaccinium spp., Sphagnum spp. low shrub, tussock sedge tundra |
| | | VIIb. Moist low shrub, moss tundra (Sphagnum-rich dwarf shrub tundra) | Moist Rubus chamaemorus, Ledum palustre spp. decumbens, Betula nana, spp. exilis, Vaccinium spp., Sphagnum spp. Cladonia spp. dwarf shrub, moss tundra |
| | | VIIc. Dry low shrub, fruticose lichen tundra (mainly river bars) | Dry Betula nana ssp. exilis, Ledum palustre ssp. decumbens, Cladina spp., low shrub, fruticose lichen tundra |

Appendix II, Table 1. Continued.

| Level A<br>VERY SMALL-SCALE UNITS | Level B<br>LANDSAT LAND COVER UNITS (suggested map colors) | Level C<br>PHOTO-INTERPRETED MAP UNITS | Level D<br>TYPICAL PLANT COMMUNITIES |
|---|---|---|---|
| | | Complex Subunit:<br>VIId. Moist tussock sedge, low shrub/ wet low shrub tundra complex (water track complex -- see note under VIc.) | Typical communities listed under VIa and VIIa |
| D. Shrubland | VIII. Shrubland or Shrub Tundra (red) | VIIIa. Wet low shrub tundra | Wet *Salix planifolia* ssp. *pulchra*, *Betula nana* ssp. *exilis*, *Sphagnum* spp. low shrub tundra (wet willow tundra)<br><br>Wet *Betula nana* ssp. *exilis*, *Sphagnum* spp. low shrub tundra (wet birch tundra) |
| | | VIIIb. Moist low shrub tundra | Moist *Betula nana* spp. *exilis*, *Ledum palustre* ssp. *decumbens*, *Salix planifolia* ssp. *pulchra*, *Vaccinium* spp., *Cladonia* spp. low shrub tundra (moist birch tundra)<br><br>Moist *Betula nana* ssp. *exilis*, *Vaccinium uliginosum*, *Potentilla fruticosa*, *Shepherdia canadensis*, *Salix* spp., *Festuca altaica* low shrub tundra (south facing shrub tundra in foothills)<br><br>Moist *Alnus crispa*, *Betula nana* ssp. *exilis*, *Salix* spp. low shrub tundra (alder shrub tundra) |
| | | VIIIc. Moist shrubland (closed riparian shrubland) | Moist *Salix alaxensis*, *Salix* spp. tall shrubland (willow riparian shrubland)<br><br>Moist *Betula nana* ssp. *exilis*, *Betula glandulosa* low shrubland (birch riparian shrubland) |
| E. Partially Vegetated and Barren | IX. Partially vegetated (violet) | Riparian areas:<br>IXa. Dry, barren/low shrub complex (open riparian shrubland) | Typical communities and ground cover listed under VIIIc and Xa. |
| | | IXb. Dry barren/dwarf shrub, forb grass complex (forb-rich river bars) | Typical communities listed under Vc, Xa, also mixed forb grass and dwarf shrub communities such as:<br>Dry *Bromus pumpellianus*, *Festuca rubra*, *Astragalus alpinus*, *Androsace chamaejasme*, *Salix ovalifolia* grass, forb, dwarf shrub tundra (forb-rich river bars)<br>Dry *Dryas integrifolia*, *Artemisia borealis*, *A. glomerata*, *Salix ovalifolia*, *Androsace chamaejasme* (dwarf shrub, forb tundra (Dryas river bars near arctic coast) |

Appendix II, Table 1. Continued.

| Level A<br>VERY SMALL-SCALE UNITS | Level B<br>LANDSAT LAND COVER UNITS (suggested map colors) | Level C<br>PHOTO-INTERPRETED MAP UNITS | Level D<br>TYPICAL PLANT COMMUNITIES |
|---|---|---|---|
| | | IXc. Dry barren/forb complex | Dry Epilobium latifolium, Artemisia arctica, Wilhelmsia physodes forb barren (active river channels) |
| | | IXd. Dry barren/low shrub forb complex (open riparian shrubland) | Dry Salix alaxensis, Salix spp. Hedysarum spp. Astragalus alpinus, Equisetum arvense, Oxytropis campestris, O.borealis, Anemone parviflora low shrub, forb tundra (river bars inland) |
| | | Sand Dunes: | |
| | | IXe. Dry barren/grass complex (sand dune grassland) | Dry Elymus arenarius grass tundra (sand dune grassland) |
| | | IXf. Dry barren/dwarf shrub, grass complex (sand dune steppe) | Dry Artemesia borealis, A. glomerata, Deschampsia caespitosa, Trisetum spicatum dwarf shrub, grass tundra (sand dune steppe) |
| | | IXg. Dry barren/low shrub complex (sand dune scrub) | Dry Salix alaxensis, S. glauca, Elymus arenarius, Carex obtusata, Dryas integrifolia low shrub, tundra (sand dune scrub) |
| | | Beaches, river deltas, and estuaries: | |
| | | IXh. Wet barren/wet sedge tundra complex (barren/saline tundra complex) | Typical ground cover listed under IIIb. |
| | | IXi. Dry barren/forb, graminoid complex (coastal barrens) | Dry Cochlearia officinalis, Stellaria humifusa, Puccinellia phryganodes, P. andersonii, Salix ovalifolia, Potentilla pulchella forb, graminoid tundra (coastal saline barrens) |
| | | Mountainous areas: | |
| | | IXj. Dry barren/dwarf shrub, graminoid tundra complex (dry alpine tundra) | Typical ground cover listed under Xd, Vc, or the following, among many others:<br>Dry Dryas octopetala, Salix phlebophylla, Carex microchaeta, Kobresia myosuroides, Saxifraga bronchialis, Hierochloe alpina, Potentilla hyparctica, Minuartia arctica dwarf shrub, graminoid tundra (dry alpine tundra) |
| | | IXk. Moist barren/moss, forb, dwarf shrub tundra (moist alpine tundra) | Moist Hylocomium splendens, Saxifraga bronchialis, Saxifraga tricuspidata, Salix phlebophylla, S. chamissonis, Cladonia spp. moss, forb, dwarf shrub tundra |
| | | IXl. Moist barren/fruticose lichen dwarf shrub tundra | Moist Cladina spp., Ledum palustre ssp. decumbens, Vaccinium uliginosum fruticose lichen, dwarf shrub tundra |

Appendix II, Table 1. Continued.

| Level A<br>VERY SMALL-SCALE UNITS | Level B<br>LANDSAT LAND COVER UNITS (suggested map colors) | Level C<br>PHOTO-INTERPRETED MAP UNITS | Level D<br>TYPICAL PLANT COMMUNITIES |
|---|---|---|---|
| | X. Light-colored Barrens (Note: Most areas classed as barrens are likely to have some vegetation depending on the micro site, but ground cover is less than 30%) | Xa. River gravels | Completely barren or with typical communities listed under IXb, IXc, IXd |
| | | Xb. Sand dunes | Typical communities listed under IXe, IXf, IXg |
| | | Xc. Barren gravel outcrops | Typical communities listed under Vd or the following, among many others:<br>Dry Dryas octopetala, Lupinus arcticus, Potentilla biflora, Smelowski calycina, Saxifraga tricuspidata, Salix phlebophylla, Silene acaulis dwarf shrub, forb barren (gravel outcrops) |
| | | Xd. Talus slopes and blockfields | Dry Rhizocarpon spp., Lecidea spp., Umbilicaria spp., Cetraria spp. crustose lichen barren (blockfields and talus) |
| | | Xe. Gravel roads and pads | Completely barren |
| | XIa. Dark Colored Barrens (gray) | XIa. Wet mud | Completely barren or with communities listed under IIIb. |
| | | XIb. Wet or dark-colored gravels | Completely barren |
| | | XIc. Bare peat | Mostly barren areas along the coast caused by storm surges or man-made disturbances, communities listed under IIIb. |
| | | XId. Talus slopes and block fields | Same as Xd |
| F. Ice | XII. Ice (white) | XII. Ice | Compeletly barren |

Appendix II, Table 2. Mapping codes for vegetation, land form, and surface form used in the 1:63,360 scale geobotanical mapping effort on the Arctic National Wildlife Refuge, Alaska (Walker et al. 1983).

| Vegetation | | Landform | | Surface form | |
|---|---|---|---|---|---|
| Code | Mapping Unit (see Appendix II, Table 1, line C) | Code | Description | Code | Description |
| 1 | Water (Ia) | 1. | Drained thaw lake basin or developing basins in residual surfaces of the coastal plain | 1. | Undifferentiated lowland patterned ground; includes low-centered polygons, pond complexes, strangmoor, disjunct polygon rims, and/or low featureless terrain, generally with less than 0.5m of micro-relief. The patterns are not distinct on the 1:60,000 CIR photographs. |
| 2 | Aquatic grass tundra (IIb) | 2. | Basin associated with hilly terrain often with thermokarst features | 2. | Well developed low-centered polygons or disjunct polygon rims strangmoor, generally with more than 0.5 m rim-trough relief. The pattern is distinct on the 1:60,000 CIR photographs. |
| 3 | Aquatic sedge tundra (IIC) | 3. | Residual Surface | 3. | Undifferentiated upland patterned ground; includes weakly developed high-centered polygons, some poylgons of mixed frost scars and featureless upland terrain, generally with less than 0.5 m micro-relief. |
| 4 | Aquatic forb tundra (IId) | 4. | Hill slope | 4. | Well developed high-centered polygons or mixed high- and low-centered polygons, generally with more than 0.5 m of relief between polygon centers and troughs. |
| 5 | Wet graminoid tundra (IIIa) | 5. | Hill crest | 5. | Weakly defined water track pattern, generally with less than 1 m of relief between track and inter-track areas. |
| 6 | Wet graminoid tundra (saline areas)(IIIb) | 6. | Talus slope | 6. | Well defined water track pattern, generally with more than 1 m of relief between track and inter-track areas. |
| 7 | Wet low shrub, graminoid tundra (IIIc) | 7. | Moraine | 7. | Slope with incised drainages with more than 1.5 m of relief. |
| 8 | Wet low shrub tundra (VIIIa) | 8. | Kame | 8. | Solifluction features, including garlands, lobes and stripes, generally with more than 1 m of micro-relief. |
| 9 | Moist sedge, dwarf shrub tundra (Va) | 9. | Elevated marine terrace | 9. | Thermokarst pits. |
| 10 | Moist tussock sedge, dwarf shrub tundra (Vb) | 10. | Pingo | 10. | Alluvium or remnant pattern of stabilized braided flood plain or delta, stream channel patterns are present but surface forms are not distinguishable on 1:60,000 CIR photographs. |
| 11 | Moist tussock sedge, low shrub tundra (VIa) | 11. | Active braided floodplain | 11. | River icing. |
| 12 | Moist low shrub, tussock sedge tundra (VIIa) | 12. | Stabilized braided floodplain | 12. | Frost scars. |
| 13 | Moist or dry dwarf shrub, fruticose lichen tundra (Vd) | 13. | Meander floodplain | 13. | Incised stream drainage with steep stream banks. |
| 14 | Moist low shrub, moss tundra (VIIb) | 14. | Old floodplain with thaw lakes and/or well-developed ice-wedge polygons | 14. | Sorted stone or gravel polygons, or blockfields. |
| 15 | Moist low shrub tundra (VIIIa) | 15. | Stream drainage | 15. | Active dunes. |
| 16 | Moist shrubland (riparian areas)(VIIIc) | 16. | Sand dunes | 16. | Stable dunes with patterned ground including high-centered polygons and reticulate pattern (both are not visible on 1:60,000 scale photographs). |
| | | 17. | Beach | 17. | Beach |
| | | 18. | Coastal Plain with marine deposits | | |
| | | 19. | Spit | | |
| | | 20. | Bluff steep slopes | | |
| | | 21. | Bluff crest | | |

Appendix II, Table 2. Continued

| Vegetation | | Landform | | Surface form | |
|---|---|---|---|---|---|
| Code | Mapping Unit (see Appendix II, Table 1, line C) | Code | Description | Code | Description |
| 17 | Moist shrub savanna tundra (VIb) | 22. | Alluvial fan | 18. | Bedrock outcrop |
| | | | | 20. | Water. |
| 18 | Moist fruticose lichen, dwarf shrub tundra (alpine areas (IXl) | 23. | Colluvial deposits including mudflows and solifluction deposits | 60. | Road or pad. |
| 19 | Dry dwarf shrub, crustose lichen tundra (Vc) | 24. | Tidal flat | | |
| | | 25. | River delta | | |
| 20 | Dry dwarf shrub, forb tundra (Dryas river terraces)(Vc) | 26. | Island | | |
| | | 50. | Water | | |
| 21 | Dry dwarf shrub, forb, grass tundra (river bars near sea coast) (IXb) | 51. | Lake or pond | | |
| | | 52. | River or stream | | |
| | | 53. | Ocean | | |
| 22 | Dry low shrub, forb, grass tundra (river bars inland) (IXd) | 54. | Artificial impoundment | | |
| | | 60. | Pad or road | | |
| 23 | Dry low shrub, fruticose lichen tundra (mainly river bars) (VIIc) | | | | |
| 24 | Dry forb tundra (IXc) | | | | |
| 25 | Dry crustose and foliose lichen land (talus and blockfields) (Xd) | | | | |
| 26 | Dry grassland (dunes) (IXe) | | | | |
| 27 | Dry shrubland (dunes) (IXg) | | | | |
| 28 | Barren (X and XI) | | | | |
| 29 | Ice (aufeis)(XII) | | | | |

Appendix II, Table 3  Mapping codes for vegetation density and percentage of open water used in the 1:63,360 scale geobotanical mapping effort on the Arctic National Wildlife Refuge, Alaska (Walker et al. 1983).

| Vegetation density | | Percentage Open Water | |
|---|---|---|---|
| Code | number of vegetation types in unit | Code | % |
| 1 | 1-2 | 1 | 0-5 |
| 2 | 3-5 | 2 | 6-30 |
| 3 | 5 | 3 | 31-60 |
| | | 4 | 61-90 |
| | | 5 | 91-100 |

APPENDIX III.

Appendix III, Table 1. Preliminary classification for a Landsat-derived vegetation map of the coastal plain study area, Arctic National Wildlife Refuge

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1. FOREST. This vegetation class is formed of tree species at least 5 m tall. Included within the concept of forest is secondary tree growth temporarily less than 5 m in height, i.e., intermediate succession stages.

a. DECIDUOUS FOREST/TALL SHRUB has 25-100% tree cover. Betula papyrifera, Populus tremuloides and P. balsamifera are the dominant species occurring in this class. Salix alaxensis may also be classified in this class of alluvial terraces by itself or mixed with P. balsamifera. Also included are Alnus crispa and Salix spp., Rosa acicularis, Shepherdia canadensis, and Calamagrostis canadensis. This class is normally found on well drained to moist soils associated with hills and alluvial terraces south of the continental divide. North of the divide this type is rare, occurring mainly along the Canning River, and in a small area near Sadlerochit Springs.

2. SCRUB. This vegetation class is predominantly composed of shrubs (greater than 25 percent cover) up to 5 m in height.

a. ALLUVIAL DECIDUOUS SCRUB occurs on frequently flooded gravel sites dominated by Salix planifolia ssp. pulchra and S. alaxensis. On some sites especially on the coastal plain, Betula spp. (dwarf birch) may occur with Salix in older alluvial terraces. The number of species occurring with the above species as co-dominants or as understory are many and may include: Salix lanata, S. richardsonii, S. glauca, S. brachycarpa, S. hastata, S. reticulata, Arctostaphylos rubra, Dryas integrifolia, Equisetum arvense, E. variegatum, E. scirpoides, Carex spp., Festuca spp., Juncus castaneus, Petasites spp., Hedysarum spp., and Hylocomium spp. On the coastal plain, this class usually occurs in small patches which can not be distinguished on Landsat imagery, and is classified as scarcely vegetated floodplain.

b. DRY PROSTRATE DWARF SCRUB formation occurs on river terraces, slightly elevated microsites on the coastal plain, and upper slope positions in the foothills. Bare soil is often an important component of the ground surface as a result of frost action. Because of the harsh environment, plants do not achieve heights greater than 10 cm. Some of the more commonly occurring shrubs are Dryas integrifolia (usually dominant) and D. octopetala with Arctostaphylos rubra, Salix reticulata, S. rotundifolia and Cassiope tetragona. Nonwoody species include Saxifraga hirculus, S. oppositifolia, Polygonum bistorta, Petasites arctica, Polemonium spp., Equisetum arvense, Carex spp., Festuca spp., Hierochloe spp., Epilobium latifolium, Geum glaciale, and the lichen Cetraria spp.

c. MOIST PROSTRATE DWARF SCRUB contains prostrate dwarf shrub and sedge formations occupying mesic habitats on gentle to moderately steep slopes. In the foothills, these habitats are frequent on mid to lower slopes which receive subsurface drainage from adjacent terrain. Dryas integrifolia is often the dominant species. Equisetum arvense and the moss, Tomenthypnum nitens, are characteristic species of this formation. Carex bigelowii gives the habitat a hummocky surface.

Moist habitats on slightly elevated microsites in the coastal plain, and alluvial terraces in the foothills and mountains are often drier, owing to greater exposure and lack of water from surrounding terrain. Lichens are more important than mosses in these drier habitats. These habitats are very similar to the moist microsites of the wet/moist dwarf shrub, graminoid land cover class. Other species important to this type include Salix arctica, S. lanata, S. pulchra, Rubus chamaemorus, Saxifraga hirculus, S. punctata, Petasites frigidus, Eriophorum vaginatum, and Carex aquatilis.

d. MESIC ERECT DWARF SCRUB contains dwarf shrubs, primarily from the taxa Betula spp., Salix spp., Vaccinium uliginosum, and Cassiope tetragona. These shrubs are usually 0.1 m to 0.5 m in height with interlocking branches. This type is common on low rolling hills. On hill sides at lower elevations (below 900 m), graminoid tussocks often occur with the dwarf shrub. Major tussock producing plants include Eriophorum vaginatum and Carex bigelowii. Major shrub species include Betula glandulosa, B. nana, Salix glauca, S. reticulata, S. planifolia ssp. pulchra, Ledum decumbens, Vaccinium vitis-idaea, and Empetrum nigrum. Other species present may include Carex lugens, Carex scirpoidea, Equisetum arvense, E. scirpoides, Hylocomium splendens, Tomenthypnum nitens, and Sphagnum spp.

3. HERBACEOUS. Herbaceous plants are without significantly woody tissue and die back to the ground surface each year. There are two major growth forms: graminoids and forbs. Graminoids include all nonwoody grasses and grasslike plants such as Carex (sedges) and Eriophorum (cottongrass). Forbs are broad-leaved herbaceous plants such as Petasites (coltsfoot) and Epilobium (fireweed).

a. VERY WET GRAMINOID is a graminoid-dominated formation associated with aquatic habitats surrounding large, open bodies of fresh water; very wet habitats which contain numerous small bodies of open water; and coastal habitats frequently inundated with salt water. Surface forms include low-centered polygons with abundant standing water, thaw lake basins, the littoral zones of lakes and the coastline. Arctophila fulva is the primary species in deeper water, up to 1 m deep, with Carex aquatilis, Eriophorum scheuchzeri, and Eriophorum angustifolium dominating areas where the water is less than 30 cm deep.

b. WET GRAMINOID formations are associated with wet habitats. These habitats often receive water by surface and subsurface flow from surrounding terrain. The habitats generally have standing water throughout the summer. Vegetative cover is continuous, as depth of water is not a limiting factor to plant establishment and growth. The habitat has few drained microsites associated with polygon rims, strangmoor, hummocks, etc. Landforms where these habitats occur are river deltas, drained lake basins, and river channels, where surface forms are low-centered polygons, and strangmoor. Primary taxa include numerous Carex spp. and Eriophorum spp. Common species occurring in this type include Carex aquatilis, C. microglochin, C. atrofusca, C. amblyorhyncha, C. scirpoidea, C. rostrata, C. bigelowii, C. physocarpa, C. misandra, Eriophorum vaginatum, E. angustifolium, E. russeolum, Equisetum fluviatile, Scirpus scirpoideas, S. caespitosus, Pedicularis spp., Valeriana capitata, Polygonum spp., Tomenthypnum nitens, and Drepanocladus spp. Some shrub species include Arctostaphylos rubra, Salix lanata, and S. arctophila.

c. MOIST/WET TUNDRA COMPLEX is a type in which dwarf shrubs and graminoids occur together in habitats intermediate in moisture regime between the wet graminoid and moist dwarf shrub formations. Wet and moist microsites are often intermixed in a complex pattern in this habitat. High-centered and flat-centered polygons are common surface features in river delta and drained lake basin landforms. Along river drainages, disjunct string bogs are the most common surface form. Common species on these sites include Dryas integrifolia, Salix lanata, S. reticulata, Cassiope tetragona, Vaccinium uliginosum, Eriophorum triste, E. vaginatum, Carex bigelowii, C. membranacea, Polygonum bistorta, Stellaria laeta, Senecio spp., Tomenthypnum nitens, and Hylocomium spp.

d. MOIST GRAMINOID TUSSOCK is a subclass related to part of the scrub subclass mesic erect dwarf scrub. Species dominating this class include the tussock producing Eriophorum vaginatum and Carex bigelowii. Also occurring are Betula nana, Salix planifolia ssp. pulchra, S. reticulata, Dryas integrifolia, Vaccinium uliginosum, V. vitis-idaea, Pyrola spp., Polygonum bistorta, P. viviparum, Cetraria spp., Tomenthypnum nitens, Hylocomium splendens, and Ptilidium ciliare.

4. SCARCELY VEGETATED AREAS. In this class plants are scattered or absent and bare mineral soil or rock determines the overall appearance of the landscape.

a. SCARCELY VEGETATED SCREE (5-20 percent plant cover) comprises steep slopes of stones beneath weathering rocks. It is a very open fellfield and often grades into dry prostrate dwarf scrub. Some shrubs commonly found in this type, in prostrate or decumbent forms, are Betula nana, Dryas integrifolia, D. octopetala, Vaccinium uliginosum, Cassiope tetragona, and Salix phlebophylla. Some other species found include Umbilcaria spp., Cystopteris spp., Diapensia lapponica, Cetraria spp., Lupinus arcticus, and Carex spp.

b. BARREN SCREE (less than 5% plant cover) is less vegetated than scarcely vegetated scree. It may form a type of lichen tundra dominated by blackish lichens, particularly the genera Umbilicaria, Cetraria, Cornicularia, and Pseudophebe. These plants are on the very limit of life's possibilities and the sites may be devoid of flowering plants.

Appendix III, Table 1. Continued.

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c. SCARCELY VEGETATED FLOODPLAIN is a subclass that is a result of the initial invasion of plants on recent river alluvium. Plant cover averages 5-20 percent. Some of the more common species include Epilobium latifolium, Calamagrostis canadensis, Bromus spp., and Salix spp. On the coastal plain (below the 500 meter contour) this type includes alluvial deciduous scrub communities.

d. BARREN FLOODPLAIN is less vegetated than scarcely vegetated floodplain. It consists of alluvium and includes silt, sand, and rocks. Plant cover is less than 5 percent and includes the same species as scarcely vegetated floodplain if present.

5. OTHER CATEGORIES.

a. CLEAR WATER including lakes, pond, and rivers.

b. CLOUDS or ICE are dependent upon individual yearly weather patterns. Ice, in the form of pack ice and aufeis, may or may not be present on the ground or in the ocean as depicted on the map. Glacial ice in the mountains is probably stable and what is shown on the map could be found on the ground.

c. SHALLOW WATER includes riverine areas in which the water is shallow or when the satellite sensor received spectral data from both water and gravel bars and recorded them as one class.

d. OFFSHORE WATER is the Beaufort Sea shoreline as was digitized on the Flaxman Island, Barter Island, Demarcation Point, and Mount Michelson quads and applied to the land cover image. Those water areas north of the shoreline were labeled offshore water.

e. SHADOW--This type includes both terrain shadow (that is, mountain shadow) and cloud shadow.

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Appendix III, Table 2. Acreages of Landsat vegetation cover classes within the coastal plain study area, Arctic National Wildlife Refuge.

| Landsat Cover Class | Hectares | Proportion (%) |
|---|---|---|
| Forest: | | |
| Deciduous forest/tall shrub | 8 | tr |
| Total | 8 | tr |
| Scrub: | | |
| Dry prostrate dwarf scrub | 4,180 | 0.7 |
| Moist prostrate dwarf scrub | 157,497 | 25.3 |
| Mesic erect dwarf scrub | 45,730 | 7.3 |
| Total | 207,407 | 33.3 |
| Herbaceous: | | |
| Very wet graminoid | 1,582 | 0.3 |
| Wet graminoid | 85,564 | 13.8 |
| Moist/wet tundra complex | 96,583 | 15.5 |
| Moist graminoid tussock tundra | 184,680 | 29.7 |
| Total | 368,409 | 59.3 |
| Scarcely Vegetated: | | |
| Scarcely vegetated scree | 174 | tr |
| Scarcely vegetated floodplain | 8,539 | 1.4 |
| Barren floodplain | 12,282 | 2.0 |
| Barren scree | 93 | tr |
| Total | 21,088 | 3.4 |
| Other: | | |
| Clear water (lakes, ponds, rivers) | 6,997 | 1.1 |
| Clouds - snow - ice | 1,024 | 0.2 |
| Shallow water | 182 | tr |
| Offshore water | 16,545 | 2.7 |
| Shadow | 470 | tr |
| Total | 25,218 | 4.0 |
| Total coastal plain area | 622,130 | 100.0 |

Appendix III, Table 3. Cross-walk of equivalent vegetation classes for 7 classification systems used on the Arctic Coastal Plain, Alaska.

| Walker et al. (1982) | USGS & FWS (1985) | Walker and Acevedo (1984) | Cowardin et al. (1979) | Walker et al. (1983) (Level C) | Viereck et al. (1982) (Level III) | Viereck et al. (1982) (Level IV) |
|---|---|---|---|---|---|---|
| I. Water | Clear water | Ia. Water | Palustrine open water, permanently flooded; lacustrine, limnetic, open water, permanently flooded; or riverine, open water, permanently flooded | Water | | |
| | Offshore water | | Marine, subtidal, open water; or estuarine, subtidal, open water | | | |
| IIa. Pond/sedge tundra complex | Very wet graminoid | | Palustrine, emergent, persistent/open water, permanently flooded | Water/tundra complex (pond complex) | | |
| | Shallow water | | Riverine, unconsolidated shore/open water | Shallow water (pond margins) | | |
| IIb. Aquatic tundra | Very wet graminoid | Ib. Aquatic grass marsh | Palustrine, emergent, persistent, permanently flooded | Aquatic grass tundra | Wet graminoid herbaceous | Fresh grass marsh |
| | | IIa. Aquatic sedge marsh | | Aquatic sedge tundra | | Wet sedge meadow tundra |
| IIIa. Wet sedge tundra (noncomplex) | Wet graminoid | IIb. Wet sedge tundra | Palustrine, emergent, persistent, semipermanently flooded or seasonally flooded | Wet graminoid tundra | Wet graminoid herbaceous | Wet sedge meadow tundra<br>Wet sedge-grass meadow<br>Wet sedge-herb meadow |
| IIIb. Wet sedge tundra (very wet complexes) | Very wet graminoid | IIa. Aquatic sedge marsh | Palustrine, emergent, persistent/ permanently flooded | Aquatic sedge tundra | Wet graminoid herbaceous | Wet sedge meadow tundra |
| | | IIb. Aquatic grass marsh | | Aquatic grass tundra | | Fresh grass marsh |

Appendix III, Table 3. Continued.

| Walker et al. (1982) | USGS & FWS (1985) | Walker and Acevedo (1984) | Cowardin et al. (1979) | Walker et al. (1983) (Level C) | Viereck et al. (1982) (Level III) | Viereck et al. (1982) (Level IV) |
|---|---|---|---|---|---|---|
| IIIc. Wet sedge tundra (moist complexes) | Moist/wet tundra complex | None. | Palustrine, emergent, persistent/ scrub-shrub, broad-leaved deciduous, semipermanently flooded or seasonally flooded | Wet sedge/moist sedge, dwarf shrub tundra complex (wet patterned-ground complex) | Combination of types listed for IIIa and Va | |
| | | | | Wet low shrub, graminoid tundra | Open low shrub scrub | Willow-sedge fen<br>Willow-sedge tundra |
| IIId. Wet sedge tundra (saline facies) | Very wet graminoid | IId. Wet sedge tundra (saline areas) | Estuarine, intertidal, emergent, persistent, irregularly flooded | Wet graminoid tundra (saline areas) | Wet graminoid herbaceous | Halophytic grass wet meadow<br>Halophytic sedge wet meadow |
| IVa. Moist/wet sedge complex | Moist/wet tundra complex | None. | Palustrine, emergent, persistent/ scrub-shrub, broad-leaved deciduous, semi-permanently flooded or seasonally flooded | Moist sedge, dwarf shrub/wet graminoid tundra complex (moist patterned ground complex) | combination of types listed for IIIa and Va | |
| IVb. Dry prostrate, shrub, forb tundra (*Dryas* river terrace) | Dry prostrate dwarf scrub | IIIe. Dry dwarf shrub, forb, lichen tundra (*Dryas* river terrace) | Non-wetland | Dry dwarf shrub, crustose lichen tundra (*Dryas* terrace)<br>Dry dwarf shrub, fruticose lichen tundra (dry acidic tundra) | Closed dwarf shrub scrub | *Dryas* tundra<br>Mat and cushion-sedge tundra<br>Cassiope tundra |
| | | IIIc. Dry dwarf shrub, crustose lichen tundra | | | Open dwarf shrub-scrub | *Dryas* - lichen tundra |
| | | | | Dry dwarf shrub, herb tundra | | *Dryas*-herb tundra |
| Va. Moist sedge, prostrate shrub tundra | Moist prostrate dwarf scrub | IIIa. Moist non-tussock sedge, dwarf shrub tundra | Palustrine, emergent, persistent/scrub-shrub, broad-leaved deciduous, saturated | Moist sedge, dwarf shrub tundra | Mesic graminoid herbaceous | Sedge-willow tundra<br>Sedge-*Dryas* tundra<br>Mesic grass-herb meadow tundra |
| Vb. Moist sedge/ barren tundra complex (frost-scar tundra) | Moist prostrate dwarf scrub<br>Dry prostrate dwarf scrub | IIIa. Moist non-tussock sedge, dwarf shrub tundra | Palustrine, emergent, persistent/scrub-shrub, broad-leaved deciduous, saturated | Moist graminoid, dwarf shrub tundra/barren complex (frost-scar complex) | Combination of types listed for Va and IVb | |
| VIa. Moist sedge tussock, dwarf shrub tundra (upland tussock tundra, acidic facies) | Moist graminoid tussock tundra | IVa. Moist tussock sedge, mixed shrub tundra | Palustrine, emergent, persistent/ scrub-shrub, broad-leaved deciduous, saturated | Moist tussock sedge, low shrub tundra (acidic tussock tundra) | Mesic graminoid herbaceous | Tussock tundra |

Appendix III, Table 3. Continued

| Walker et al. (1982) | USGS & FWS (1985) | Walker and Acevedo (1984) | Cowardin et al. (1979) | Walker et al. (1983) (Level C) | Viereck et al. (1982) (Level III) | Viereck et al. (1982) (Level IV) |
|---|---|---|---|---|---|---|
| VIb. Moist sedge tussock, dwarf shrub tundra (alkaline facies) | Moist prostrate dwarf scrub | IIIb. Moist tussock sedge, dwarf shrub tundra | Palustrine, emergent, persistent/scrub-shrub broad-leaved deciduous, saturated | Moist tussock sedge, dwarf shrub tundra | Mesic graminoid herbaceous | Sedge-dryas tundra |
| VIIa. Moist dwarf shrub, sedge tussock tundra (upland dwarf shrub, tussock tundra) | Mesic erect dwarf scrub | IIIb. Moist tussock sedge, mixed shrub | Palustrine, emergent, persistent/scrub-shrub, broad-leaved deciduous, saturated | Moist low shrub, tussock sedge tundra (shrubby tussock tundra) | Mesic graminoid herbaceous | Tussock tundra |
| VIIb. Moist dwarf shrub, sedge tussock tundra (birch tundra) | Moist prostrate dwarf scrub | Va. Moist dwarf shrub, moss tundra | Palustrine, scrub-shrub, broad-leaved, deciduous/ emergent, persistent saturated | Moist low shrub, moss tundra (<u>Sphagnum</u>-rich dwarf shrub tundra) | Open low shrub scrub | Dwarf shrub-ericaceous shrub-<u>Sphagnum</u> bog |
| | | Ve. Dry low shrub, fruticose lichen tundra (dwarf birch, lichen tundra, mainly river bars inland) | Non-wetland | Dry low shrub, fruticose lichen tundra (mainly river bars) | Open low shrub scrub | Dwarf birch<br><br>Birch and ericaceous shrub tundra |
| VIIc. Moist sedge tussock, dwarf shrub/wet dwarf shrub tundra complex (water track complex) | Mesic erect dwarf scrub | IIIb. Moist tussock sedge, mixed shrub tundra | Palustrine scrub-shrub, broad-leaved deciduous/ emergent, persistent, saturated | Moist tussock sedge, low shrub/wet low shrub tundra complex (water track complex) | Mesic graminoid herbaceous and open low shrub scrub | Tussock tundra and willow-sedge tundra |
| VIII. Shrub tundra | | Vc. Wet low shrub tundra | Palustrine, scrub-shrub, broad-leaved deciduous, seasonally flooded | Wet low shrub tundra | Closed low shrub scrub | Low willow<br><br>Dwarf birch-willow |
| | Mesic erect dwarf scrub | Vb. Moist low shrub tundra | Palustrine, scrub-shrub, broad-leaved deciduous, saturated | Moist low shrub | Open low shrub scrub | Dwarf birch<br><br>Low willow<br><br>Dwarf birch-willow<br><br>Birch-ericaceous shrub<br><br>Mixed shrub tundra |
| | Alluvial deciduous scrub | Vd. Moist low shrub-land (riparian areas) | Palustrine, scrub-shrub, broad-leaved deciduous, temporarily flooded | Moist shrubland (closed riparian shrubland) | Closed tall shrub scrub | Willow |

Appendix III, Table 3. Continued

| Walker et al. (1982) | USGS & FWS (1985) | Walker and Acevedo (1984) | Cowardin et al. (1979) | Walker et al. (1983) (Level C) | Viereck et al. (1982) (Level III) | Viereck et al. (1982) (Level IV) |
|---|---|---|---|---|---|---|
| IXa. Partially vegetated areas (river bars) | Scarcely vegetated floodplain (includes riparian willows) | VId. Dry, open, low shrub, forb, grass tundra | Riverine, unconsolidated shore, temporarily flooded | Dry barren/low shrub forb complex (open riparian shrubland) | Open low shrub scrub | Low willow |
| | | VIc. Dry dwarf shrub, forb grass tundra | | Dry barren/dwarf shrub, forb, grass complex (forb-rich river bars) | Open dwarf shrub scrub | Low willow<br>*Dryas*-herb tundra |
| | | VIIa. Dry forb barren | | Dry barren/forb complex | Dry forb herbaceous | Seral herbs |
| IXb. Partially vegetated areas (alpine tundra) | Scarcely vegetated scree | IIId. Dry dwarf shrub, fruticose lichen tundra (acidic, dry, exposed sites) | Non-wetland | Dry barren/dwarf shrub, graminoid tundra complex (dry alpine tundra) | Dry forb herbaceous | Alpine herbs |
| | | | | Moist barren/moss, forb, dwarf shrub tundra (moist alpine tundra) | | |
| | | | | Moist barren/fruticose lichen, dwarf shrub tundra. | Lichen | Fruticose lichens |
| IXc. Partially vegetated areas (sorted stone nets) | | IIId. Dry dwarf shrub, fruticose lichen tundra (acidic, dry, exposed sites) | Non-wetland | | | |
| IXd. Partially vegetated areas (beaches) | | | Estuarine, intertidal, unconsolidated shore, irregularly flooded | Wet barren/wet sedge tundra complex (barren/saline tundra complex) | | |
| | | | | Dry barren/forb, graminoid complex (coastal barrens) | | |
| IXe. Partially vegetated areas (sand dunes) | | | Non-wetland | Dry barren/grass complex (sand dune grassland) | Dry graminoid herbaceous | *Elymus* |
| | | | | Dry barren/low shrub complex (sand dune scrub) | Open low shrub scrub | Low willow |

Appendix III, Table 3. Continued

| Walker et al. (1982) | USGS & FWS (1985) | Walker and Acevedo (1984) | Cowardin et al. (1979) | Walker et al. (1983) (Level C) | Viereck et al. (1982) (Level III) | Viereck et al. (1982) (Level IV) |
|---|---|---|---|---|---|---|
| X. Barren gravel or rock | Barren floodplain | VIIc. Barren | Riverine, unconsolidated shore, temporarily flooded or non-wetland | River gravels | | |
| | | | | Sand dunes | | |
| | | | | Barren gravel outcrops | | |
| | Barren scree | VIIb. Dry crustose and foliose lichen barren | | Talus slopes and blockfields | Lichen | Crustose lichen |
| XI. Wet gravel or mud | | | | Wet mud | | |
| | | | | Wet or dark-colored gravels | | |
| XII. Ice | Clouds | | | | | |
| | Snow | | Non-wetland for permanent snow field | | | |
| | Ice | | Non-wetland for permanent ice | Ice | | |

Appendix III, Item A

Taxonomy of soils on the study area

Of the 10 soil orders recognized in Soil Taxonomy (Soil Survey Staff, 1975) 4 are found in ANWR. Soils belonging to the order Mollisols are probably most extensive, occurring in all terrain types, but especially in the Foothills and Hilly Coastal Plain. Mollisols are dark colored mineral soils. The color reflects included organic material (2.5% organic carbon) in the upper 18 cm of the profile. In addition to the dark color Mollisols have a base saturation over 50% i.e., Mollisols are neutral or slightly alkaline in reaction (pH). Wet Mollisols are classified as Aquolls (aqu indicating an aquic (reducing) moisture regime and oll indicating the soil order Mollisols). The prefix Cry appears at the Great Group level of classification for all soils found in ANWR and indicates a mean annual temperature of 8°C. The term Pergelic (permanently frozen) appears at the subgroup level of all ANWR soils. Thus Pergelic Cryaquol defines a cold, wet dark colored, base and organic rich mineral soil underlain by permanently frozen material. Pergelic Cryaquolls in very wet areas may have a surface horizon greater than 20 but less than 40 cm of organic material. These soils are designated as Histic (fibers) Pergelic Cryaquolls. Mollisols on well drained sites are termed Pergelic Cryoborolls.

The next most extensive soil order represented in ANWR includes the Inceptisols. These are mineral soils that have only weakly differentiated soil horizons. This is due primarily to ineffectiveness of the leaching process in the cold wet tundra. Organic carbon in the Inceptisols is not evenly distributed in a distinct mollic epipedon (surface horizon) as in the Mollisols. The wet Inceptisols (Aquepts - the same principals of name formation apply here as with the Mollisols) commonly show some degree of mottling (iron oxidation) in the mineral soil below the organic surface horizon. Mineral soil colors generally are grey, reflecting a saturated, reducing environment. In some cases an organic surface horizon greater than 20 cm thick forms the epipedon and the soils are termed Histic Pergelic Cryaquepts. Those soils lacking such a epipedon are simply termed Pergelic Cryaquepts. Most Cryaquepts show some quantity of organic matter enmixed in the sub-surface horizons, presumably due to frost action. It is also common for these soils to have organic concentrations at or near the seasonal permafrost table. Many Cryaquepts developed in silt-silt loam or fine sandy loam display thixotropic (jelly-like) characteristics upon vibration.

Cryaquepts may have any pH and are common components in soil complexes and associations with Mollisols particularly where they occur with frost scars. In such cases the complex is termed Ruptic-(interrupted) Entic (Entisol) Cryaquepts.

Relatively well drained and stable sites especially on crest areas have Pergelic Cryumbrepts - Inceptisols with a dark colored (due to organic matter) surface horizon (epipedon) underlain by an acid (base poor) sub-horizon. Similar soils lacking the Umbric (dark colored) surface horizon are usually designated Cryochrepts.

Soils that show no profile differentiation or have (for the most part) only an organic surface horizon above a mineral substrate coarser than loamy fine sand belong to the soil order Entisols. In ANWR Entisols, primarily Pergelic Cryorthents are found most commonly in Alpine and Riverine terrain types where site instability or the short time span since sediment deposition has prevented profile differentiation.

Perhaps the least extensive and least predictable of occurrence are organic soils (Histosols). These soils have a surface horizon composed of 40 cm of organic materials (generally greater than 60% organic matter) overlying grey, sometimes mottled, fine textured mineral materials. Normally these soils are very wet - to the degree that organic materials are buoyant or partially so. They occur on flat areas - either crest or low land.

Three taxa of cold Histosols are recognized - Pergelic Cryofibrists (fibrous low density organic matter), Pergelic Cryosaprists (non-fibrous, highly decomposed and dense organic matter), and Cryohemists (intermediate organic matter characteristics). Histosols may have any pH although in ANWR most are near neutral in reaction.



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