ARCTIC NATIONAL WILDLIFE REFUGE COASTAL PLAIN
RESOURCE ASSESSMENT

1984 UPDATE REPORT BASELINE STUDY OF THE FISH, WILDLIFE, AND THEIR HABITATS

Volume II
Section 1002C
Alaska National Interest Lands Conservation Act

U.S. Department of the Interior
U.S. Fish and Wildlife Service
Region 7
Anchorage, Alaska
March 1985

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Edited by
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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 (Sl) 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 (1 lb/acre)
Cubic meters per second (m^3/s)	35.7143	Cubic feet per second (ft^3/s)
Degrees Celsius (°C)	(°Cx1.8+32)	Degrees Fahrenheit (°F)

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ANWR Progress Report Number FY85-13

TERRESTRIAL BIRD POPULATIONS AND HABITAT USE ON COASTAL PLAIN TUNDRA OF THE ARCTIC NATIONAL WILDLIFE REFUGE

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Mark A. Masteller

Key words: Anseriformes, Charadriiformes, waterfowl, shorebirds, tundra, wetlands, breeding bird census, populations, habitat use, community structure, status and distribution, Arctic-Beaufort, north slope

Arctic National Wildlife Refuge
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2 January 1985

Terrestrial bird populations and habitat use on coastal plain tundra of the Arctic National Wildlife Refuge, Alaska.

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Abstract: Four breeding season and three post-breeding season bird censuses were conducted on 45 10-ha plots representing seven habitat types at three study sites on the coastal plain of the Arctic National Wildlife Refuge, Alaska, June - August 1984. Study design and methods were similar to previous years of this study, but the three study sites were different. Snow-melt, plant flowering, and bird nesting phenology occurred earlier in 1984 than in previous years of this study. Analysis of variance indicated significant differences due to location within each of the three habitats found at all three 1984 study sites. In Wet Sedge habitat, coastal sites had significantly higher total bird densities than inland sites throughout the summer in both 1983 and 1984, and significantly higher shorebird densities in the post-breeding season in 1984. The Aichilik site in 1984 had significantly higher densities of most bird species in Moist Sedge-Shrub habitat than in other habitats, and the Katakturuk site in 1983 and Sadlerochit site in 1984 had significantly higher densities of many bird species in Riparian habitat. Three habitats tended to rank significantly higher than the others in bird use at all three 1984 sites, of which Moist Sedge-Shrub ranked highest at Aichilik, Riparian ranked highest at Sadlerochit, and Mosaic ranked highest at Jago Delta. Wet Sedge habitat ranked low at Aichilik; high at Sadlerochit; and low for breeding, but high for post-breeding at Jago Delta. Tussock habitat, which occurred at two locations, ranked high at Aichilik, but low at Sadlerochit. Moist Sedge habitat, which only occurred at Aichilik, ranked generally low in bird use. Flooded habitat, which occurred only at Jago Delta, ranked high for shorebirds and low for passerines. Site-specific densities of individual species in certain habitats did not reflect these generalized results. Flooded habitat ranked highest in total bird density in 1983, but ranked significantly lower than three other habitats during the breeding season in 1984. Riparian habitat had significantly higher total nest density than all other habitats in 1983, as did Mosaic habitat in 1984. These inter-year differences may have been due to habitat differences between sites censused in each of the two years or due to annual variation in bird populations and habitat use. Total bird densities increased significantly from breeding to post-breeding seasons in 1984 in three habitats: Wet Sedge (primarily at Jago Delta), Moist Sedge (at Aichilik), and Riparian (primarily at the two coastal sites). Increased densities were primarily due to flocking and migrating shorebirds. Tussock habitat also showed a peak density during the last post-breeding census, primarily due to higher densities of ptarmigan. Spatial and temporal variability of bird densities increased in the post-breeding season, largely due to migratory flocks. Seasonal use patterns between habitats and between coastal and inland sites were different in 1984 than in previous years. A clustering and ordination analysis (TWINSPAN) of 1983 and 1984 breeding season plot census data showed Flooded and Riparian plots were distinct from all other habitats, with higher and more diverse bird use. The remaining five plot types were separated into those

with very wet habitats or high interspersion of habitats (all Mosaic plots, most Wet Sedge plots, and Moist Sedge-Shrub plots and Tussock plots with interspersion of ponds) versus those with more uniform and generally drier habitats (all Moist Sedge plots, most Tussock plots, Moist Sedge-Shrub plots without ponds, and a few marginally wet Wet Sedge plots). The former category had higher and more diverse bird use than the latter. This analysis suggests defining tundra bird habitats by factors such as micro-relief, interspersion of ponds, and shrub cover rather than on broad vegetation-type classes.

Fig. 1 Terrestrial bird study sites on the coastal plain study area, Arctic National Wildlife Refuge, Alaska.

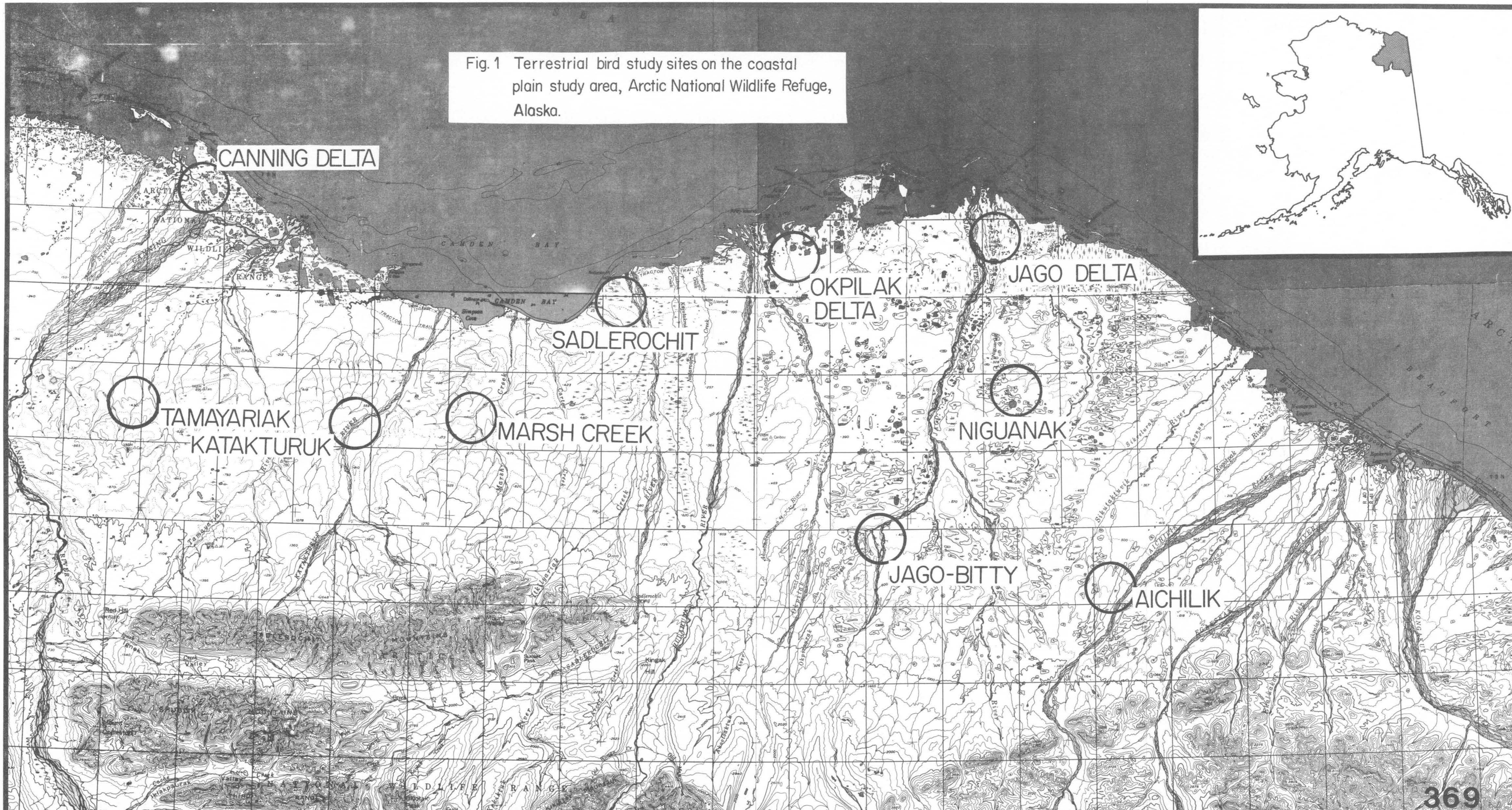

Table 2. Number of 10-ha plots of each habitat type at each bird study area, coastal plain, Arctic National Wildlife Refuge, Alaska.

Study areas (census years)	Habitat (Class No.)						
	Flooded (II)	Wet Sedge (III)	Moist Sedge (IV)	Mosaic (IVa)	Moist Sedge-Shrub (V)	Tussock (VI)	Riparian (IX)
Coastal sites:							
Okpilak (78[a], 82[b], 83)	3	3		4	2		2
Canning Delta (79[c], 80[c])	3	3		3	3		
Jago Delta (84)	3	3		3	3		3
Sadlerochit (84)		3		3	3	3	3
Inland sites:							
Katakturuk (82[b], 83)		1	2		3	3	3
Jago Bitty (83)		3	3		3	3	3
Aichilik (84)		3	3		3	3	3
Marsh Creek		1	3		4	3	3
Niguanak	3	3			3	3	
Tamayariak					3	3	

[a] Not all habitats censused; see Spindler (1978) for sampling design.
[b] Not all habitats censused; see Spindler and Miller (1983) for sampling design.
[c] Not all habitats censused; see Martin (1983) and Martin and Moitoret (1981) for sampling design.

Table 3. Landform types represented at each bird study site, coastal plain, Arctic National Wildlife Refuge, Alaska in 1984.

Study area	Landform type[a]			
	Floodplain	Thaw-lake plain	Hilly coastal plain	Foothills
Coastal Sites				
Okpilak	x	x	x	
Canning Delta		x		
Jago Delta	x		x	
Sadlerochit	x		x	x
Inland Sites				
Katakturuk	x			x
Jago Bitty	x		x	x
Aichilik	x			
Marsh Creek	x			x
Niguanak			x	
Tamayariak				x

[a]Walker et al. (1982)

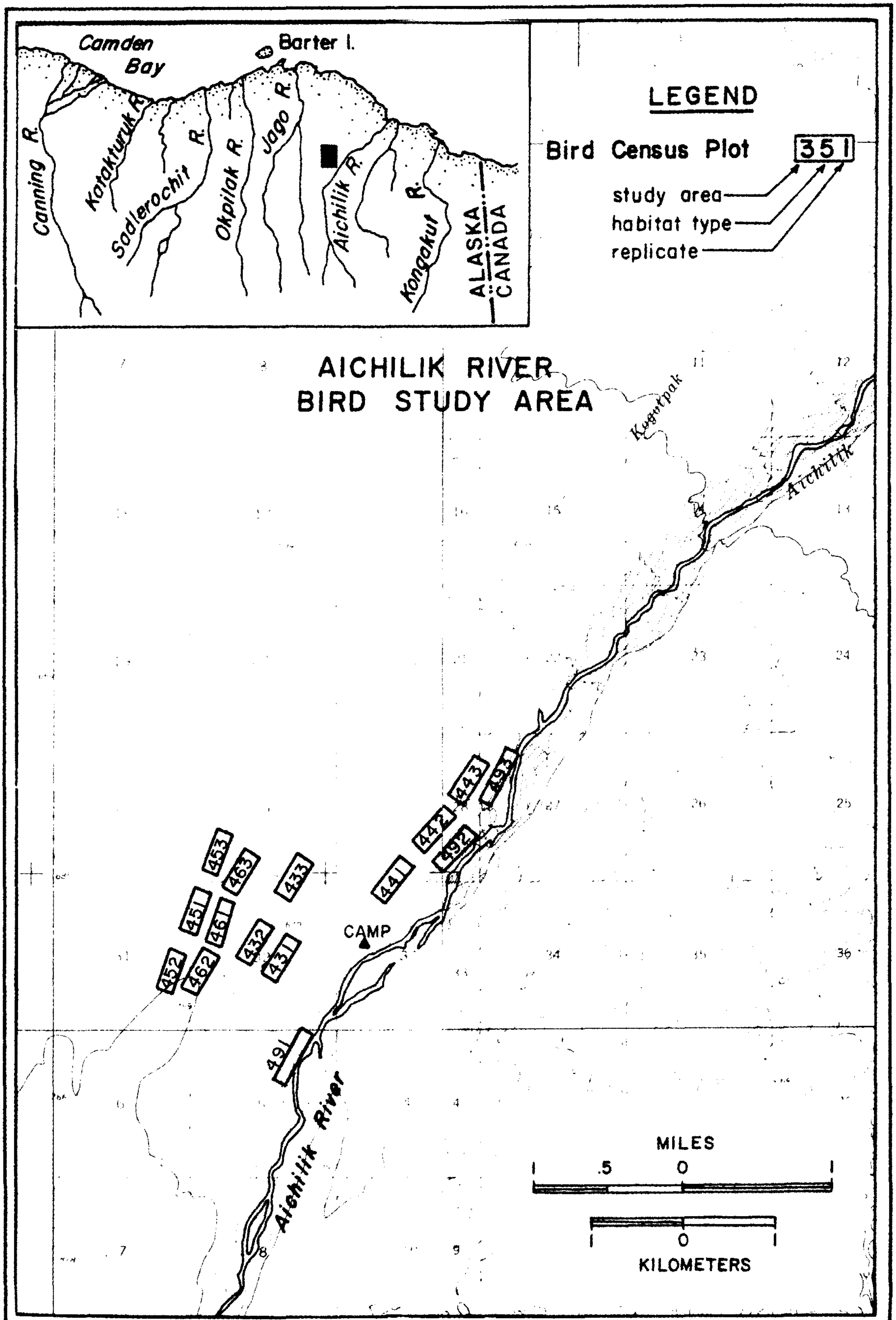

Fig. 2. Aichilik River study area, Arctic National Wildlife Refuge, Alaska.

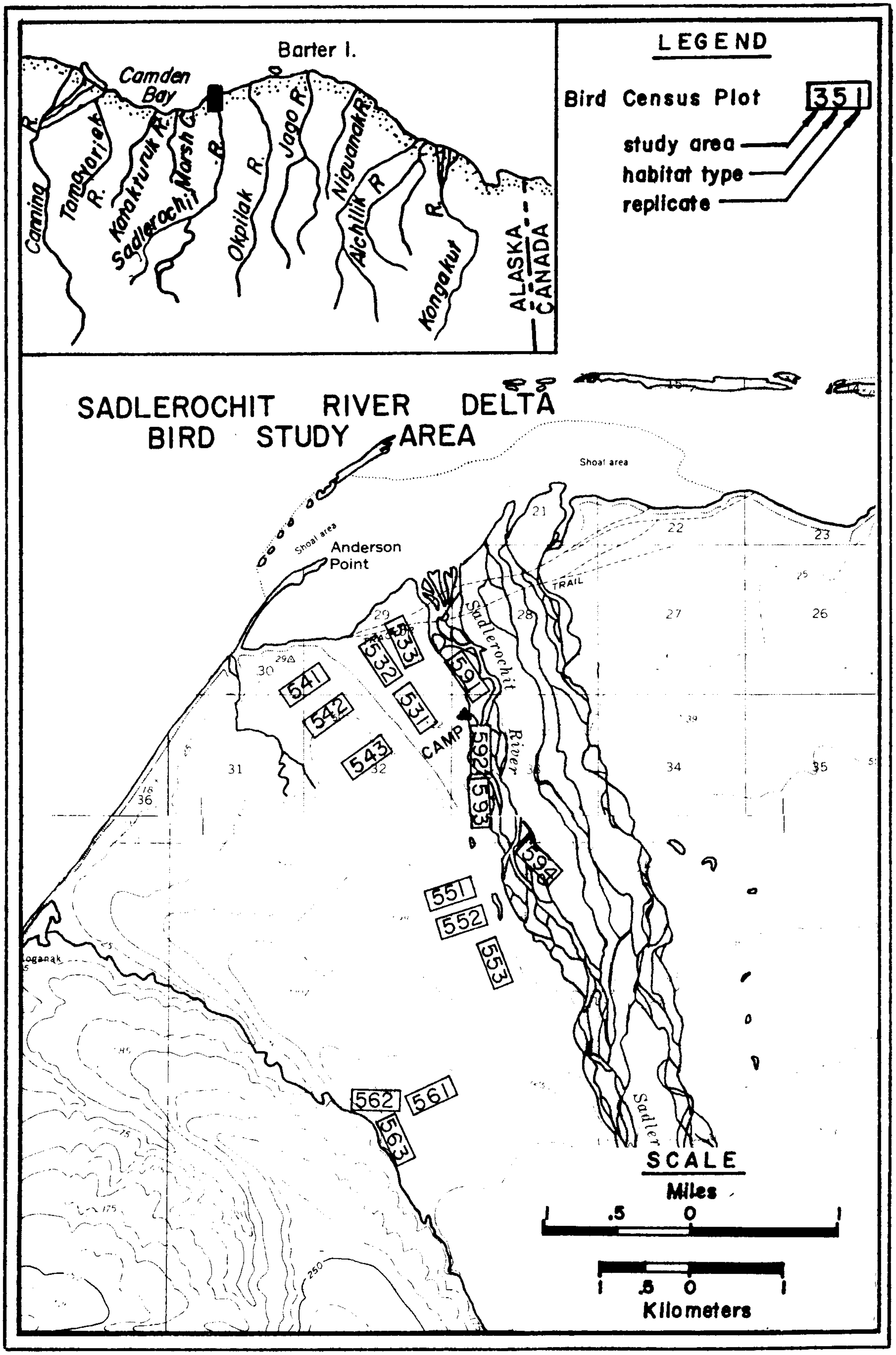

Fig. 3. Sadlerochit River study area, Arctic National Wildlife Refuge, Alaska.

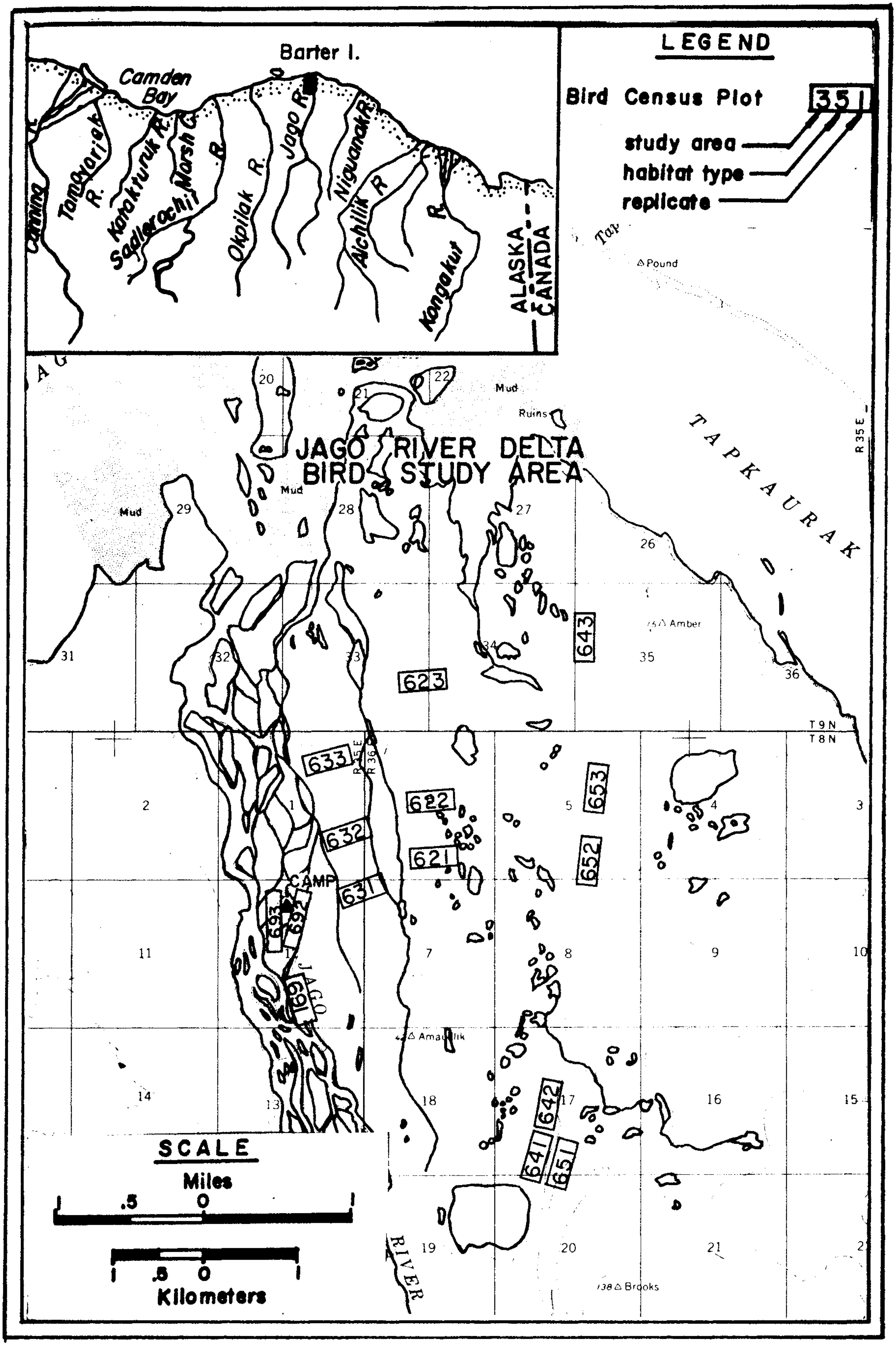

Fig. 4. Jago River Delta study area, Arctic National Wildlife Refuge, Alaska.

floodplain and hilly coastal plain in which there were relatively few large lakes.

Three study sites were used in previous years of this study, Okpilak Delta, Katakturuk River, and Jago-Bitty, and have been described elsewhere (Spindler 1978, Spindler and Miller 1983, Spindler et al. 1984).

Four new sites surveyed between 21 July and 24 August 1984 for use in 1985 consisted of three inland areas: Marsh Creek, Niguanak, and Tamayariak, and one coastal area: Canning Delta. The Marsh Creek site was located 58 km southwest of Kaktovik and 13 km inland from the Beaufort Sea, on Marsh Creek (Fig. 5). This area was characterized by lush, riparian willows and sedge meadows along the creek, and dense tussocks on the surrounding hills, with shrub cover being generally taller and more extensive than in the other study areas. Extensive wetlands or lakes were absent, and the area was primarily within the foothills landform type, with a narrow strip of floodplain along the creek.

The Niguanak site, 30 km southeast of Kaktovik, was located adjacent to a large lake between the Jago and Niguanak Rivers (Fig. 6). It was 24 km inland from the Beaufort Sea coast and 42 km from the Brooks Range. It was the only site located exclusively within the hilly coastal plain landform, and differed from other inland sites by the presence of extensive wetlands. Drier ridges were interspersed throughout the wetlands, and rolling hills dissected by steep drainages were present in the northern part of the study site.

The Tamayariak site was located 97 km southwest of Kaktovik (Fig. 7). It was equidistant (30 km) from the Beaufort Sea coast and the Sadlerochit Mountains, between the west branch of the Tamayariak River and the Canning River near the western ANWR boundary. It was the only site located entirely within the foothills landform type and it had a low diversity of Landsat habitat types. Despite its location away from major river or lake systems, numerous small creeks and drainages traversed the area and contributed to interspersion of the comparatively few habitat types present.

The Canning Delta site was located 83 km west of Kaktovik between the main and west branches of the Canning River, and 1-4 km inland from the Beaufort Sea (Fig. 8). This area was exclusively within the thaw-lake plain landform type, and was characterized by extensive areas of wetlands (small ponds, larger lakes, and drained lake basins) interspersed with a few drier upland ridges. Vegetation differed from other sites in being dominated by sedges and dwarf shrubs, with an absence of low or high shrubs. It was the site of intensive bird-habitat studies in 1979 and 1980 (Martin and Moitoret 1981, Martin 1983) and some of the new plots were surveyed within the boundaries of the original large study plots.

Habitat Descriptions

Plant species lists were maintained for each study site, with date of first flowering and habitats where observed. Qualitative descriptions of plant communities were made for all census plots at the three 1984 study areas. Communities were identified to the Level IV specification of Viereck et al. (1982). Percent cover in each Level IV class was visually estimated for each 50 m x 100 m transect block on each plot. Plant names are from Hultén (1968), except for the genus Salix which follows Viereck and Little (1972).

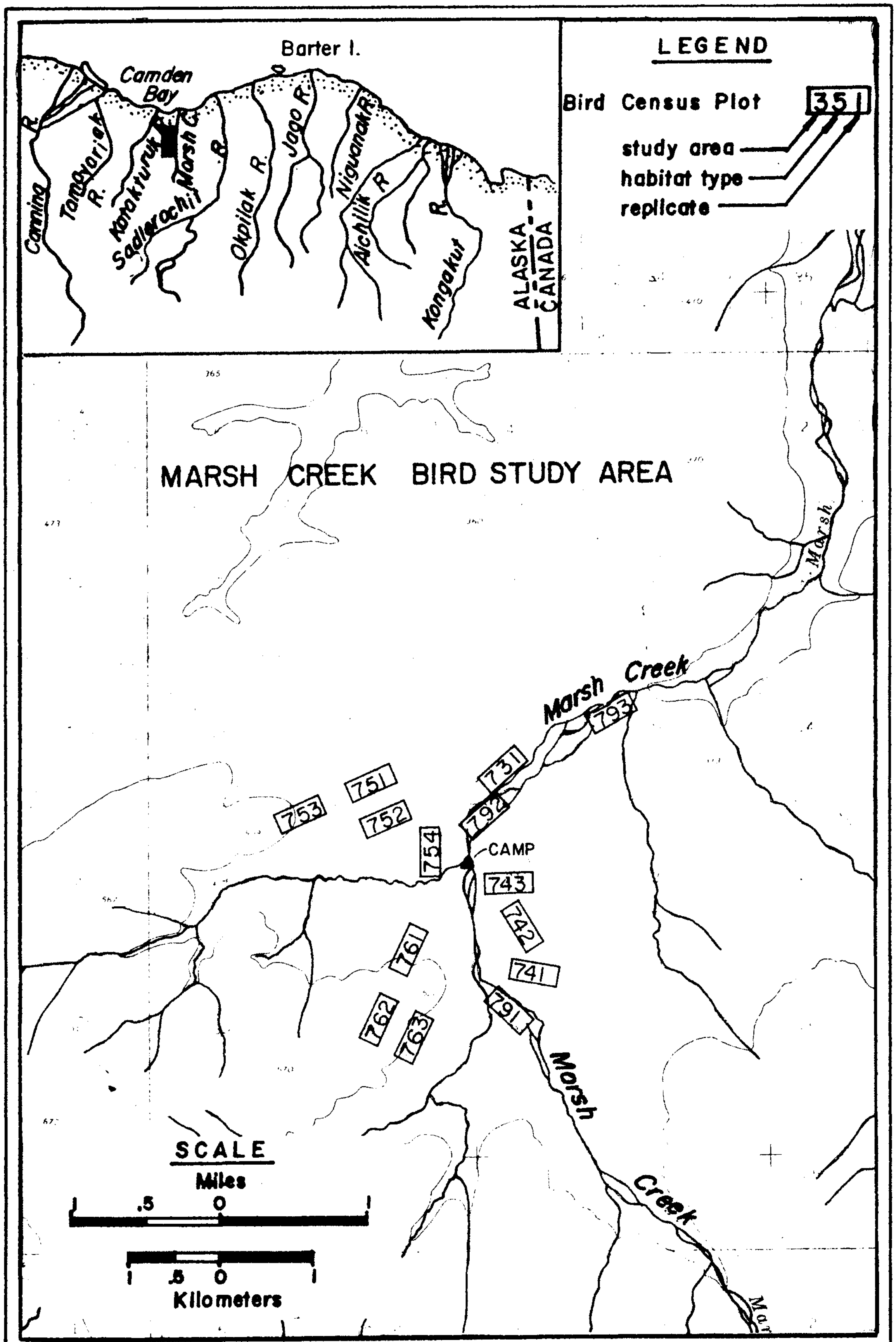

Fig. 5. Marsh Creek study area, Arctic National Wildlife Refuge, Alaska.

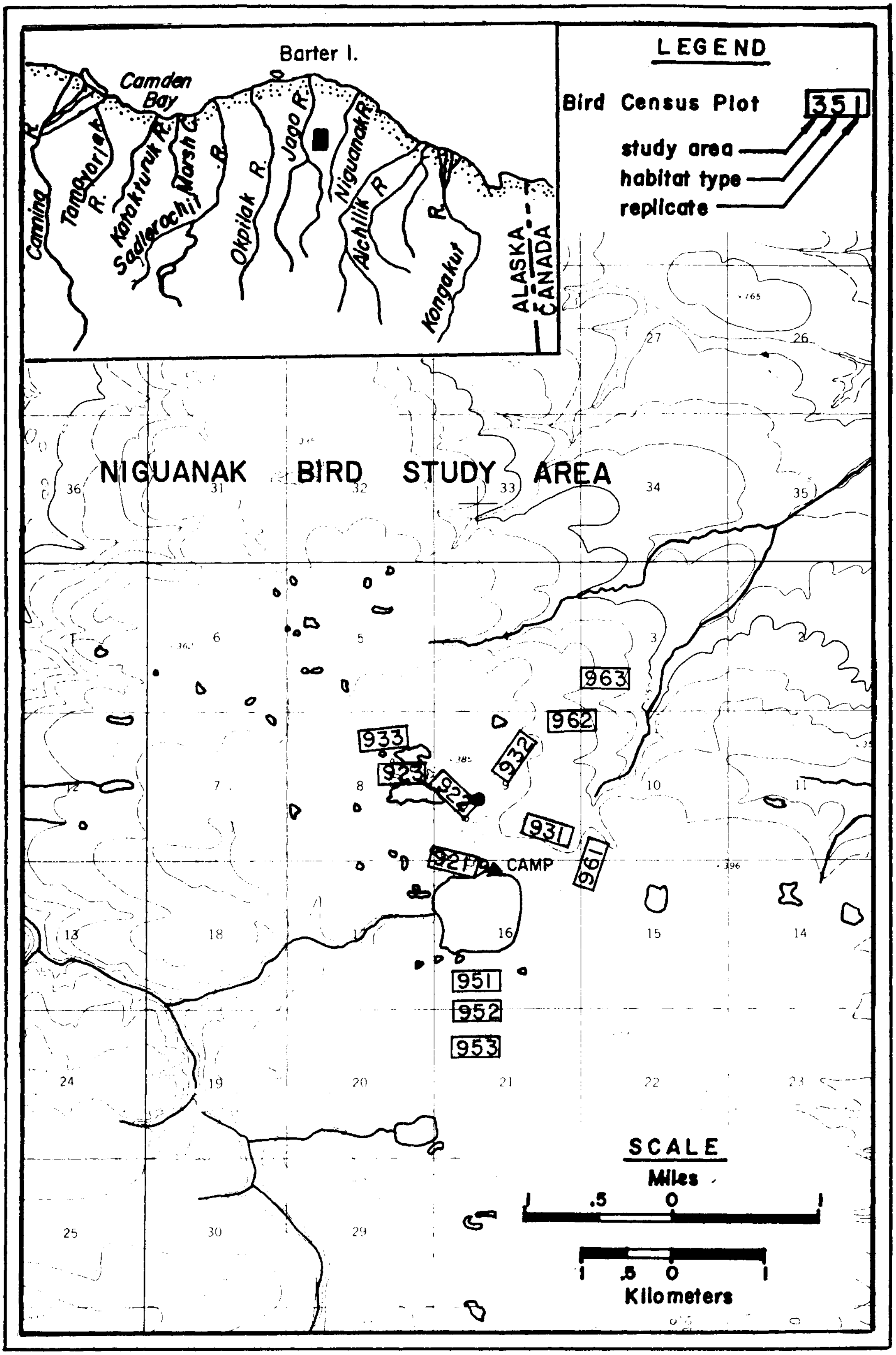

Fig. 6. Niguanak study area, Arctic National Wildlife Refuge, Alaska.

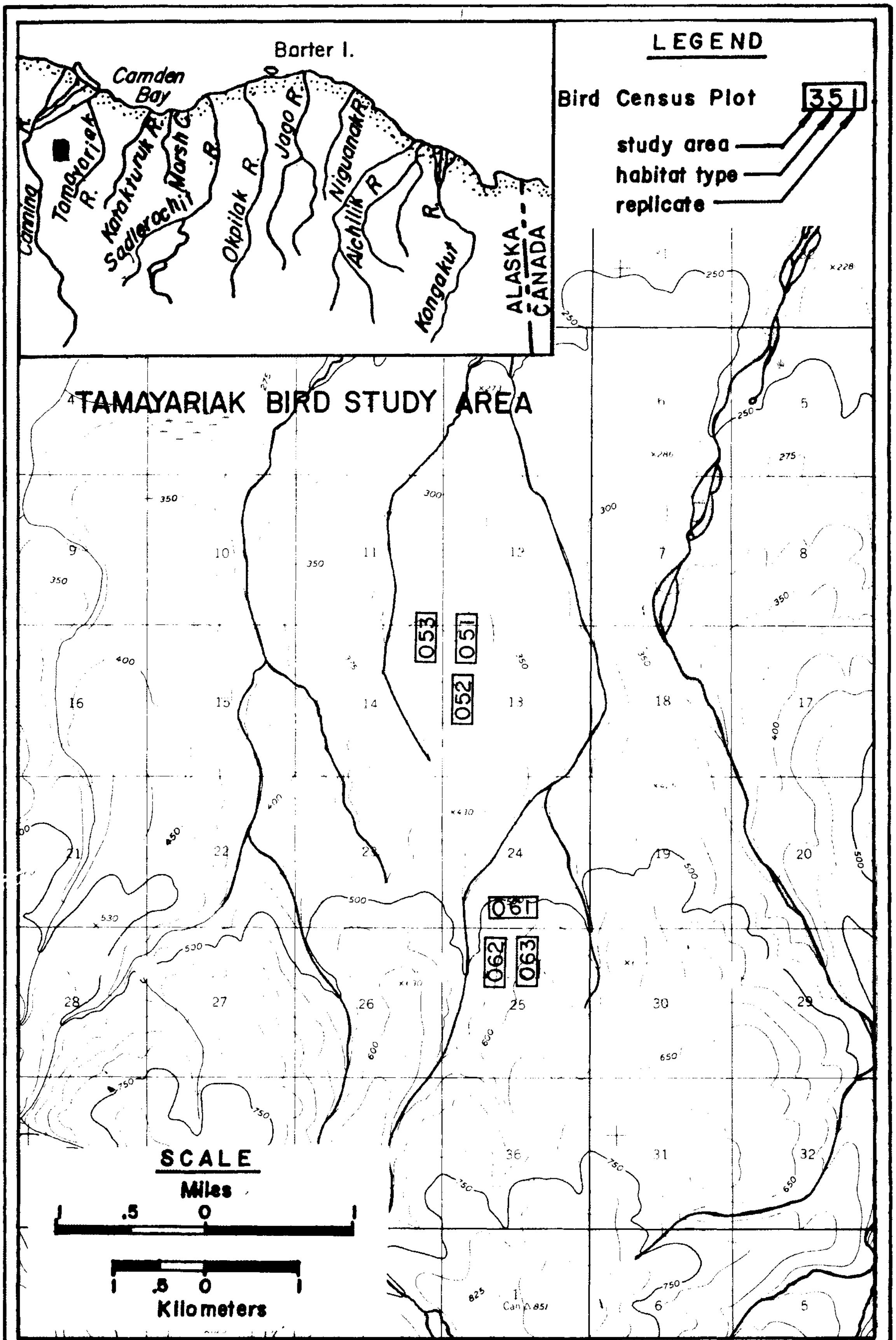

Fig. 7. Tamayariak study area, Arctic National Wildlife Refuge, Alaska.

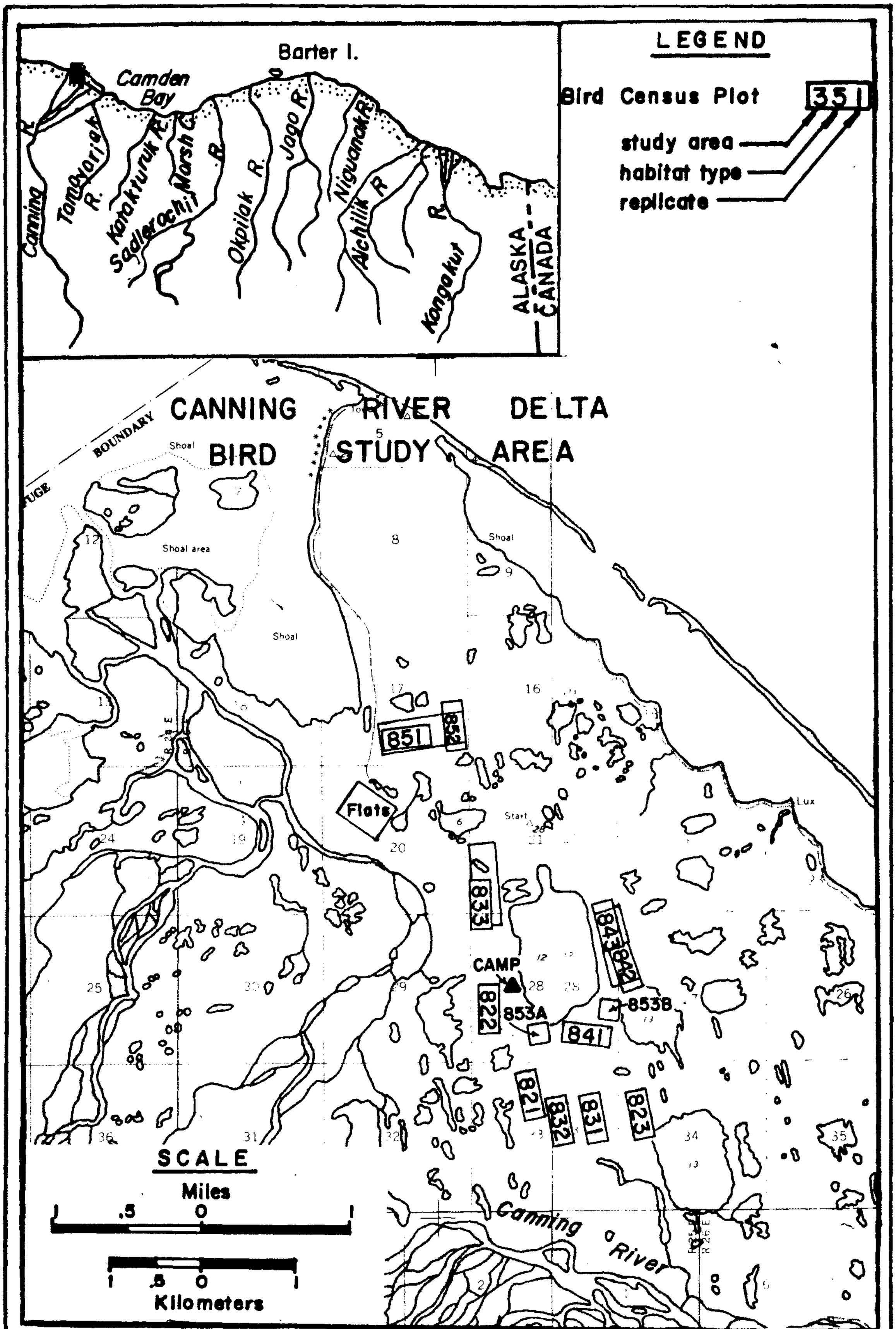

Fig. 8. Canning River study area, Arctic National Wildlife Refuge, Alaska.

Plot Selection and Surveying

Three replicate plots were chosen randomly within each habitat at each location whenever sufficient habitat existed. If available habitat precluded random selection, plots and their orientation were selected to fit within available habitat, with plots no closer than 100 m to another replicate in the same habitat. Representation of sampled and surveyed plots within each habitat type is shown in Table 2.

Bird census plots were 10-ha, and generally were 200 m by 500 m. Plots of 150 m by 667 m were established in habitats (particularly riparian willow) which were too linear for 200 m wide plots. In addition, patchy habitats at the Canning Delta site resulted in the establishment of a 250 m by 400 m type IVa plot and two 200 m by 250 m type V subplots. At Sadlerochit one new 250 m by 400 m riparian plot was surveyed for censusing in 1985.

Sadlerochit Delta study plots were surveyed using a Silva Ranger hand-held compass and 50 m surveyor's chain. All other plots censused in 1984 and plots surveyed for 1985 were surveyed using an Ushikata transit and 50 m chain. All plots were marked on a 50 m x 100 m grid system using numbered wooden surveyor's stakes at each intersection. Plot corners were also marked with 46 cm long steel concrete reinforcement bar labeled with aluminum tags. Census plot locations were documented on aerial photographs of 1:18,000 scale and are on file at the ANWR office, Fairbanks, Alaska.

Plot Census

Censuses consisted of (1) counting all birds present to estimate total bird populations and (2) intensive search for nests and mapping of birds and their territorial activities to estimate breeding bird density. All plots at the 1984 study sites were censused weekly during the last three weeks of June and first two weeks of July. Two additional censuses on each plot were conducted in mid-August.

Methods were consistent with those described by Spindler (1978), Martin and Moitoret (1981), and Spindler and Miller (1983), an adaptation of the spot mapping method (Williams 1936, IBCC 1970). Each census was performed by three people walking abreast, evenly spaced between the grid lines. When only two people were available for censusing, a zig-zag pattern was followed to insure complete coverage of plots. Species, sex, behavior, direction of flight, and location of all birds were recorded on a scaled map of the plot. Notes were made of any behavior suggesting a nearby nest, and extra effort was made to find nests in such situations. Eggs in unoccupied nests were identified using Harrison (1978). Censuses were not initiated during adverse weather conditions of strong wind (greater than 24 km/h), precipitation, or fog. If weather conditions deteriorated, censuses already initiated were completed, but no new censuses were initiated until conditions improved.

Nests were marked with a numbered tongue depressor placed in the ground 1 m north of the nest. Nest number, plot number, coordinate location of nest within plot, compass bearing in degrees and distance from nearest plot stake, species, date, sex of bird flushed from nest, how nest was found, and any hatching success/predation information were recorded on North American Nest Record Cards provided by Cornell University, Ithaca, N.Y. for each nest. Bird names and phylogenetic order follow the American Ornithologists' Union (1983).

Censuses were generally conducted on all plots of the same habitat at all study sites on the same day. Habitats were censused in the same order each week, but the order in which replicate plots within a habitat were censused was varied. A different starting point within each plot was chosen for each census.

Nest Density

Breeding bird population estimates were based on number of nests found in intensive nest searches of plots, supplemented by territory mapping for passerines and some other species (Myers and Pitelka 1975, Jones et al. 1982). In addition, probable nest locations as determined by behavioral observations were recorded for species with particularly well-concealed nests (e.g. pectoral sandpiper, long-billed dowitcher, yellow wagtail, and savannah sparrow).

Total Bird Density

Population density for each species (including breeders, transients, and migrants) in each habitat type, was estimated by averaging the total number of birds, excluding unfledged young, observed in each replicate plot, for each of the four censuses in the breeding season. Post-breeding population density was estimated in the same way using data from the last three censuses. The fifth census (which occurred in mid-July) was intended to be part of the breeding season population estimates, but due to earlier-than-usual nesting phenology in 1984, it was included in the post-breeding population estimates. Bird densities from the 10-ha plots were expressed as birds/km^2. Total counts on each census of each plot comprised the raw data used in statistical tests.

Data Analysis

Bird and nest densities were analyzed with a nested analysis of variance (MANOVA). Replicate plots were nested within habitat type and habitat types were nested within study site. Each replicate was censused seven times during the field season, and replicates were treated as split-plots through time (Steel and Torrie 1980). Analyses of location, habitat, and seasonal difference were performed using the SPSS MANOVA computer program (Hull and Nie 1981) with data from all plots. After preliminary MANOVA procedures were done for the pooled data, separate MANOVA were done to test for differences due to location within each of the three habitat types present at all three study sites: Wet Sedge, Moist Sedge-Shrub and Riparian. Variables tested were total birds, total shorebirds, total passerines, number of species, and individual totals of five key species: lesser golden-plover, red-necked phalarope, semipalmated sandpiper, pectoral sandpiper, and Lapland longspur. Additional MANOVA were performed separately for each location to further test for differences due to habitat on total bird, shorebird, and passerine densities and on total nest, shorebird nest, and passerine nest densities. Analyses were performed on both total bird densities and nest densities for these species and species groups for the breeding season (first four censuses) and on total bird densities for the post-breeding season (last three censuses).

Duncan's new multiple range test (Steel and Torrie 1980) was used to determine significant differences between mean bird densities of individual habitats, of individual locations within habitats, and of individual habitats within each location, when statistical significance (at P=0.05) was indicated by the MANOVA analysis. The formulas given by Kramer (1956, as cited by Steel and Torrie 1980) were used for cases of unequal sample sizes. The results from 1983 (Spindler et al. 1984) were re-analyzed with Duncan's test to allow inter-year comparisons.

The TWINSPAN analysis of the Cornell Ecology Program Series (Hill 1979) was used to clarify habitat differences based on bird use. This analysis performs a dichotomous-branching and clustering ordination of taxa and samples simultaneously, using the multivariate technique of reciprocal averaging (Hill 1973). This particular program was chosen for its ease in handling large numbers of zeroes. The data sets used in these analyses were totals by plot of all bird sightings by species for the four breeding season censuses in 1983 and 1984, and for the three post-breeding censuses in 1984, and of nests per plot for 1983 and 1984.

Graphics and simple 2-way MANOVA for analyses of seasonal variability were obtained using the program BMDP 7D (Dixon et al. 1981).

Results and Discussion

Phenology

Snow melt. Snow melt across the ANWR coastal plain occurred earlier than in previous years of the project, probably due to lower than normal snow fall during the winter months (Alaska Climate Center 1983, 1984 a and b). Approximately 30-50% of the tundra was exposed across the study area on 16 May and on 17-18 May the Hulahula and Jago Rivers began flowing at the deltas. The ANWR coastal plain was nearly snow-free by 1 June and the majority of lakes and ponds were ice-free. Snow cover was still 80% complete on this date in 1983. Break-up in 1984 was more gradual from late May through early June than in 1983 when most snow melted suddenly between 1-3 June. Snow cover at the the coastal study sites consisted of remnant snow banks along river bluffs and ice in river channels on 1 June 1984. At Jago Delta, the lakes were only partially ice-covered on 2 June, but ice on the largest lakes remained until after 12 June. Aichilik had greater snow cover than the other two study sites, with 20-30% remaining on 2 June, less than 5% by 9 June and no snow on 14 June. Snow remained along the Sadlerochit bluff until 8 July.

Plant flowering. First flowering dates for common plant species were compared to assess phenological differences between the three study sites censused in 1984 and between years (Appendix Table 1). There was a significant difference between the three study sites in 1984 for first flowering dates of 29 species (Friedman Test, P=0.002). Significantly earlier dates were found for Aichilik and Jago Delta compared to Sadlerochit (Wilcoxon signed-ranks test, P=0.005 and P=0.04 respectively). However, no significant difference existed between the Aichilik and Jago Delta sites. These results may have largely been due to differences in sampling effort as opposed to plant phenology. Aichilik and Jago Delta camps were located in riparian areas which had a high variety of species and were sampled daily, whereas Sadlerochit riparian habitats were visited only during censuses. There were no significant differences in first flowering dates at the three sites censused in 1983 (Spindler et al. 1984).

Since location was probably not a significant factor in plant phenology for sites censused in 1983 and 1984, inter-year comparisons should reveal differences in plant phenology. First flowering of 19 species common to sites studied in both years was significantly earlier (Wilcoxon signed-ranks test, $P \leq 0.05$) in 1984 than in 1983 by a mean of 8.3 days. The first date of flowering recorded for 29 common species was earlier in 1984 compared to 1978, 1982, and 1983, for all species except one record in 1983 (Appendix Table 1).

Bird nesting. Apparent differences in nesting chronology were found between 1984 and previous years of this study, although censusing different study sites in different years allowed only general comparisons. Dates for bird nest initiation and hatching by dominant species were earlier in 1984 compared with previous years of study, with pectoral sandpipers showing the largest difference (Spindler 1978, Spindler and Miller 1983, Spindler et al. 1984). First pectoral sandpiper nests were found 9, 10, and 19 June 1984 (Fig. 9) compared with 17, 18, and 26 June 1983, 27 June 1982, and 6 July 1978. First pectoral hatching dates were also earlier in 1984 (24, 25, and 28 June) compared with 1983 (29 June and 2 July), 1982 (12 July), and 1978 (9 July). However, the date when the majority of pectoral nests at a site were found hatched, with chicks or empty, was similar for 1984 (30 June and 5 July) and 1983 (29 June, 2, 4 July). Pectoral sandpiper nesting activity extended slightly later in 1984 (16 July) compared with other years (1982: 15 July, 1978: 11 July) except 1983 (18 July) suggesting possibly more favorable nesting conditions for renest attempts of failed nesters or more nests by later arriving and possibly younger pectorals.

First nesting dates (8 and 9 June respectively) and first hatching dates (24 and 27 June respectively) were similar in 1984 (Fig. 10) and 1983 for semipalmated sandpipers. First nests and hatching dates were found on later dates in 1982 (14 and 27 June) and 1978 (15 June and 5 July). Semipalmated sandpiper nesting was recorded until 7 July in 1983 and 1984, but lasted until 12 July 1982 and 16 July 1978. Because semipalmated sandpiper nests are usually located in dry microsites (Myers and Pitelka 1980, Martin and Moitoret 1981), which may be among the first areas uncovered by snow melt, the early snow melt in 1984 and 1983 may have contributed to the earlier nesting chronology of this species.

Breeding chronology of Lapland longspurs was earlier in 1984 (Fig. 11) than 1983 as evidenced by earlier nesting period (5 June - 14 July 1984, 10 June - 18 July 1983), earlier first hatching date (14 June 1984, 20 June 1983), and an earlier date when the majority of nests had hatched (17-20 June 1984, 25-26 June 1983). The 1984 chronology was a week earlier than noted for 1982 and 1978 (first nest 12 June in both years, first hatching 27 June 1982 and 23 June 1978). However, longspur nesting extended to a later date in 1984 than in 1982 or 1978, probably due to more favorable conditions for second nesting attempts.

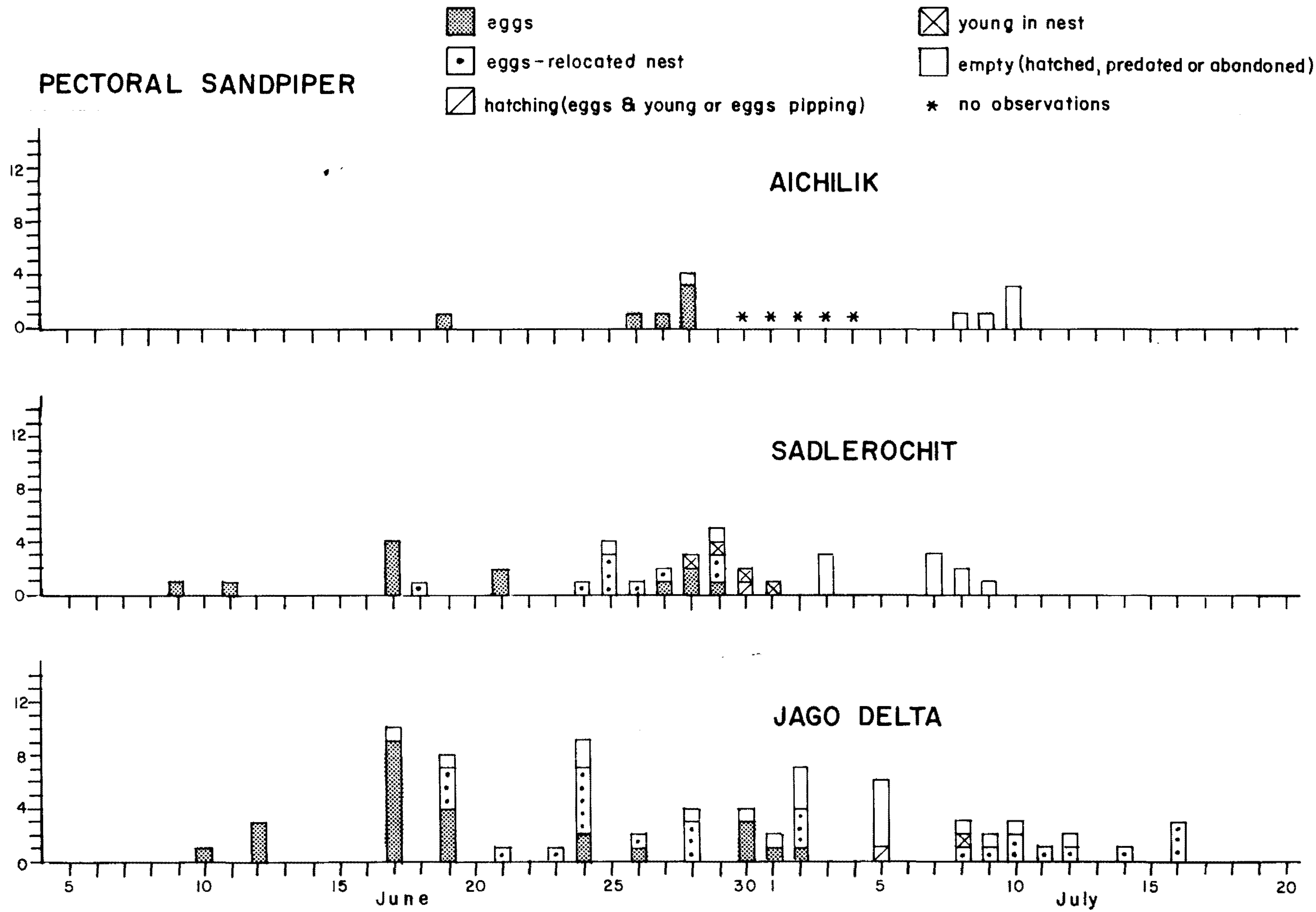

Fig. 9. Nesting chronology of pectoral sandpipers at three study sites, Arctic National Wildlife Refuge, Alaska, 1984.

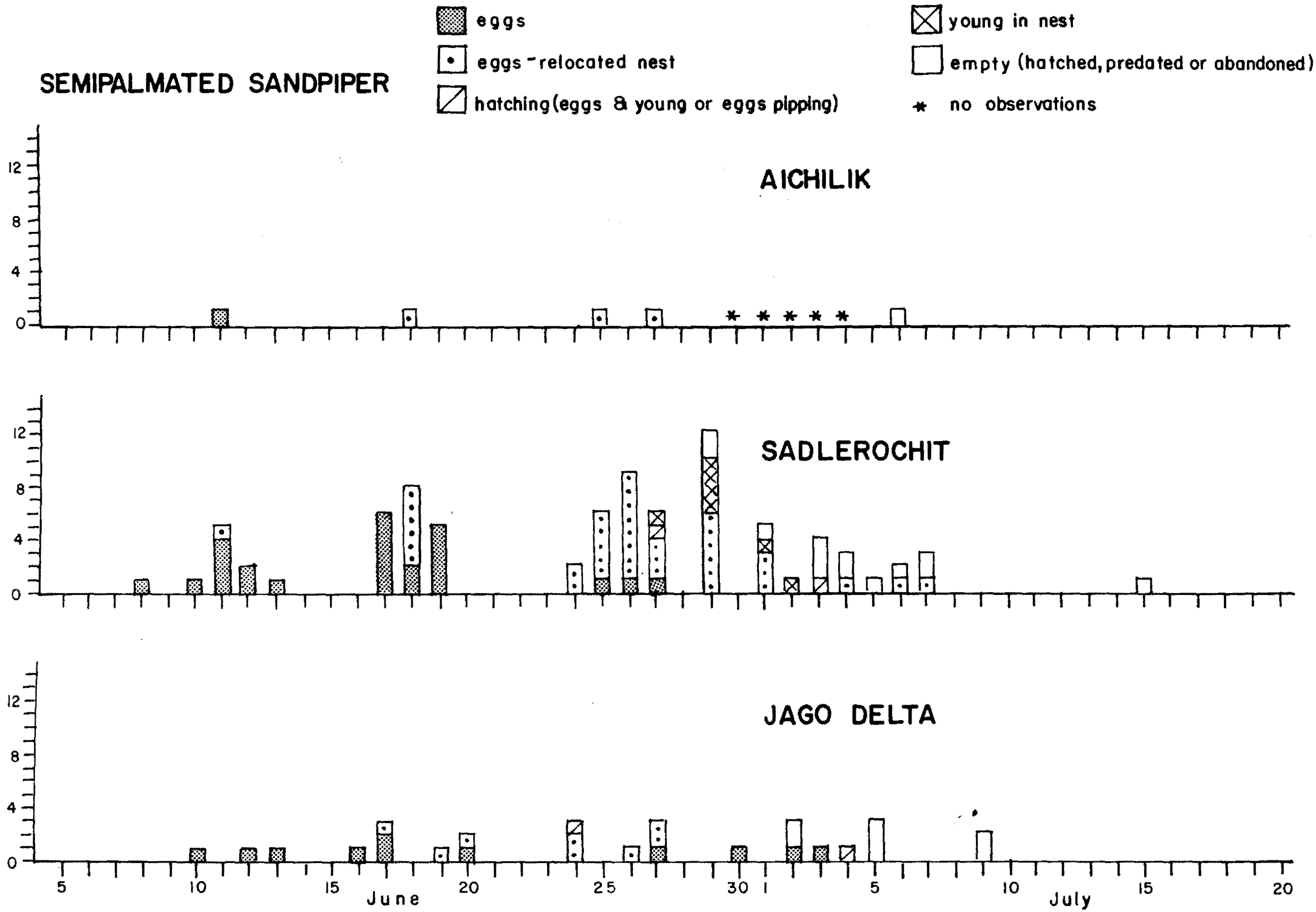

Fig. 10. Nesting chronology of semipalmated sandpipers at three study sites, Arctic National Wildlife Refuge, Alaska, 1984.

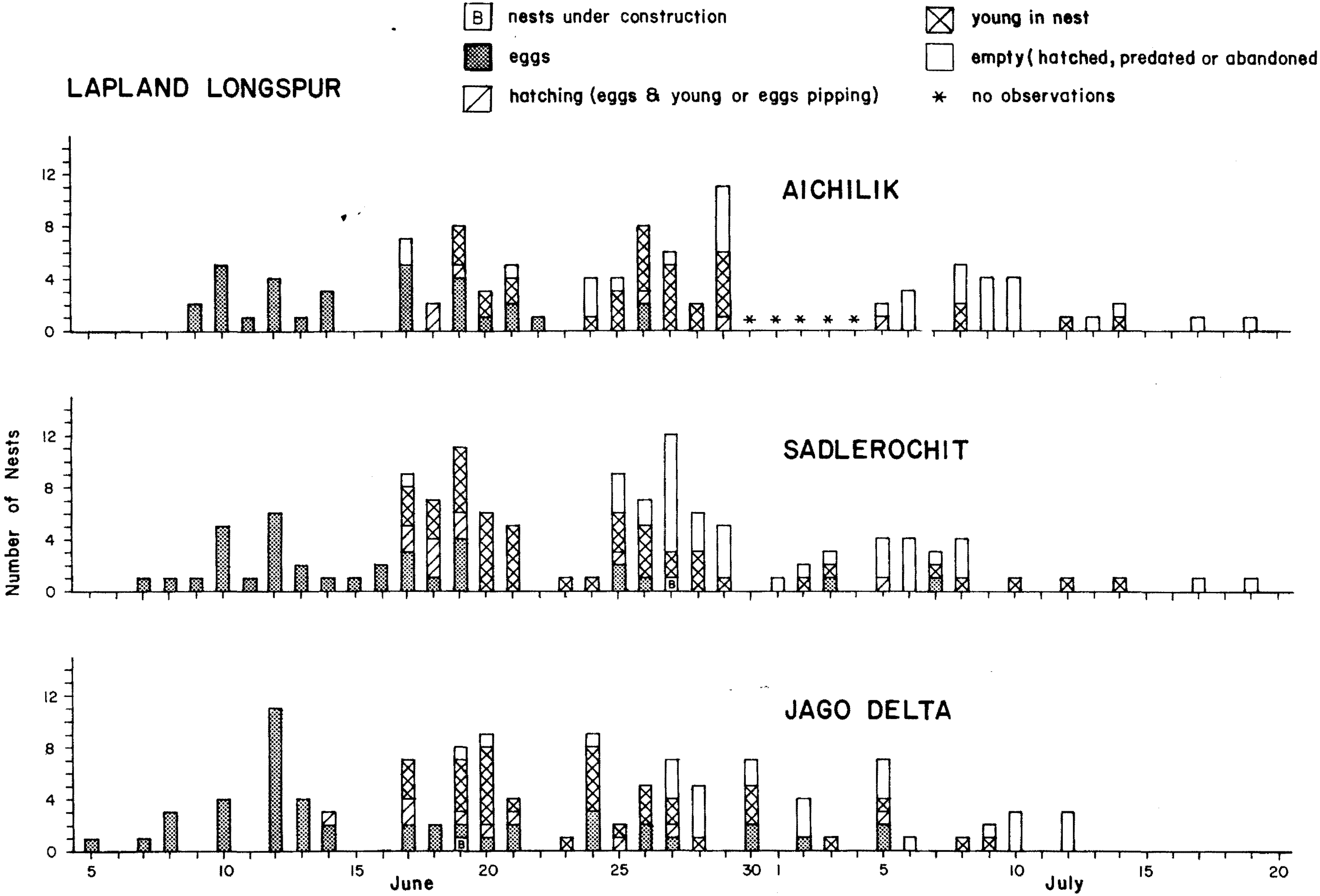

Fig. 11. Nesting chronology of Lapland longspurs at three study sites, Arctic National Wildlife Refuge, Alaska, 1984.

Habitat Descriptions

The seven habitats censused in 1984 represented the modified Landsat types (Table 1) described for previous years of the study. The following descriptions summarize the primary characteristics used to distinguish each type, as well as the variation observed within each type, between the three sites censused in 1984 and the three sites censused in 1983. Some of the differences are evident from the varying percentages of Viereck et al. (1982) vegetation classes (Tables 4, 5, 6), but other differences such as micro-relief features and size and distribution of ponds or standing water have not yet been quantified. General descriptions of these habitat features are included here, as these may account for some of the variability in bird populations encountered within habitat types (Defining Tundra Bird Habitats).

Flooded. This habitat was characterized by sedge tundra with standing water present, interspersed with shallow ponds and/or deeper lakes with emergent *Arctophila fulva*. At Jago Delta this habitat was primarily Pond/Sedge Tundra Complex (Landsat type IIa). At three other study sites (not censused in 1984) Flooded habitat additionally consisted of Aquatic Tundra (Landsat type IIb). Flooded plots at Okpilak (censused in 1978, 1982, 1983) were comparable to plots at Jago Delta in amount of wet sedge meadow tundra, but differed in the other vegetation types present. At Okpilak the remaining vegetation was primarily fresh grass marsh (*Arctophila fulva*), while at Jago Delta it was a combination of sedge-*Dryas* tundra and sedge-willow tundra. Jago Delta had shallow ponds covering 12-15% of the Flooded plots, while Okpilak Flooded plots had larger expanses of deeper water. Some of the shallow ponds at Jago Delta dried up in July, but refilled during August rains.

Wet Sedge. This habitat was characterized by very wet or saturated soils with little micro-relief, on which a uniform sedge cover was the dominant vegetation. There were some obvious differences in appearance of this habitat between the three sites censused in 1984. Plots at Aichilik contained the greatest amount of wet sedge meadow tundra which occurred in strangmoor formation , with a small proportion of sedge-willow and sedge-birch tundra. Plots at Jago Delta were intermediate in the amount of wet sedge meadow tundra and also contained sedge-willow tundra and sedge-*Dryas* tundra. The low relief, low center polygon formations were saturated in June and August, but dried up in July at Jago Delta. At Sadlerochit, soils were saturated throughout the summer, but only 10-24% of the vegetation was classified as pure wet sedge meadow. The dominant vegetation on the plots was sedge-willow with some very shrubby areas (willow-sedge) on polygon rims. Both strangmoor and low center polygon features were present. *Arctophila* ponds (1%) occurred on two of the plots.

Of the 1983 sites, Wet Sedge plots at Jago-Bitty were most similar in vegetation to those at Aichilik, but they contained less sedge-birch, more ponds, and were polygonized. Vegetation types on Wet Sedge plots at Katakturuk and Okpilak were more similar to those at Jago Delta, but the plot at Katakturuk was not polygonized.

Moist Sedge. This habitat was similar to Wet Sedge except that better drainage and less saturated soils allowed dwarf shrubs (*Salix*, *Dryas*) to co-exist within the uniform sedge cover. This type occurred at Aichilik in 1984, where Moist Sedge plots were dominated by sedge-willow tundra and

Table 4. Percent cover of Viereck et al. (1982) Level IV vegetation classes on Flooded, Wet Sedge, and Moist Sedge bird census plots for 1984, coastal plain, Arctic National Wildlife Refuge, Alaska. (* = less than 1% cover)

Viereck et al. (1982) level IV vegetation classes	Habitat	Flooded(II)			Wet Sedge (III)									Moist Sedge(IV)		
	Study area	Jago Delta			Aichilik			Sadlerochit			Jago Delta			Aichilik		
	Plot number	621	622	623	431	432	433	531	532	533	631	632	633	441	442	443
2 C 1 Closed low shrub scrub																
b (low willow)																
2 Open low shrub scrub																
a (dwarf birch)																
b (low willow)																
r (willow-sedge tundra)								10	1	9						
s (willow-grass tundra)																
2 D 1 Closed dwarf shrub scrub																
a (mat & cushion-sedge tundra)		*														
b (mat & cushion-grass tundra)																
c (*Dryas* tundra)																
d (*Cassiope* tundra)		*		*												
g (low ericaceous shrub tundra)																
2 Open dwarf shrub scrub																
b (*Dryas*-lichen tundra)																
c (*Dryas*-herb tundra)																4
e (low willow tundra)																
3 A 1 Dry graminoid herbaceous																
a (*Elymus*)																
2 Mesic graminoid herbaceous																
d (tussock tundra)														3	3	
h (sedge-willow tundra)		6	3	4	4	5	2	79	74	69	25	25	24	60	39	26
i (sedge-birch tundra)					14	17	3									
j (sedge-*Dryas* tundra)		21	16	15							18	20	6	25	52	50
3 Wet graminoid herbaceous																
a (wet sedge meadow tundra)		61	67	66	80	78	95	10	24	22	57	55	70	12	6	20
b (wet sedge-grass meadow tundra)					2											
c (wet sedge-herb meadow tundra)																
e (fresh grass marsh)								1	1							
3 B 1 Dry forb herbaceous																
a (seral herbs)																
2 Mesic forb herbaceous																
e (riparian herbs)[a]																
3 Wet forb herbaceous																
e (old stream channel)[a]																
water		12	14	15					*		*					
sand, gravel, mud																

[a] Types not described by Viereck et al. (1982) - see text

Table 5. Percent cover of Viereck et al. (1982) Level IV vegetation classes on Mosaic and Moist Sedge-Shrub bird census plots for 1984, coastal plain, Arctic National Wildlife Refuge, Alaska. (* = less than 1% cover)

Viereck et al. (1982) level IV vegetation classes	Habitat	Mosaic(IVa)						Moist Sedge-Shrub(V)								
	Study area	Sadlerochit			Jago Delta			Aichilik			Sadlerochit			Jago Delta		
	Plot number	541	542	543	641	642	643	451	452	453	551	552	553	651	652	653
2 C 1 Closed low shrub scrub																
b (low willow)																
2 Open low shrub scrub																
a (dwarf birch)											*					
b (low willow)																
r (willow-sedge tundra)											16	2	2			
s (willow-grass tundra)					2	*					2		2			
2 D 1 Closed dwarf shrub scrub																
a (mat & cushion-sedge tundra)							9							26	17	8
b (mat & cushion-grass tundra)											7	9	19			
c (*Dryas* tundra)																
d (*Cassiope* tundra)					18	29	*							*	*	*
g (low ericaceous shrub tundra)		20	40	48							6	19	7		*	*
2 Open dwarf shrub scrub																
b (*Dryas*-lichen tundra)						1								*	3	1
c (*Dryas*-herb tundra)														*		
e (low willow tundra)		25	21	11							19	2	9			
3 A 1 Dry graminoid herbaceous																
a (*Elymus*)																
2 Mesic graminoid herbaceous																
d (tussock tundra)			1	3				3		5	*	9	4	9	8	3
h (sedge-willow tundra)		28	14	18	29	15	19	60	70	61	45	41	49	10	54	72
i (sedge-birch tundra)								8	2	5						
j (sedge-*Dryas* tundra)					12	12	40							54	12	5
3 Wet graminoid herbaceous																
a (wet sedge meadow tundra)		27	24	20	39	34	30	20	20	13	5	18	8	1	6	11
b (wet sedge-grass meadow tundra)								3	8	4						
c (wet sedge-herb meadow tundra)								3		6						
e (fresh grass marsh)		*														
3 B 1 Dry forb herbaceous																
a (seral herbs)																
2 Mesic forb herbaceous																
e (riparian herbs)[a]																
3 Wet forb herbaceous																
e (old stream channel)[a]																
water					1	9	2	3						*		
sand, gravel, mud							*								*	*

[a] Types not described by Viereck et al. (1982) - see text

Table 6. Percent cover of Viereck et al. (1982) Level IV vegetation classes on Tussock and Riparian bird census plots for 1984, coastal plain, Arctic National Wildlife Refuge, Alaska. (* = less than 1% cover)

Viereck et al. (1982) level IV vegetation classes	Habitat	Tussock(VI)						Riparian(IX)									
	Study area	Aichilik			Sadlerochit			Aichilik			Sadlerochit				Jago Delta		
	Plot number	461	462	463	561	562	563	491	492	493	591	592	593	594	691	692	693
2 C 1 Closed low shrub scrub																	
b (low willow)													11	9			
2 Open low shrub scrub																	
a (dwarf birch)		1					*										
b (low willow)		3						49	24	22	31	39	44	48	1	*	2
r (willow-sedge tundra)			3	3	11	11	8						1	1			
s (willow-grass tundra)						*											
2 D 1 Closed Dwarf Shrub Scrub																	
a (mat & cushion-sedge tundra)					7	9	5										
b (mat & cushion-grass tundra)					28	13	20										
c (<u>Dryas</u> tundra)										3							
d (<u>Cassiope</u> tundra)																	
g (low ericaceous shrub tundra)		2	*	*													
2 Open dwarf shrub scrub																	
b (<u>Dryas</u>-lichen tundra)																	
c (<u>Dryas</u>-herb tundra)								28	16	34			4	13	56	7	5
e (low willow tundra)									14	5					17	36	44
3 A 1 Dry graminoid herbaceous																	
a (<u>Elymus</u>)															*	*	*
2 Mesic graminoid herbaceous																	
d (tussock tundra)		71	73	72	23	39	43										
h (sedge-willow tundra)		23	23	25	28	27	23			5			10	2			
i (sedge-birch tundra)																	
j (sedge-<u>Dryas</u> tundra)										11							
3 Wet graminoid herbaceous																	
a (wet sedge meadow tundra)		2	1		1	1	1				1	1	3		6	15	6
b (wet sedge-grass meadow tundra)											1	*	5	3			
c (wet sedge-herb meadow tundra)																	
e (fresh grass marsh)						*						*					*
3 B 1 Dry forb herbaceous																	
a (seral herbs)								6	10	3	17	15	3	12	14	27	30
2 Mesic forb herbaceous																	
e (riparian herbs)												3	4	*			
3 Wet forb herbaceous																	
e (old stream channel)											11	1	6	9			
water								8	8	4	8	19	6			3	
sand, gravel, mud								9	28	13	31	22	3	3	6	12	13

[a] Types not described by Viereck et al. (1982) - see text

sedge-*Dryas* tundra, and contained lesser amounts of wet-sedge tundra, tussock tundra, and *Dryas*-herb tundra. Moist Sedge plots censused in 1983 at Katakturuk were similar, but those at Jago-Bitty contained more willow and more tussocks.

Further examination of Moist Sedge habitat indicated that it had similarities to Moist Sedge-Shrub (type V), due to the dominant uniform cover of sedge-willow or sedge-Dryas, and could be classified as a Non-complex Moist Sedge-shrub. It was quite different in appearance from the Moist Sedge-Shrub (type V) habitats which contained sedge-willow interspersed with wet sedge, tussocks, ericaceous shrubs, and ponds, and therefore it was considered a separate type in this analysis.

Mosaic. This habitat was characterized by a high degree of micro-relief (high or low centered polygons) which allowed moist vegetation types (sedge-willow, low ericaceous shrub, sedge-*Dryas*, *Cassiope*) to be interspersed with pockets of wet sedge tundra and numerous small shallow or deep ponds and troughs. The Jago Delta plots had a greater amount of wet sedge meadow and water than those at Sadlerochit, but the two sites had similar cover of sedge-willow tundra. The remaining vegetation cover was quite different between the two 1984 sites.

At Sadlerochit, the tops of the high-centered polygons were covered with either low (dwarf) willow tundra composed of *Salix arctica*, *S. reticulata* and *S. phlebophylla*, low ericaceous shrub tundra comprised of *Cassiope*, *Ledum*, *Vaccinium*, *Rubus*, with some *Betula* and miscellaneous herbs such as *Pedicularis*, *Saxifraga*, *Polygonum* or tussock tundra. At Jago Delta there were low as well as high centered polygons, less micro-relief, and the major remaining vegetation types were sedge-*Dryas* tundra, *Cassiope* tundra, and mat and cushion-sedge. The plots censused at Okpilak in 1983 were most similar to those at Jago Delta, but without the *Cassiope* cover, and with more wet-sedge.

Moist Sedge-shrub. This habitat was recognized by a dominant vegetation cover of sedge-willow tundra, but the complex of other types interspersed with the sedge-willow gave this habitat a wide range of appearances. Slightly polygonized ground with many small ponds or thaw pits occurred in some places.

At Aichilik sedge-willow and wet sedge were the only major vegetation types, with lesser amounts of sedge-birch, wet sedge-grass, wet sedge-herb, and tussock. These plots were most similar to 1983 plots at Katakturuk and Jago-Bitty (also inland sites), but had less tussock cover and greater interspersions of small ponds.

At Sadlerochit the Moist Sedge-Shrub plots had less sedge-willow and less wet sedge than at Aichilik. The remaining vegetation types reflected portions of the plots which were more similar to the Mosaic and the Tussock habitats: low willow tundra, low ericaceous shrub tundra, mat and cushion-grass, willow-sedge, and tussock tundra. Some plots had many small ponds.

At Jago Delta, two of the plots were dominated by sedge-willow with lesser amounts of wet-sedge, tussock, sedge-*Dryas* tundra, mat and cushion-sedge, and *Dryas*-lichen tundra. The third plot represented Moist Sedge/Barren Tundra Complex (frost scar tundra, Landsat type Vb). On this plot sedge-*Dryas* tundra was the dominant vegetation type with mat and cushion-sedge ranking second. Sedge-willow, tussock, and wet-sedge comprised minor portions of the plot.

Tussock. Tussock habitats at Katakturuk and Jago-Bitty in 1983 were defined as having 50% or more tussock cover (Spindler et al. 1984). Tussock plots at Aichilik in 1984 had 71-73% tussock with the remaining cover primarily sedge-willow.

No habitat was present with 50% tussock cover at the Sadlerochit site. Therefore tussock plots were established in an area of highest available tussock cover (23-43%). The remainder of these plots consisted of mat and cushion-grass (or sedge), sedge-willow, and willow-sedge. Although these plots might better fit the definition of Moist Sedge-Shrub habitat, they differed significantly from the other Moist Sedge-Shrub plots censused in 1984 in having greater tussock cover and almost no (1%) Wet Sedge habitat. Thus they were considered more similar to the Tussock plots, and classified as such for this analysis.

Riparian. This habitat type was distinguished by stands of willow shrubs along rivers. Since these riparian willow stands seldom occurred in solid 10-ha blocks, these plots also typically contained Dryas river terraces and sparsely vegetated sand or gravel bars.

Of the three sites censused in 1984, Aichilik had Riparian plots that were most similar to those at sites censused in 1983 (Katakturuk, Jago-Bitty, Okpilak). At Aichilik the plots had 27-49% dwarf or low willow, with Dryas-herb and seral herb being the other major vegetation types present. These plots also had considerable amounts of water and sand or gravel.

Riparian plots at Jago Delta were quite different in appearance. They contained only small scattered clumps of dwarf or occasionally low willow, on sandy dunes. Dryas-herb and seral herb were more widespread than at Aichilik, and wet sedge-meadow was also present in old river channels.

At Sadlerochit, two Riparian plots were similar to those at Jago Delta in having only scattered clumps of willow on sandy dunes. However, the willows at Sadlerochit were taller than those at Jago Delta, and Dryas-herb tundra did not appear on these plots. The other major vegetation consisted of seral herbs with large amounts of bare sand or gravel and water. The third Riparian plot at Sadlerochit contained denser and more extensive low willow stands, with less bare sand and gravel, or herb vegetation types, than the other two plots. The vegetation on this third plot seemed consistent with that on sites censused in 1983.

Two vegetation cover types were identified at Sadlerochit on Riparian plots which could not easily be assigned to any of the Viereck et al. (1982) vegetation classes. The first of these, designated as "mesic forb herbaceous: riparian herbs" consisted of dense cover of various herbs, primarily Oxytropis and Astragalus, but Hedysarum and Lupinus were also common. Sedge, willow, and/or Dryas sometimes occurred with these species, but the herbs were dominant over significant portions of these plots. This vegetation type differed from "Dry forb herbaceous: seral herb" which at Sadlerochit consisted of Epilobium latifolium, Artemisia arctica, and other species which generally formed a very sparse cover on dry sand or gravel bars. The other newly designated type at Sadlerochit was "wet forb herbaceous: old stream channels". This category included areas of frequently saturated mud that were sparsely vegetated with some or all of the following: Equisetum, prostrate willow, sedge, grass, moss, and Dryas.

Differences Due to Location. No species or species group tested in 1984 showed significant differences in mean nest or bird densities due to location relative to habitat when tested over all habitats (Tables 7 and 8). These results differed from 1983 (Spindler et al. 1984) when pectoral sandpipers and shorebirds were found to show a significant difference in density due to location. The difference in 1983 was attributed to the presence of habitats containing high densities of shorebirds, especially pectoral sandpipers, at the coastal study site at Okpilak. Coastal study sites censused in 1984 differed in quality and quantity of these habitats, but whether the differences in results were due to habitat differences or annual variability could not be determined.

Table 7. Significance levels (MANOVA) of differences in mean nest densities[a] due to study area location and habitat type over three locations[b] in 1983 and 1984, coastal plain, Arctic National Wildlife Refuge, Alaska.

	Location		Habitat	
Variable	1983	1984	1983	1984
Total nests	P=0.848	P=0.570	P<0.003	P<0.001
Total species nesting	P=0.975	P=0.207	P<0.250	P<0.020
Shorebird nests	P=0.162	P=0.589	P>0.250	P<0.001
Passerine nests	P=0.814	P=0.799	P=0.000	P<0.002
Lesser golden-plover nests	P=0.652	P=0.158	P>0.250	P<0.500
Red-necked phalarope nests	P=0.095	P=0.519	P<0.250	P<0.050
Semipalmated sandpiper nests	P=0.892	P=0.087	P<0.010	P<0.050
Pectoral sandpiper nests	P=0.217	P=0.836	P<0.250	P<0.001
Lapland longspur nests	P=0.847	P=0.536	P=0.000	P<0.001

[a]Nest densities were determined from number of nests or territories per 10-ha plot.

[b]The three locations censused in 1983 were different from the three locations censused in 1984.

Separate MANOVA analyses were used to test for differences due to location within those habitat types that were present at all three 1984 study sites: Wet Sedge, Moist Sedge-Shrub, and Riparian; and these were compared with similar analyses for the 1983 study sites (Table 9).

Wet Sedge - Wet Sedge habitat at the two 1984 coastal sites (Sadlerochit and Jago Delta) had significantly higher total bird densities than Wet Sedge at the inland site (Aichilik) in both the breeding and post-breeding seasons (Table 9). However, there was no significant difference between sites for passerine densities in either season, and Lapland longspur density was significantly higher at the coastal sites only during the breeding season. The Sadlerochit site had significantly higher densities of shorebirds and pectoral sandpipers during the breeding season and densities of these two groups were significantly higher at both coastal sites during the post-breeding season. Jago Delta had significantly higher densities of semipalmated sandpipers in Wet Sedge habitat during both the breeding and post-breeding season. In Wet Sedge habitat in 1983 the coastal site (Okpilak)

Table 8. Significance levels (MANOVA) of differences in mean total bird densities due to location, habitat, and census over three locations[a] in 1983 and 1984, coastal plain, Arctic National Wildlife Refuge, Alaska.

	Location			Habitat			Census		
	Breeding and post-breeding season	Breeding season	Post-breeding season	Breeding and post-breeding season	Breeding season	Post-breeding season	Breeding and post-breeding season	Breeding season	Post-breeding season
Variable	1983[b]	1984[c]	1984[d]	1983[b]	1984[c]	1984[d]	1983[b]	1984[c]	1984[d]
Total birds	P=0.227	P=0.726	P=0.915	P=0.000	P<0.001	P<0.001	P=0.000	P=0.001	P=0.000
Total species	P=0.226	P=0.368	P=0.881	P=0.000	P<0.001	P<0.001	P=0.100	P=0.017	P=0.000
Shorebirds	P=0.022	P=0.787	P=0.742	P=0.000	P<0.001	P<0.001	P=0.000	P=0.000	P=0.000
Passerines	P=0.534	P=0.781	P=0.472	P=0.000	P<0.005	P<0.010	P=0.000	P=0.000	P=0.001
Lesser golden-plover	P=0.138	P=0.156	P=0.252	P>0.250	P<0.010	P>0.500	P=0.038	P=0.001	P=0.021
Red-necked phalarope	P=0.054	P=0.666	P=0.607	P=0.000	P<0.001	P<0.002	P=0.000	P=0.005	P=0.000
Semipalmated sandpiper	P=0.755	P=0.138	P=0.555	P=0.000	P<0.001	P<0.001	P=0.000	P=0.000	P=0.730
Pectoral sandpiper	P=0.014	P=0.994	P=0.967	P=0.000	P<0.001	P<0.001	P=0.000	P=0.000	P=0.000
Lapland longspur	P=0.613	P=0.762	P=0.398	P=0.000	P 0.001	P<0.010	P=0.000	P=0.000	P=0.001

[a]The three locations censused in 1983 were different from the three locations censused in 1984.
[b]Based on five censuses: four breeding and one post-breeding.
[c]Based on four censuses.
[d]Based on three censuses.

Table 9. Significant differences[a] in mean total bird densities and mean nest densities[b] due to study area location, for three 1983 study sites[c] and three 1984 study sites[d], within three habitat types, Arctic National Wildlife Refuge, Alaska.

	Habitat								
	Wet Sedge (III)			Moist Sedge-Shrub (V)			Riparian (IX)		
	Breeding and post-breeding season	Breeding season	Post-breeding season	Breeding and post-breeding season	Breeding season	Post-breeding season	Breeding and post-breeding season	Breeding season	Post-breeding season
Variable	1983	1984	1984	1983	1984	1984	1983	1984	1984
Total birds	OBK	SJA	JSA	ns	ASJ	AJS	KOB	ns	ns
Total species	ns	SAJ	JSA	ns	ASJ	AJS	KOB	SAJ	SAJ
Shorebirds	ns	SJA	SJA	ns	ASJ	AJS	ns	ns	SJA
Passerines	OKB	ns	ns	ns	ns	ns	KOB	ns	ns
Lesser golden-plover	ns	ns	ns	ns	ns	ns	ns	ASJ	ns
Red-necked phalarope	ns	ns	ns	ns	ASJ	ASJ	OKB	ns	ns
Semipalmated sandpiper	---	JSA	JSA	ns	ns	ns	OKB	SAJ	SJA
Pectoral sandpiper	ns	SAJ	SJA	ns	ASJ	AJS	ns	ns	SJA
Lapland longspur	OKB	JSA	ns	ns	ASJ	ns	ns	ns	ns
Total nests	ns	ns	---	ns	ns	---	ns	ns	---
Total species nesting	ns	ns	---	ns	ns	---	ns	ns	---
Shorebird nests	ns	ns	---	ns	ns	---	ns	ns	---
Passerine nests	ns	ns	---	ns	ns	---	ns	ns	---

[a]Determined by Duncan's new multiple range test for cases in which MANOVA analysis indicated significant difference at P = 0.05. 1984 probability values from MANOVA analysis listed in Appendix Table 10. Probability values for 1983 from Spindler et al. (1984). Study site abbreviations are listed in order of decreasing mean density and underlining indicates sites that were not significantly different at P = 0.05. ns = not significantly different at P = 0.05 in MANOVA analysis.

[b]Nest Densities were determined from number of nests or territories per 10-ha plot.

[c]Okpilak (O), Katakturuk (K), Jago-Bitty (B)

[d]Aichilik (A), Sadlerochit (S), Jago Delta (J)

had significantly higher densities of total birds, passerines, and Lapland longspurs than the two inland sites. Although not consistent over all species or in both years, Wet Sedge habitat in coastal areas apparently often contained higher bird densities than Wet Sedge at inland sites, especially during the post-breeding season.

Moist Sedge Shrub - All species and species groups tested showed significant differences in density due to location in Moist Sedge-Shrub habitat in 1984, except for lesser golden-plover, semipalmated sandpiper, and passerines (Table 9). All groups tested showed the same pattern, with Moist Sedge-Shrub plots at Aichilik having significantly higher densities and more species than the other two sites, in both the breeding and post-breeding seasons. Contrastingly, there were no significant differences in bird densities due to study site location in Moist Sedge-Shrub habitat in 1983. Although Aichilik was the only inland site censused in 1984, the lack of significant differences between 1983 sites suggests that the higher densities at Aichilik represented a site-specific difference in habitat rather than a characteristic of inland sites, although differences due to annual variability cannot be discounted.

Riparian - There was no significant difference in total bird densities in Riparian habitat between the three 1984 study sites, but Sadlerochit and Aichilik had significantly more species in the breeding season than Jago Delta, and Sadlerochit had significantly more species in the post-breeding season than the other two sites (Table 9). Riparian habitat at Sadlerochit had significantly higher densities of semipalmated sandpipers in both the breeding and post-breeding seasons, and significantly higher densities of pectoral sandpipers in the post-breeding season, than Riparian habitat at the other sites. Lesser golden-plovers were more abundant in Riparian habitat at Aichilik and Sadlerochit during the breeding season, and shorebirds were more abundant in coastal Riparian habitat in the post-breeding season. In Riparian habitat in 1983, Katakturuk and Okpilak had significantly higher total bird densities, semipalmated sandpiper densities, and numbers of species compared with Jago-Bitty. There were significantly greater densities of passerines at Katakturuk, and of red-necked phalaropes at Okpilak, than at the other 1983 sites. Differences between sites in Riparian habitat use did not show a coastal vs. inland pattern, and it is likely that the differences in bird densities reflect differences in the quality of Riparian habitat at the various sites. Riparian habitat at Katakturuk (inland) and Sadlerochit (coastal) appeared to attract the highest bird densities. Katakturuk had a particularly high density and diversity of passerines, while Sadlerochit had an unusually high density of semipalmated sandpipers.

Nest Densities - There were no significant differences due to location within any of the three habitats occurring at all three study sites for total nest density, number of species nesting, and shorebird and passerine nest densities (Table 9). These results were the same as those obtained from the same analyses on 1983 data, and may reflect insufficiency of the sample size for nest densities, or may be real.

Summary - Between-site differences in total bird densities within each of three habitats showed different patterns in 1984 than in 1983. These differences could have been due to the different sites sampled in each year or due to differences between the 2 years. It appeared that some locational differences in bird densities were due to coastal versus inland influence, while others were due to local differences in quality of habitat. Other possible sources of variation in bird densities due to location could be differences in ranges of different species, differences in patterns of habitat interspersion at various sites, seasonal bird movements, and location of sites along migration routes. Some of these are discussed in other sections of this report, while some require further study.

Differences Due to Habitat. The preliminary MANOVA analysis of 1984 bird plot census data over all three locations indicated that differences in bird and nest densities between habitats were significant for all species and species groups tested except for lesser golden-plover nest density (Table 7) and post-breeding density (Table 8). The results for bird densities were similar to those obtained in 1983 (Table 8), but shorebird nest and red-necked phalarope nest densities showed significant differences due to habitat which did not appear in the 1983 results (Table 7). To verify if these results were consistent for all three locations censused in 1984, similar MANOVAS were performed separately for each location (Table 10).

Table 10. Significance levels (MANOVA) of differences in mean total bird densities and mean nest densities[a] due to habitat within three study site locations, coastal plain, Arctic National Wildlife Refuge, Alaska, 1984.

	Location		
Variable	Aichilik	Sadlerochit	Jago Delta
Bird densities - Breeding season			
Total birds	P=0.001	P=0.100	P=0.002
Shorebirds	P=0.005	P=0.026	P=0.001
Passerines	P=0.018	P=0.258	P=0.001
Bird densities - Post-breeding season			
Total birds	P=0.005	P=0.000	P=0.040
Shorebirds	P=0.002	P=0.000	P=0.456
Passerines	P=0.033	P=0.092	P=0.042
Nest densities			
Total nests	P=0.032	P=0.121	P=0.000
Shorebird nests	P=0.137	P=0.016	P=0.000
Passerine nests	P=0.012	P=0.255	P=0.002

[a]Nest densities were determined from number of nests or territories per 10-ha plot.

Aichilik - Moist Sedge-Shrub habitat consistently showed the highest bird and nest densities during the breeding season at Aichilik although two other habitats, Riparian and Tussock, were not significantly different from Moist Sedge-Shrub (Tables 11, 12). Moist Sedge and Wet Sedge habitats consistently had the lowest bird and nest densities during the breeding season. The same apparent pattern of habitat use existed in the post-breeding season for total birds, but the pattern differed for shorebird and passerine densities. Moist Sedge-Shrub habitat was significantly higher than all other habitats for shorebird density, while Riparian habitat ranked highest, though not significantly higher than Moist Sedge-Shrub and Tussock, for passerine density (Table 13).

Table 11. Significant differences[a] between habitats[b] in mean bird densities at three sites in the breeding season, 1984, coastal plain, Arctic National Wildlife Refuge, Alaska[c].

Variable	Variable value				
Aichilik					
Habitat	V	IX	VI	IV	III
Mean total birds/km²	429	365	293	124	118
Habitat	V	IX	VI	III	IV
Mean total shorebirds/km²	129	98	80	25	15
Habitat	V	IX	VI	IV	III
Mean total passerines/km²	265	200	181	83	72
Sadlerochit					
Habitat	IX	IVa	V	III	VI
Mean total birds/km²	409	340	302	214	159
Habitat	IX	IVa	V	III	VI
Mean total shorebirds/km²	144	121	79	71	21
Habitat	IX	V	IVa	III	VI
Mean total passerines/km²	249	206	193	132	117
Jago Delta					
Habitat	IVa	V	IX	II	III
Mean total birds/km²	362	222	205	187	174
Habitat	IVa	II	IX	V	III
Mean total shorebirds/km²	113	96	73	45	29
Habitat	IVa	V	III	IX	II
Mean total passerines/km²	231	164	144	131	84

[a]Duncan's new multiple range test. Underlining indicates means that are not significantly different at P=0.05.
[b]Habitat names are given in Table 1.
[c]n=12.

Table 12. Significant differences[a] between habitats[b] in mean nest densities[c] at three sites, 1984, coastal plain, Arctic National Wildlife Refuge, Alaska[d].

Variable	Variable value				
Aichilik					
Habitat	V	IX	VI	III	IV
Mean total nests/km^2	132	97	87	45	43
Habitat	V	IX	VI	III	IV
Mean total shorebird nests/km^2	47	33	30	13	12
Habitat	V	IX	VI	III	IV
Mean total passerine nests/km^2	85	63	53	28	28
Sadlerochit					
Habitat	IVa	IX	V	III	VI
Mean total nests/km^2	147	133	121	65	63
Habitat	IVa	IX	V	III	VI
Mean total shorebird nests/km^2	80	54	43	17	12
Habitat	V	IX	IVa	III	VI
Mean total passerine nests/km^2	78	75	57	45	35
Jago Delta					
Habitat	IVa	V	II	IX	III
Mean total nests/km^2	174	114	85	75	67
Habitat	IVa	II	V	IX	III
Mean total shorebird nests/km^2	68	45	33	25	13
Habitat	IVa	V	II	IX	II
Mean total passerine nests/km^2	100	76	53	45	33

[a]Duncan's new multiple range test. Underlining indicates means that are not significantly different at P=0.05.
[b]Habitat names are given in Table 1.
[c]Nest densities were determined from total nests or territories per 10-ha plot.
[d]n=3

Table 13. Significant differences[a] between habitats[b] in mean bird densities at three sites in the post-breeding season, 1984, coastal plain, Arctic National Wildlife Refuge, Alaska[c].

Variable	Variable value				
Aichilik					
Habitat	V	IX	VI	IV	III
Mean total birds/km^2	446	339	273	233	133
Habitat	V	VI	IV	IX	III
Mean total shorebirds/km^2	173	91	90	60	30
Habitat	IX	V	VI	IV	III
Mean total passerines/km^2	226	221	148	120	87
Sadlerochit					
Habitat	IX	III	IVa	VI	V
Mean total birds/km^2	516	244	184	177	160
Habitat	IX	III	IVa	V	VI
Mean total shorebirds/km^2	283	169	59	46	4
Habitat	IX	V	IVa	VI	III
Mean total passerines/km^2	218	107	96	89	70
Jago Delta					
Habitat	IX	III	V	IVa	II
Mean total birds/km^2	374	307	273	259	191
Habitat	IX	III	IVa	II	V
Mean total shorebirds/km^2	163	152	122	114	76
Habitat	IX	V	III	IVa	II
Mean total passerines/km^2	208	192	153	124	72

[a]Duncan's new multiple range test. Underlining indicates means that are not significantly different at P=0.05.
[b]Habitat names are given in Table 1.
[c]n=9

Sadlerochit - There was no significant difference between habitats at Sadlerochit during the breeding season for total birds, passerines, total nests, or passerine nests (Table 10). Highest densities of shorebirds were recorded in Riparian habitat, but these were not significantly higher than the densities in other habitats except Tussock (Table 11). Shorebird nests were most abundant in Mosaic habitat, but the density was not significantly different from those in Riparian or Moist Sedge-Shrub habitat (Table 12). One Riparian plot (593) at Sadlerochit had higher shorebird and total nest density than any other plot at Sadlerochit or than any other plot previously recorded on the ANWR coastal plain (Appendix Table 2). The lowest bird and nest densities at Sadlerochit during the breeding season were consistently found in Wet Sedge and Tussock habitats. Total and shorebird densities were significantly higher in Riparian habitat than in all other habitats during the post-breeding season at Sadlerochit (Table 13). Wet Sedge had the second highest total bird density, and was significantly higher than all others except Riparian in shorebird density. There was no significant difference between habitats in passerine density in the post-breeding season (Table 13).

Jago Delta - Mosaic habitat ranked consistently highest at Jago Delta in bird and nest densities during the breeding season (Tables 11, 12). It was significantly higher than all others for total birds, total nest, total passerines, and total shorebird nests. It was not significantly different from Flooded habitat for total shorebirds, and not significantly different from Moist Sedge-Shrub habitat for passerine nests (Tables 11, 12). Wet Sedge habitat had the lowest shorebird and shorebird nest densities, while Flooded had the lowest passerine and passerine nest densities (Tables 11, 12). During the post-breeding season at Jago Delta, as at Sadlerochit, Riparian habitat had the highest bird density, but unlike Sadlerochit it was not significantly higher than any other habitat except Flooded for total and passerine densities (Table 13). There was no significant difference between habitats for shorebird density in the post-breeding season at Jago Delta (Table 13).

Pooled Results-Analyses of pooled data from the three study sites revealed that Mosaic, Riparian, and Moist Sedge-shrub habitats had significantly higher total bird densities (Table 14) during the breeding season than other habitats. These three habitats plus Flooded habitat had significantly higher shorebird densities than other habitats, and the same three plus Tussock habitat had significantly higher passerine densities than other habitats (Table 14). Rankings were similar for nest density, but Mosaic habitat was significantly higher than all others for total nests and shorebird nests (Table 15). During the post-breeding season Riparian habitat ranked highest in both shorebird and passerine density, and was significantly higher than all other habitats in total bird density (Table 16). Ranking of habitats for mean number of species generally followed the same patterns as for bird densities, but showed more of a gradient between habitats rather than clear-cut groups of significantly different habitats.

Results from the pooled data obscured some of the patterns shown at individual locations. Of the three habitats ranking highest overall in bird use, a different habitat ranked highest at each site: Moist Sedge-Shrub at Aichilik, Riparian at Sadlerochit, and Mosaic at Jago Delta. These individual site differences may have been partially due to locally high populations of individual species: the highest densities of pectoral sandpipers ($77/km^2$ - Appendix Table 5) and pectoral sandpiper nests ($51/km^2$ - Appendix Table 6) from all habitats and sites censused during the 1984 breeding season were

Table 14. Significant differences[a] between habitats[b] for mean total bird density, mean number of species, and mean total densities of selected species, for breeding season 1984, coastal plain, Arctic National Wildlife Refuge, Alaska[c].

Variable	Variable value						
Habitat	IVa	IX	V	VI	II	III	IV
Mean total birds/km^2	351	326	318	226	187	169	124
Habitat	IX	IVa	V	II	VI	IV	III
Mean number of species	6.3	5.8	5.5	4.9	4.7	3.7	3.5
Habitat	IVa	IX	II	V	VI	III	IV
Mean total shorebirds/km^2	117	105	96	84	50	42	15
Habitat	V	IVa	IX	VI	III	II	IV
Mean total passerines/km^2	212	212	193	149	116	84	83
Habitat	IX	VI	IV	IVa	II	V	III
Mean total lesser golden-plovers/km^2	22	13	10	9	9	8	2
Habitat	V	IVa	II	III	VI	IX	IV
Mean total red-necked phalaropes/km^2	8	5	4	3	2	1	0
Habitat	IX	IVa	V	III	II	VI	IV
Mean total semipalmated sandpipers/km^2	38	30	19	5	4	1	0
Habitat	IVa	II	V	VI	III	IX	IV
Mean total pectoral sandpipers/km^2	64	47	40	30	28	3	3
Habitat	IVa	V	IX	VI	III	II	IV
Mean total Lapland longspurs/km^2	204	195	153	147	107	84	82

[a]Duncan's new multiple range test. Underlining indicates means that are not significantly different at P = 0.05.
[b]Habitat names are given in Table 1.
[c]Sample sizes for each habitat are: II - 12, III - 36, IV - 12, IVa - 24, V - 36, VI - 24, IX - 36.

Table 15. Significant differences[a] between habitats[b] for mean total nest density, mean number of species nesting, and mean nest densities[c] of selected species during the breeding season in 1984, coastal plain, Arctic National Wildlife Refuge, Alaska[d].

Variable	Variable value						
Habitat	IVa	V	IX	II	VI	III	IV
Mean total nests/km^2	161	122	101	85	75	59	43
Habitat	IVa	IX	II	V	VI	III	IV
Mean number of species nesting	5.2	4.8	4.7	4.3	3.3	2.7	2.3
Habitat	IVa	II	V	IX	VI	III	IV
Mean total shorebird nests/km^2	74	45	41	38	21[e]	14	12
Habitat	V	IVa	IX	VI	III	II	IV
Mean total passerine nests/km^2	80	78	61	44	42	33	28
Habitat	IV	IX	IVa	VI	II	V	III
Mean total lesser golden-plover nests/km^2	10	7	5	5	3	1	0
Habitat	IVa	V	III	IX	VI	IV	II
Mean total red-necked phalarope nests/km^2	7	4	1	0	0	0	0
Habitat	IVa	IX	V	III	II	IV	VI
Mean total semipalmated sandpiper nests/km^2	18	16	10	3	0	0	0
Habitat	IVa	II	V	VI	III	IV	IX
Mean total pectoral sandpiper nests/km^2	38	22	20	16	8	2	1
Habitat	IVa	V	IX	VI	III	II	IV
Mean total Lapland longspur nests/km^2	78	75	50	44	38	33	28

[a]Duncan's new multiple range test. Underlining indicates means that are not significantly different at P = 0.05.

[b]Habitat names are given in Table 1.

[c]Nest densities were determined from total nests or territories per 10-ha plot.

[d]Sample sizes for each habitat are: II - 3, III - 9, IV - 3, IVa - 6, V - 9, VI - 6, IX - 9.

[e]Habitat V was significantly different from habitat VI, but habitat II was not significantly different from habitat VI, probably due to sample size differences.

Table 16. Significant differences[a] between habitats[b] for mean total bird density, mean number of species, and mean total densities of selected species, for post-breeding season 1984, coastal plain, Arctic National Wildlife Refuge, Alaska[c].

Variable	Variable value						
Habitat	IX	V	IV	III	VI	IVa	II
Mean total birds/km^2	410	293	233	228	225	222	191
Habitat	IX	II	IVa	V	VI	III	IV
Mean number of species	5.2	4.7	3.9	3.6	3.0	2.7	2.7
Habitat	IX	III	II	V	IVa	IV	VI
Mean total shorebirds/km^2	169	117	114[d]	98	91	90	48
Habitat	IX	V	IV	VI	IVa	III	II
Mean total passerines/km^2	217	173	120	118	110	103	72
Habitat	IX	IV	IVa	V	III	VI	II
Mean total lesser golden-plovers/km^2	24	14	12	8	7	6	4
Habitat	IVa	II	V	III	VI	IX	IV
Mean total red-necked phalaropes/km^2	4	3	3	2	2	0	0
Habitat	IX	III	II	IVa	V	VI	IV
Mean total semipalmated sandpipers/km^2	25	3	2	2	1	0	0
Habitat	III	V	IX	IV	II	IVa	VI
Mean total pectoral sandpipers/km^2	102	85	71	71	70	63	39
Habitat	IX	V	IV	VI	IVa	III	II
Mean total Lapland longspurs/km^2	204	168	120	117	110	101	72

[a]Duncan's new multiple range test. Underlining indicates means that are not significantly different at P = 0.05.

[b]Habitat names are given in Table 1.

[c]Sample sizes for each habitat are: II - 9, III - 27, IV - 9, IVa - 18, V - 27, VI - 18, IX - 27.

[d]Habitat IX was significantly different from habitat III, but not from habitat II, probably due to sample size differences.

found on Mosaic habitat at Jago Delta, and the highest densities of semipalmated sandpipers (85/km^2 - Appendix Table 5) and semipalmated sandpiper nests (40/km^2-Appendix Table 6) were found on Riparian habitat at Sadlerochit.

The pooled data obscured the high varibility of Wet Sedge habitat among locations and seasons: at Sadlerochit it was not significantly different from the three highest ranking habitats for total bird density during the breeding season; and during the post-breeding season it ranked second highest for total and shorebird densities at the coastal sites (Sadlerochit and Jago Delta) but lowest at the inland site (Aichilik). These differences were primarily due to use by migratory flocks of shorebirds. Tussock habitat was among the three highest ranking habitats for total bird and nest densities at Aichilik, but ranked lowest at Sadlerochit. This difference may have been due to the proximity of other habitat types to the Aichilik Tussock plots.

The pooled results for individual species also reflected biases due to locally abundant populations in certain habitats, such as pectoral sandpipers in Mosaic at Jago Delta, semipalmated sandpipers in Riparian at Sadlerochit, and red-necked phalaropes in Moist Sedge-Shrub at Aichilik. Each of these species showed peak densities in different habitats at locations where they were less abundant (Appendix Table 5). Likewise, the pooled results for shorebirds may not reflect the different habitat preferences of the individual species, since the results were dominated by the most abundant species. This points out the need to examine the ranges and habitat requirements of individual species when ranking bird habitats.

A general analysis of differences between habitats, in which data from several locations are pooled and species are lumped into groups such as "shorebirds", may obscure site-specific differences in habitat use by certain species.

1983 - 1984 Differences. Comparison of results from 1983 and 1984 revealed differences in patterns of habitat use. In 1983, Flooded habitat ranked higher than any other habitat in total bird density, and was significantly higher than all other habitats in total shorebird density and number of species (Table 17). In 1984, Flooded habitat had significantly lower total bird density during the breeding season than Mosaic, Riparian, and Moist Sedge habitats, and was not significantly different from this group in shorebird density (Table 14). This difference probably reflected a difference in the quality of Flooded habitat between the 1983 site (Okpilak) and 1984 site (Jago Delta). The Flooded plots at Okpilak contained a large percentage of gulls and waterfowl (Spindler et al. 1984), which were uncommon in Flooded plots at Jago Delta, and the Okpilak Flooded plots had over twice as many shorebirds but only half as many passerines as Jago Delta. These differences in species composition were most likely related to the larger deeper ponds in Flooded Plots at Okpilak (see Habitat Descriptions), but annual variability cannot be discounted.

Moist Sedge-Shrub habitat was not significantly different from Mosaic or Riparian in total bird density in 1984, while in 1983 it was significantly lower than these two habitats. This difference was probably due to the greater interspersion of ponds and wet habitats on Moist Sedge-Shrub plots censused in 1984, especially at Aichilik, which made these plots more similar to the Mosaic type, as discussed in "Defining Tundra Bird Habitats".

Table 17. Significant differences[a] between habitats[b] for mean total bird density, mean number of species, and mean total densities of selected species in 1983, coastal plain, Arctic National Wildlife Refuge, Alaska[c].

Variable	Variable value						
Habitat	II	IX	IVa	V	III	VI	IV
Mean total birds/km^2	384	345	256	161	142	113	87
Habitat	II	IX	IVa	V	III	VI	IV
Mean number of species	8.1	5.9	5.0	3.7	3.4	3.1	2.2
Habitat	II	IVa	III	IX	V	VI	IV
Mean total shorebirds/km^2	239	99	69	62	38	21	14
Habitat	IX	IVa	V	VI	IV	III	II
Mean total passerines/km^2	268	134	109	83	67	65	46
Habitat	IX	VI	IV	V	IVa	II	III
Mean total lesser golden-plovers/km^2	11	9	7	7	5	4	2
Habitat	II	IVa	III	V	IX	VI	IV
Mean total red-necked phalaropes/km^2	25	6	4	2	1	0	0
Habitat	IX	VI	V	II	IVa	IV	III
Mean total semipalmated sandpipers/km^2	34	8	8	6	3	2	0
Habitat	II	IVa	III	V	IX	IV	VI
Mean total pectoral sandpipers/km^2	152	74	56	21	8	5	4
Habitat	IX	IVa	V	VI	IV	III	II
Mean total Lapland longspurs/km^2	193	134	101	72	66	62	46

[a]Duncan's new multiple range test. Underlining indicates means that are not significantly different at P = 0.05.
[b]Habitat names are given in Table 1.
[c]Sample sizes for each habitat are: II - 15, III - 35, IV - 25, IVa - 20, V - 40, VI - 30, IX - 40. Based on four breeding season and one post-breeding season census.

Mosaic habitat ranked significantly higher than all other habitats for total nest density in 1984 (Table 15). In contrast, Riparian habitat had significantly higher total nest densities in 1983 than all other habitats (Table 18). The difference between 1983 and 1984 in the habitat with the highest nest density was due mainly to differences recorded on the Mosaic plots rather than differences on Riparian plots. Total Riparian nest density was only slightly lower in 1984 than 1983, with fewer passerine but more shorebird nests, probably reflecting the contribution of two coastal sites in 1984 versus two inland sites in 1983. In contrast, total nest density recorded in Mosaic habitat at Sadlerochit and Jago Delta in 1984 was more than double the density recorded in this habitat at Okpilak in 1983, due to a doubling of passerine nest density and tripling of shorebird nest density. It is unclear whether this difference was due to a difference in quality of Mosaic habitat between sites censused in each of the 2 years, or due to annual variability in bird populations and habitat selection.

Riparian habitat was significantly higher than all other habitats in 1983 for passerine density and passerine nest density (Tables 17, 18), while in 1984 Riparian habitat was not significantly different from Mosaic and Moist Sedge-Shrub habitats (which both ranked higher) for these values (Tables 14, 15). Again, these differences in rank were due mainly to the higher densities recorded in Mosaic and Moist Sedge-Shrub habitat in 1984.

Differences Due to Season. Habitat use patterns of tundra bird communities vary seasonally within single sites and between geographic areas such as inland or coastal. These differences may be consistent for the entire bird community or diverge between species complexes such as shorebirds and passerines or individual species. Large shifts from use of one habitat to another within a single site, or from one location to another, may indicate seasonal differences in habitat selectivity by particular species. These seasonal differences may result from varying patterns of resource availability, as well as differing habitat requirements of breeding, post-breeding, staging, and migrant birds (Pitelka 1959, Holmes and Pitelka 1968, Seastedt and MacLean 1979, Myers and Pitelka 1980, Martin 1983, and others). Dramatic increases in post-breeding season bird densities compared with breeding season levels, may indicate importance to juveniles or migrants. Many of these migrants may originate from breeding areas outside of the ANWR study area.

Census period, when tested over all habitats and locations, was a highly significant factor in variation of total bird densities for all individual species and species groups tested within the breeding season and all except semipalmated sandpiper within the post-breeding season in 1984 (Table 8). Similar findings were obtained in 1983 (Spindler et al. 1984), with census period found to be a highly significant factor for total bird densities and all species tested.

Post-breeding season total bird densities were higher than breeding season levels in three habitats: Wet Sedge, Moist Sedge, and Riparian (except at Aichilik)(Fig. 12). Peak seasonal densities were achieved on the last census for Wet Sedge, Moist Sedge, Riparian and Tussock habitats. This difference in seasonal use was largely due to higher numbers and proportions of shorebirds in the community for the Wet Sedge and Moist Sedge habitats (Fig. 13). Wet Sedge shifted in rank among habitats from a low in shorebird densities during the breeding season, to a high level for post-breeding (Tables 14, 16). Density changes in Tussock habitat were largely due to higher densities of ptarmigan and slightly increased densities of shorebirds.

Table 18. Significant differences[a] between habitats[b] for mean total nest density[c], mean number of species nesting, and mean nest densities of selected species in 1983, coastal plain, Arctic National Wildlife Refuge, Alaska[d].

Variable	Variable value						
Habitat	IX	IVa	VI	V	II	III	IV
Mean total nests/km^2	117	70	59	56	55	54	40
Habitat	IX	II	VI	V	IVa	III	IV
Mean number of species nesting	4.2	3.7	3.0	2.6	2.5	2.1	1.8
Habitat	III	IVa	IX	II	V	VI	IV
Mean total shorebird nests/km^2	27	25	24	23	17	13	10
Habitat	IX	IVa	VI	V	IV	III	II
Mean total passerine nests/km^2	91	42	42	35	30	25	22
Habitat	IV	VI	IVa	IX	V	III	II
Mean total lesser golden-plover nests/km^2	4	3	3	1	1	0	0
Habitat	II	IVa	III	V	IX	VI	IV
Mean total red-necked phalarope nests/km^2	7	2	0	0	0	0	0
Habitat	IX	VI	V	II	IVA	IV	III
Mean total semipalmated sandpiper nests/km^2	17	7	4	0	0	0	0
Habitat	III	IVa	V	II	IV	VI	IX
Mean total pectoral sandpiper nests/km^2	27	20	12	10	6	3	2
Habitat	IX	IVa	VI	V	IV	III	II
Mean total Lapland longspur nests/km^2	65	42	35	32	30	24	22

[a]Duncan's new multiple range test. Underlining indicates means that are not significantly different at P = 0.05.
[b]Habitat names are given in Table 1.
[c]Nest densities were determined from total nests or territories per 10-ha plot.
[d]Sample sizes for each habitat are: II - 3, III - 7, IV - 5, IVa - 4, V - 8, VI - 6, IX - 8.

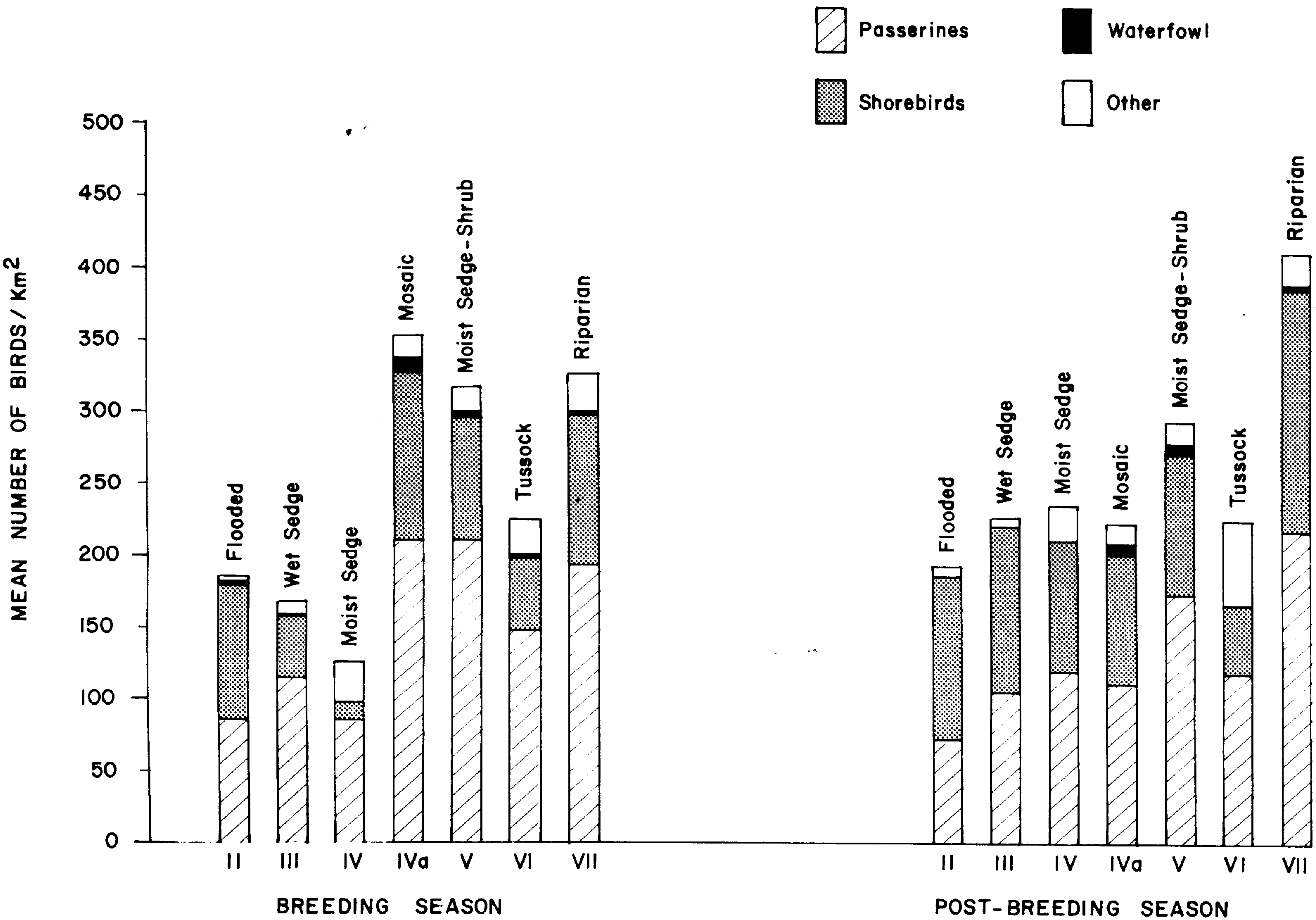

Fig. 12. Mean total densities of four bird groups in seven habitat types during breeding and post-breeding seasons, Arctic National Wildlife Refuge, Alaska, 1984.

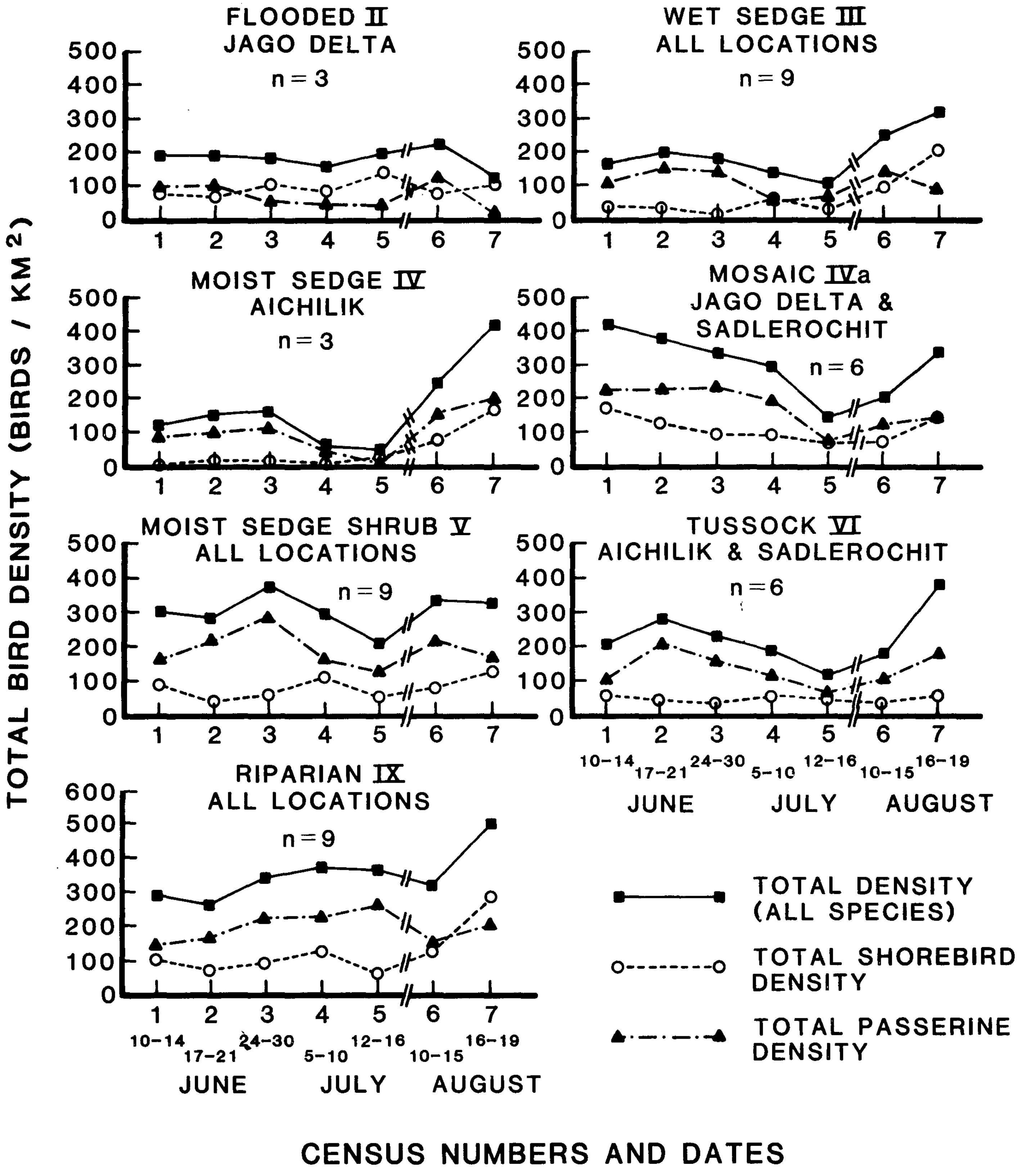

FIG. 13. SEASONAL PATTERNS OF TOTAL BIRD DENSITY IN SEVEN COASTAL PLAIN HABITATS ON ALL STUDY SITES COMBINED, ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, JUNE-AUGUST, 1984.

Lowest total bird densities were recorded for most habitats on the first post-breeding season census (census 4) (Fig. 13). This census was prior to most migratory influxes, and low densities were likely due to the departure of male pectoral sandpipers and female phalaropes, dispersion of adult birds and broods after hatching, and departure of early nesting adults with independent young. In contrast, Flooded habitat had lowest levels on the last census, and Riparian habitat had lowest levels on the first census.

There were generally less pronounced differences between the breeding and post-breeding season bird use of the upland area habitat types, Moist Sedge-Shrub and Tussock, compared with most of the wetter types (Wet Sedge, Moist Sedge, and Mosaic) and Riparian habitat (Fig. 13), although there was some variability in this due to location (Figs. 14, 15).

Seasonal shifts of habitat use at the inland site were less than at the coastal sites in 1984, except for post-breeding season increases of birds in Moist Sedge (Figs. 14, 15), primarily rock ptarmigan and pectoral sandpipers (Figs. 16, 17). Flocking shorebirds contributed to higher post-breeding than breeding densities in Wet Sedge at all areas, but were greatest at Jago Delta. The largest disparity between inland and coastal sites in seasonal use occurred in Riparian habitat, which received increased post-breeding season use only in coastal areas. Comparisons with previous years (1982, 1983) revealed some different patterns of seasonal use, most notably differences in presence or absence of migratory shorebird flocks in certain habitats or between inland or coastal sites.

Variability of bird numbers greatly increased with the onset of the post-breeding season (census 5) and was most extreme for the last two censuses (6 and 7), except in Moist Sedge-Shrub and Flooded habitats (Appendix Table 9). Habitats which generally had the most intense use by flocking shorebirds also showed the largest variability in the post-breeding season censuses. Temporal variability was also greater during post-breeding season than in breeding season, which was most evident when mean total densities for each plot were considered separately for different time periods throughout the season (Appendix Table 8).

Flooded- Total bird densities in Flooded habitat remained fairly constant throughout the season, with variable numbers of passerines in the later censuses contributing to the peak and lowest levels recorded (Fig. 15). Total bird densities and seasonal differences at Jago Delta were lower in 1984 than levels recorded at Okpilak in 1982 and 1983. Shorebirds showed a slight increase in density and proportion of the bird community during the post-breeding season in Flooded habitat in 1984 (Fig. 15). However, large numbers of shorebirds were seen in nearby Wet Sedge and Riparian habitats (Fig. 14). In 1983 Flooded habitat showed the only sharp increase in use by migrating shorebird flocks of any habitat. It is unclear whether this difference in use of Flooded habitat by migrant flocks was due to differences in habitat characteristics between the areas, or due to different selective factors of the birds between years.

Wet Sedge - Peak total bird densities in Wet Sedge habitat were achieved on one of the August censuses at all study sites and increases over the first post-breeding census (census 5) for shorebirds occurred at all areas (Fig. 13). Jago Delta had the largest increase in use by shorebirds from breeding

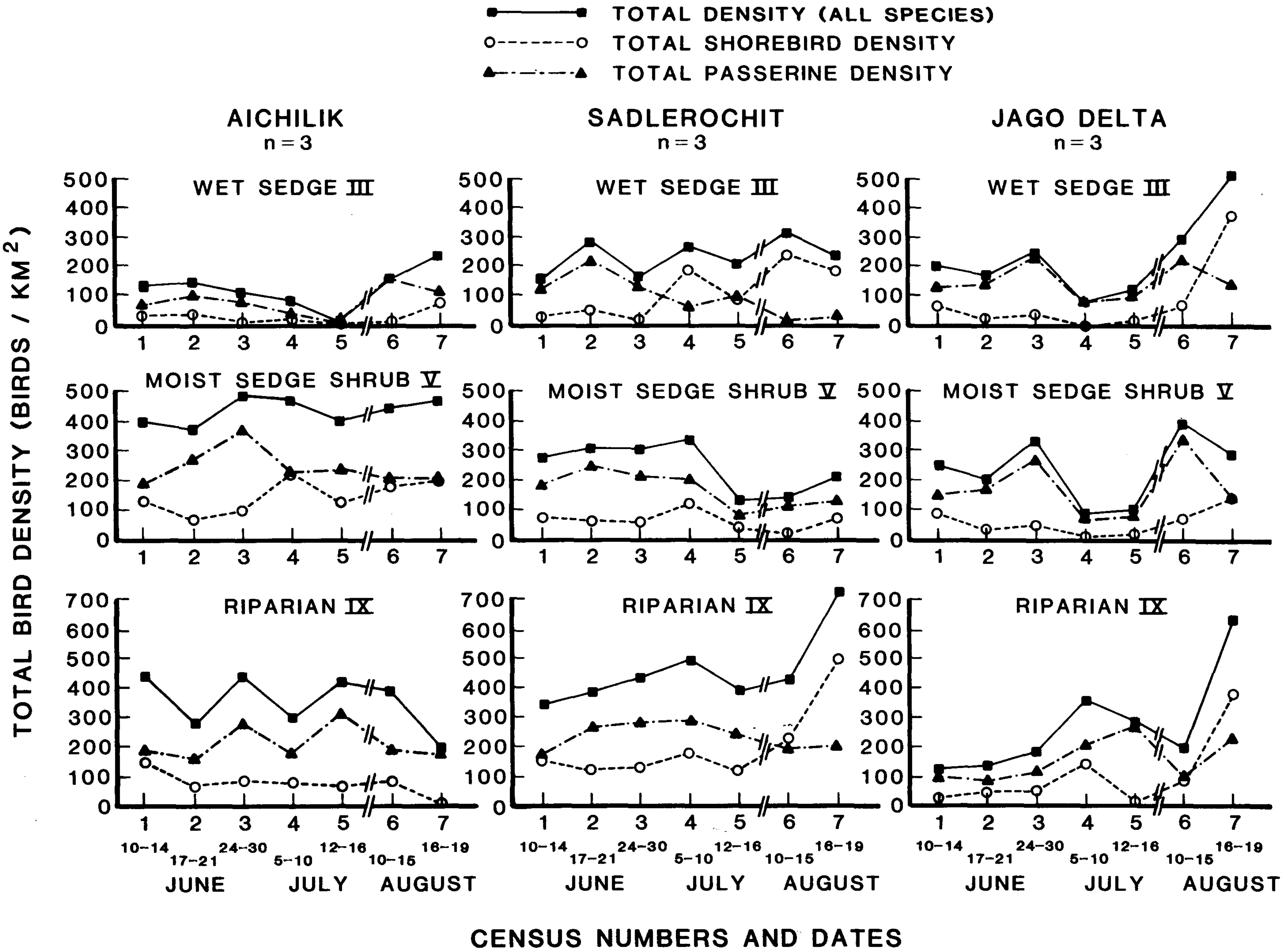

FIG. 14. SEASONAL PATTERNS OF TOTAL BIRD DENSITY IN THREE HABITATS AT THREE STUDY SITES, ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, JUNE-AUGUST, 1984.

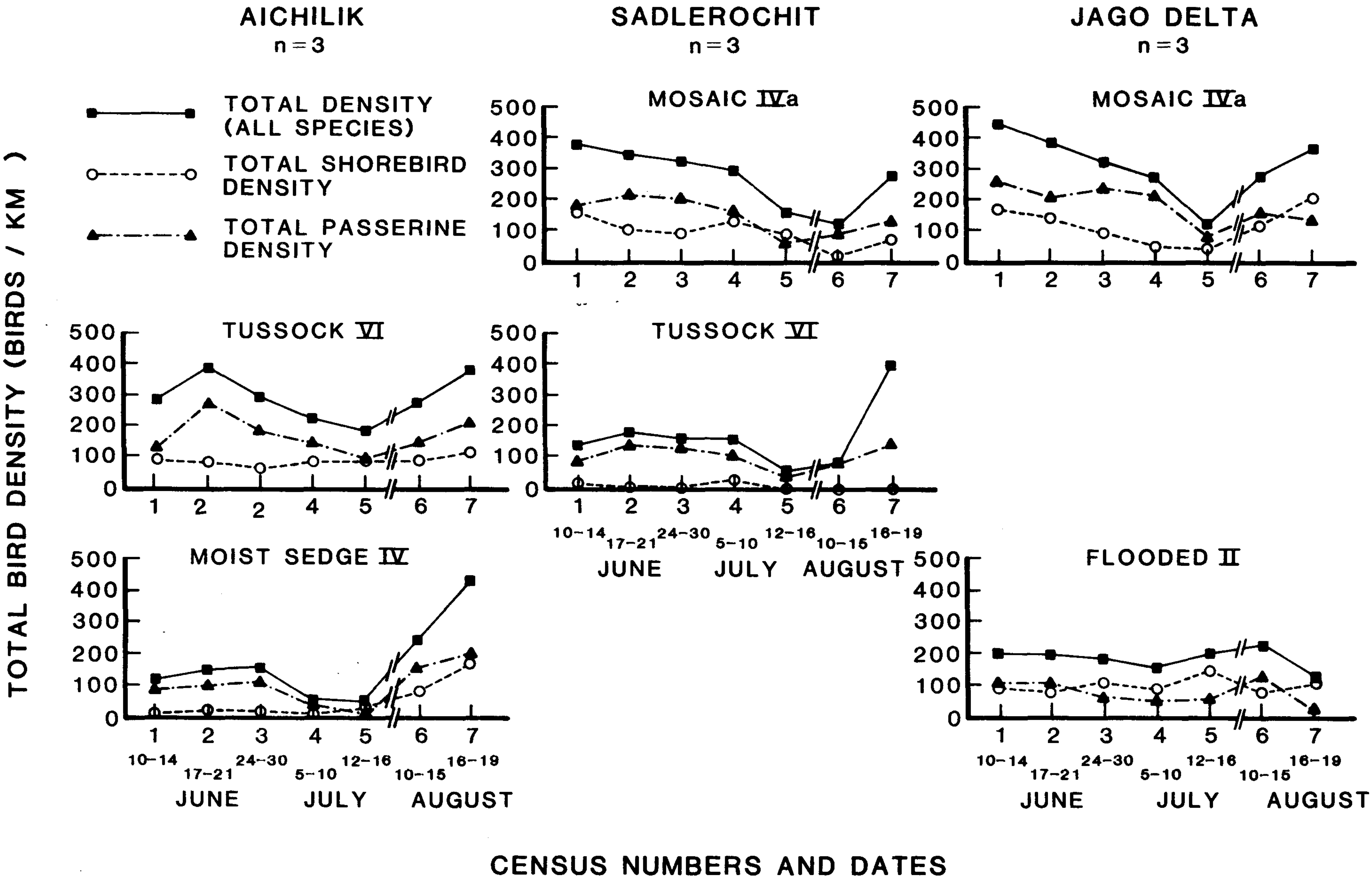

FIG. 15. SEASONAL PATTERNS OF TOTAL BIRD DENSITY IN FOUR HABITATS WHICH OCCURRED AT SOME OF THREE STUDY SITES, ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, JUNE-AUGUST, 1984.

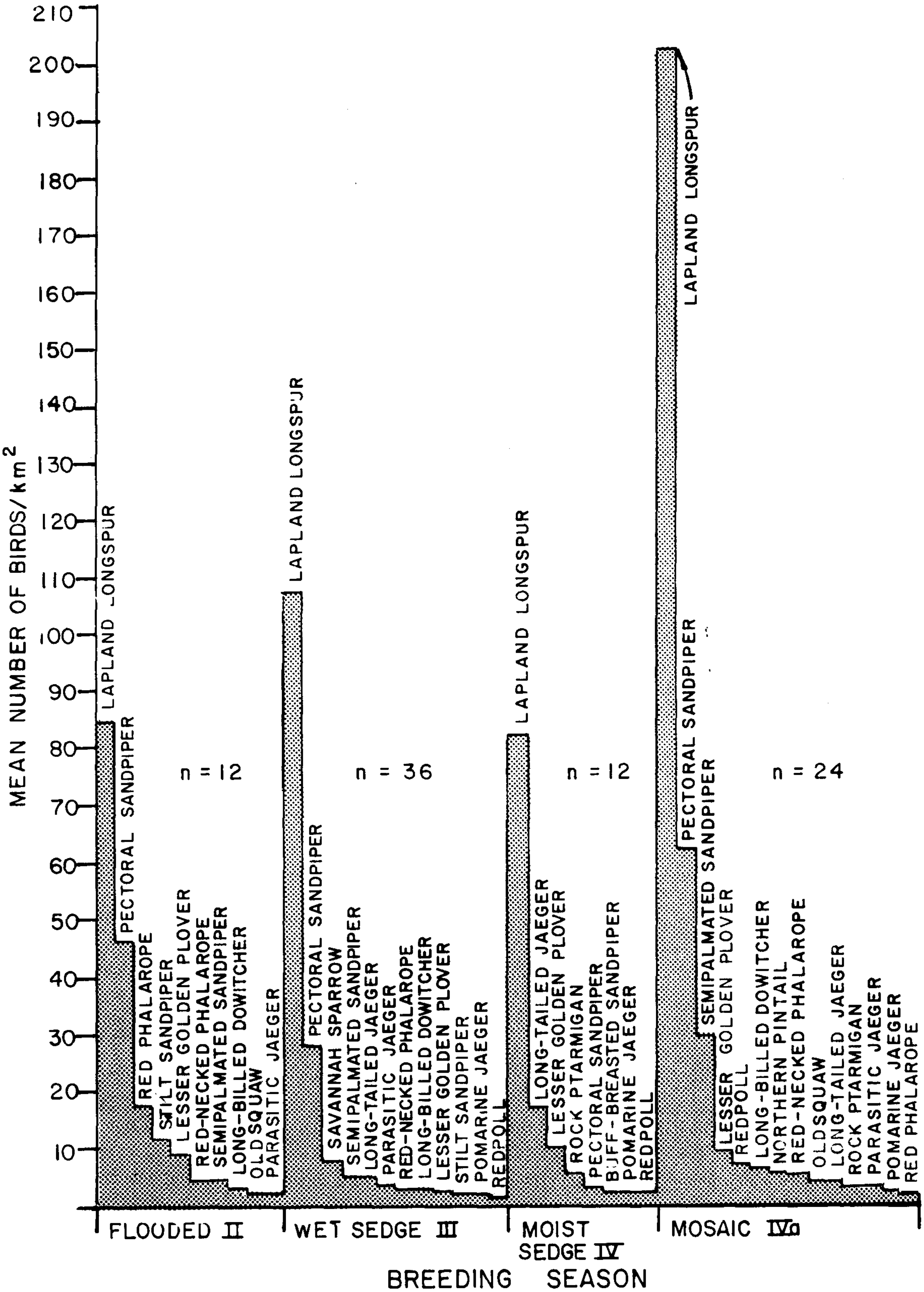

Fig. 16. Densities of most abundant bird species in four habitats during the breeding season on the coastal plain of the Arctic National Wildlife Refuge, Alaska, 1984.

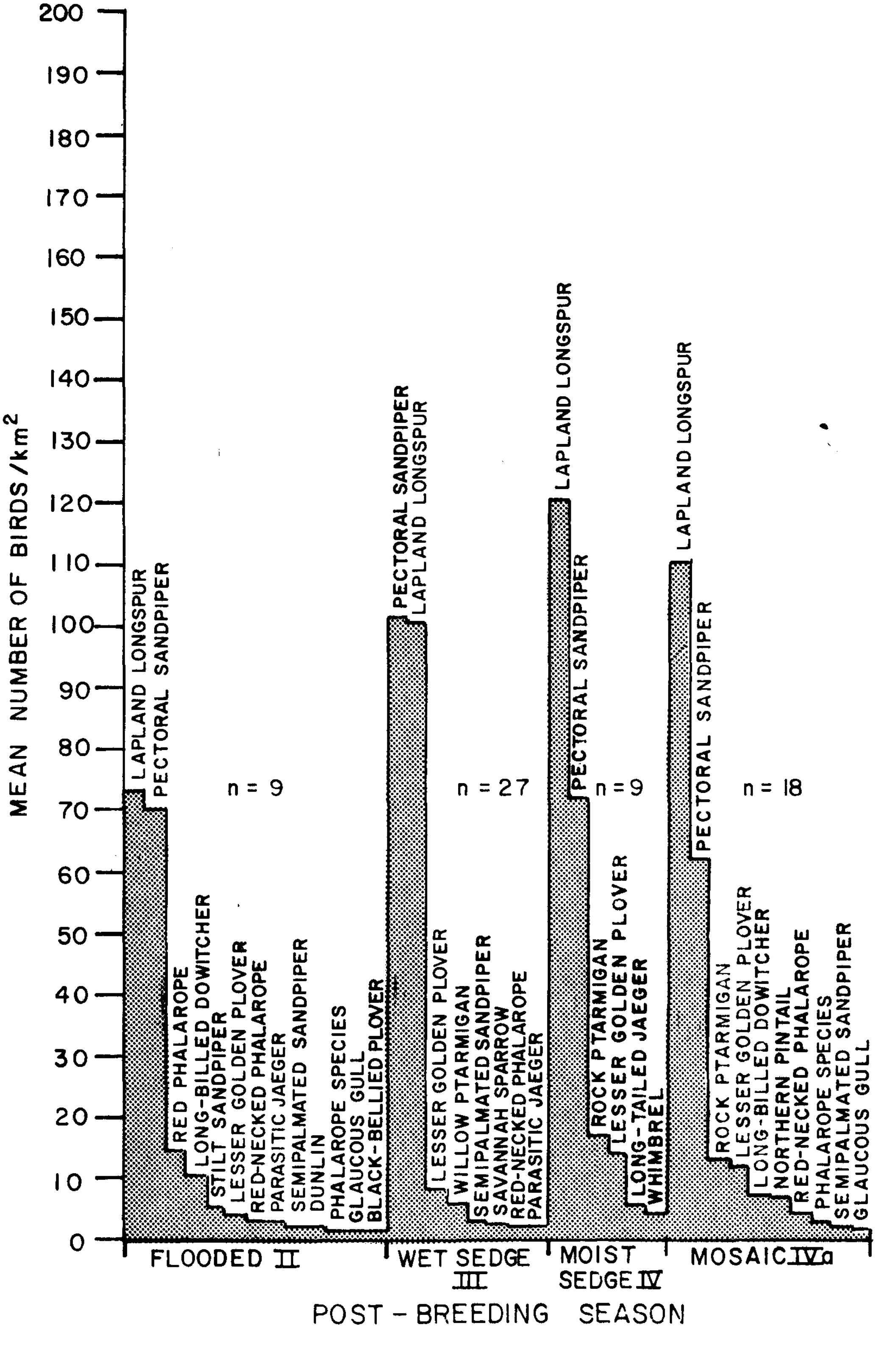

Fig. 17. Densities of most abundant bird species in four habitats during the post-breeding season on the coastal plain of the Arctic National Wildlife Refuge, Alaska, 1984.

season to post-breeding season of the three study sites, which contributed to its change in rank for total bird densities among all habitats at this site between the two seasons (Tables 11, 13). This large shift in shorebird use of Wet Sedge habitat in post-breeding at Jago Delta, as well as to a lesser degree at the other sites, resulted in significant differences in the ranking of this habitat among all the others for shorebird use, from having second lowest densities in the breeding season, to second highest in post-breeding (Tables 14, 16).

Passerine densities in Wet Sedge in 1984 remained fairly constant for both breeding and post-breeding seasons, but declined in the middle of the season (censuses 4 and 5), a pattern less evident at Aichilik and not apparent at Sadlerochit (Fig. 14). Total bird densities in Wet Sedge at Sadlerochit remained fairly constant, reflecting an increase in shorebird numbers during the season while passerines decreased. In 1983 increased use of Wet Sedge habitat by shorebirds in the post-breeding season was evident only for the Okpilak area at the end of breeding (11-18 July), when peak shorebird densities were recorded (Spindler et al. 1984). In contrast, diminished use of this habitat was apparent at Katakturuk and Jago-Bitty with decreased densities of total birds in August 1983 (Spindler et al. 1984).

Moist Sedge - Total bird densities in Moist Sedge habitat increased in August 1984 (Figs. 13, 15) due primarily to increased numbers of rock ptarmigan, passerines, and shorebirds, specifically pectoral sandpipers (Figs. 12, 16, 17). Total bird use of this habitat relative to others rose from lowest during breeding season to one of the highest in post-breeding (Table 16). The ranking of Moist Sedge among other habitats at the Aichilik study site changed only for densities of shorebirds (Tables 11, 13). By contrast, 1983 post-breeding season bird use of Moist Sedge was less than during the breeding season at Katakturuk and Jago-Bitty. However, peak densities for this habitat in 1982 were reported at Katakturuk in late August, largely due to flocking pectoral sandpipers (Spindler and Miller 1983). Spatial and temporal variability in use of this habitat by migrant shorebird flocks was high.

Mosaic- Bird use of Mosaic habitat decreased on the average from the breeding season to post-breeding (Fig. 14). Mosaic habitat decreased in rank from highest during breeding season to one of the lowest in total bird density in post-breeding (Tables 14, 16). Densities of shorebirds and passerines (particularly longspurs) declined from peak levels at the beginning of the breeding season throughout the season, to the lowest level at the beginning of the post-breeding season (Figs. 13, 15, 16, 17). Seasonal trends in bird use of Mosaic habitat were similar at Sadlerochit and Jago Delta (Fig. 15).

Mosaic habitat was utilized by birds at high densities throughout the entire 1983 season (Spindler et al. 1984) without the initial post-breeding season decline noted in 1984. However, at Okpilak in 1982, the pattern of bird use included seasonal fluctuations similar to 1984, with lowest densities during the same period (15 July). The 1982 pattern differed by the occurrence of peak levels of use by both shorebirds and Lapland longspurs in late August (Spindler and Miller 1983).

Moist Sedge-Shrub - Densities at Aichilik remained high throughout the season with a peak for passerine hatching (census 3) and shorebird hatching (census 4) (Fig. 14), which strongly influenced the overall pattern (Fig. 13). While densities at Sadlerochit were high during the breeding season, diminished levels remained during post-breeding. Lapland longspurs influenced the seasonal density pattern at Jago Delta with peaks occurring at hatching (census 2) and migratory flocking (census 5) with dramatically lower densities between these events. A higher diversity of shorebirds utilized Moist Sedge-Shrub during the breeding season (Fig. 18), but increases in shorebird densities during post-breeding season (Tables 14, 16), were largely due to an influx of pectoral sandpipers (Fig. 19). This general pattern of shorebird use was not evident at Sadlerochit, where levels were low throughout the season (Fig. 14).

The greatest seasonal fluctuations in bird use of Moist Sedge-Shrub in 1983 occurred at Okpilak with peak densities late in the breeding season due to passerines (Spindler et al. 1984). Inland sites exhibited fairly constant levels throughout the 1983 season with a slight increase in passerine use in August. However, Katakturuk achieved nearly peak densities of passerines in August 1982 following low densities early in post-breeding, with a decline of other species throughout the season (Spindler and Miller 1982).

Tussock- Bird use of Tussock habitat in 1984 was similar during breeding and post-breeding seasons (Tables 14, 16; Fig. 13). Seasonal patterns were the same at Aichilik and Sadlerochit, with slight declines in passerines and increases in ptarmigan (willow at Aichilik, rock at Sadlerochit) from breeding to post-breeding seasons (Figs. 15, 18, 19). Seasonal patterns in 1983 were similar, but lacked the increase of ptarmigan in August (Spindler et al. 1984). A different trend was seen at Katakturuk in 1982 with a decline of shorebirds after breeding, followed by peak levels late in the post-breeding season (Spindler and Miller 1983).

Riparian- Bird densities increased during the post-breeding season in Riparian habitat at coastal sites and decreased at the inland site in 1984 (Fig. 12). Shorebirds, more than other birds, increased in density at both coastal sites. This increase was largely due to the presence of large flocks of pectoral sandpipers and dunlin which rarely used this habitat in the breeding season, and lesser golden-plovers which possibly shifted from inland habitats to coastal Riparian habitat (Figs. 18, 19). These results contrast with 1983 when there was increased post-breeding season shorebird use of Riparian habitats inland, and decreased use coastally by all bird groups. In 1982, only an inland Riparian site was sampled, but shorebird densities were nearly as high, or peaked, in the post-breeding season (Spindler and Miller 1983).

Defining Tundra Bird Habitats

This study was originally designed to use the recently published Landsat mapping effort on the ANWR (Walker et al. 1982) as a basis for defining bird habitats, and to correlate bird densities with the major Landsat classes. Ambiguities in the results of the analyses, as well as problems with the Landsat system itself, led to the question of whether the Landsat classification, even with modifications (Table 1), adequately defined tundra bird habitats. The TWINSPAN computer program of the Cornell Ecology Program Series (Hill 1979) was used to characterize bird habitats based on relative bird densities within habitats, and to determine whether grouping of 10-ha plots for analysis based on their Landsat class was appropriate in terms of similarity of bird use. It was also used to delineate patterns that might guide in future determination of more appropriate parameters for defining bird habitats.

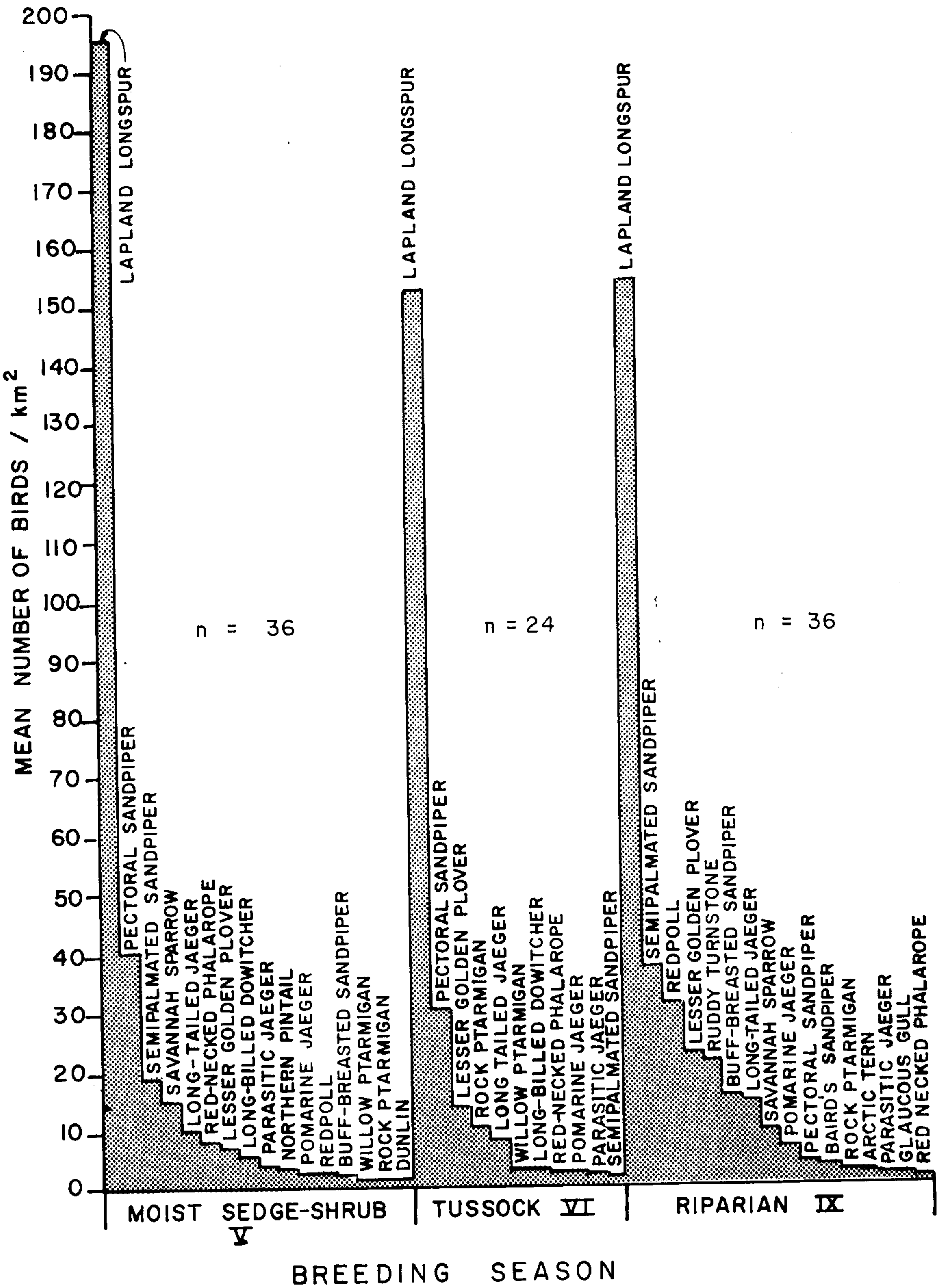

Fig. 18. Densities of most abundant bird species in three habitats during the breeding season on the coastal plain of the Arctic National Wildlife Refuge, Alaska, 1984.

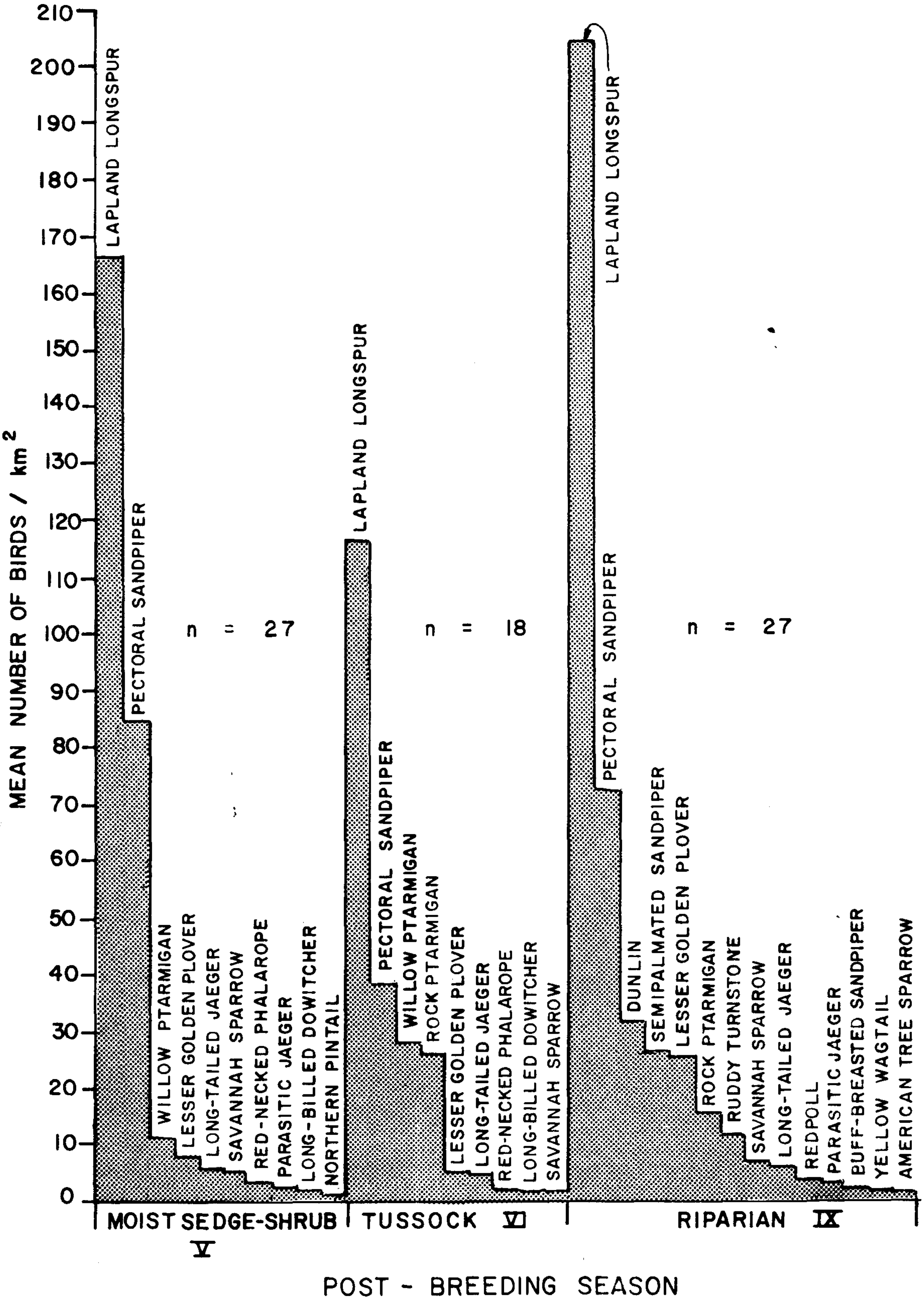

Fig. 19. Densities of most abundant bird species in three habitats during the post-breeding season on the coastal plain of the Arctic National Wildlife Refuge, Alaska, 1984.

Problems encountered with the Landsat classification system were inaccuracies in the Landsat map as well as inability of the Landsat map to distinguish some habitats known to be important to birds (Spindler et al. 1984). Riparian willow stands were too limited in area to be distinguished by Landsat. Landsat types III and IV both included uniform wet or moist sedge habitats as well as Mosaic (wet/moist) habitats, which showed very different patterns of bird use. Landsat types V and VI showed much overlap on the Landsat map, and type V (Moist Sedge-Shrub) appeared to be highly variable in bird densities. Landsat type II (Flooded) was the only habitat which was consistently well identified and defined. Some of these problems were resolved by modifications of the original Landsat classification (Table 1).

Examination of MANOVA and Duncan's (multiple range test) results from two years of plot census data revealed that no significant differences in bird densities were found between several Landsat habitat types. This result could indicate that the birds were non-selective of habitats, but work by Myers and Pitelka (1980) and Troy (1984) has demonstrated habitat selectivity by tundra birds. A high degree of within-habitat variability may have obscured the significance of between-habitat variability.

The Landsat system grouped areas with a fine pattern of interspersion of wet and dry habitats in the same class with areas of uniform moistness, because it could not distinguish the microhabitat features (such as ponds, ridges, and shrubs) which are important in determining bird habitats. Riparian and Mosaic habitat types which were defined independently of the Landsat classification, were significantly higher in bird density than all other habitats. If these types had been lumped with the other types (such as Wet Sedge and Moist Sedge) which fell in the same Landsat class, it is unlikely that significant differences would have appeared.

Other methods have been used to define tundra bird habitats. Troy (1984) has successfully used the more intensive geobotanical mapping system of Klinger et al. (1983) to distinguish tundra bird habitats in the Prudhoe Bay area and has identified 15 habitat types each showing a different pattern of bird use. Myers and Pitelka (1980) measured numerous habitat and vegetation variables and then used factor analysis to find patterns and correlations with bird use.

TWINSPAN analysis was performed on bird plot census data for 86 10-ha plots from three sites censused in 1983 and three different sites censused in 1984. This analysis performed a dichotomous-branching and clustering ordination of taxa and samples simultaneously, using the multivariate technique of reciprocal averaging (Hill 1973). The data set consisted of cumulative totals of birds seen on each plot, by species, over four weekly censuses during the breeding season. The plots were established to represent homogenous units of bird habitat, so the assumption was made that plots grouped for their similarity in bird species and density would represent similar bird habitats. This approach had been previously used successfully by Moitoret (1983) in defining arctic shoreline bird habitats at Canning River delta on the ANWR coastal plain.

Similar analyses were performed on 1984 post-breeding season data and on nest density data for both years. Results of these analyses were similar to the one discussed here, but distinctions were less definite, probably due to high variability in the post-breeding season data and densities too low for analysis in the nest data. Therefore, for simplicity, only the 1983-84 breeding season total population analysis is presented here. Results are interpreted with caution since data from two different years were combined, and Myers and Pitelka (1980) have shown that bird selectivity of habitats varies strongly from year to year.

TWINSPAN performed a two-way ordination: of plots, according to bird species and their densities (Fig. 20), and of birds, according to the grouping of the plots with which they were associated (Fig. 21). TWINSPAN analysis gave indicator species and preferential species for each division of bird plots. Preferential species were those which were more likely to occur in one group than the other, while an indicator species was one whose presence most faithfully followed the grouping by TWINSPAN.

The primary indicator for the first division was a higher density of pectoral sandpipers in one group than the other (Fig. 21). Although more of the plots with high pectoral densities were coastal (70%) and more of the plots with low pectoral densities were inland (63%), this was not a simple coastal versus inland division (Fig. 20).

The preferential species for the "high pectoral" plots were northern pintail, oldsquaw, stilt sandpiper, long-billed dowitcher, and red and red-necked phalaropes. The preferential species for the "low pectoral" plots were rock ptarmigan, ruddy turnstone, buff-breasted sandpiper, redpoll, and lesser golden-plover.

The second TWINSPAN divisions clearly distinguished two habitat types at opposite ends of the ordination (Fig. 20). On the "high pectoral" end, all six Flooded plots separated as a distinct group. On the "low pectoral" end, 15 out of 17 Riparian plots formed a distinct group. The only non-Riparian plot in this group was a Tussock plot at Katakturuk, whose proximity to a bluff edge above the river appeared to strongly influence the bird community present.

The indicator species for the Flooded plots was red phalarope, and other preferential species for these plots were red-throated and arctic loons, brant, oldsquaw, stilt sandpiper, glaucous gull, and northern pintail. The "non-Flooded high pectoral" plots had higher densities of Lapland longspurs, semipalmated sandpipers, savannah sparrows, redpolls, and pomarine jaegers.

The indicator species for the Riparian plots were ruddy turnstone, redpoll, semipalmated sandpiper, and lesser golden-plover. Yellow wagtails and savannah sparrows were also preferential species on these plots. The "non-Riparian low pectoral" plots were characterized by higher pectoral sandpiper and willow ptarmigan densities than on the Riparian plots.

The TWINSPAN ordination of the "non-Flooded high pectoral" and "non-Riparian low pectoral" plots did not correspond to Landsat classification of habitats.

Of the Landsat type IV plots, all of those which were designated "Mosaic" fell in the "high pectoral" portion of the ordination, while all those designated "Moist Sedge" fell in the "low pectoral" group (Fig. 20). Thus TWINSPAN confirmed that Landsat failed to distinguish two very distinct bird habitats.

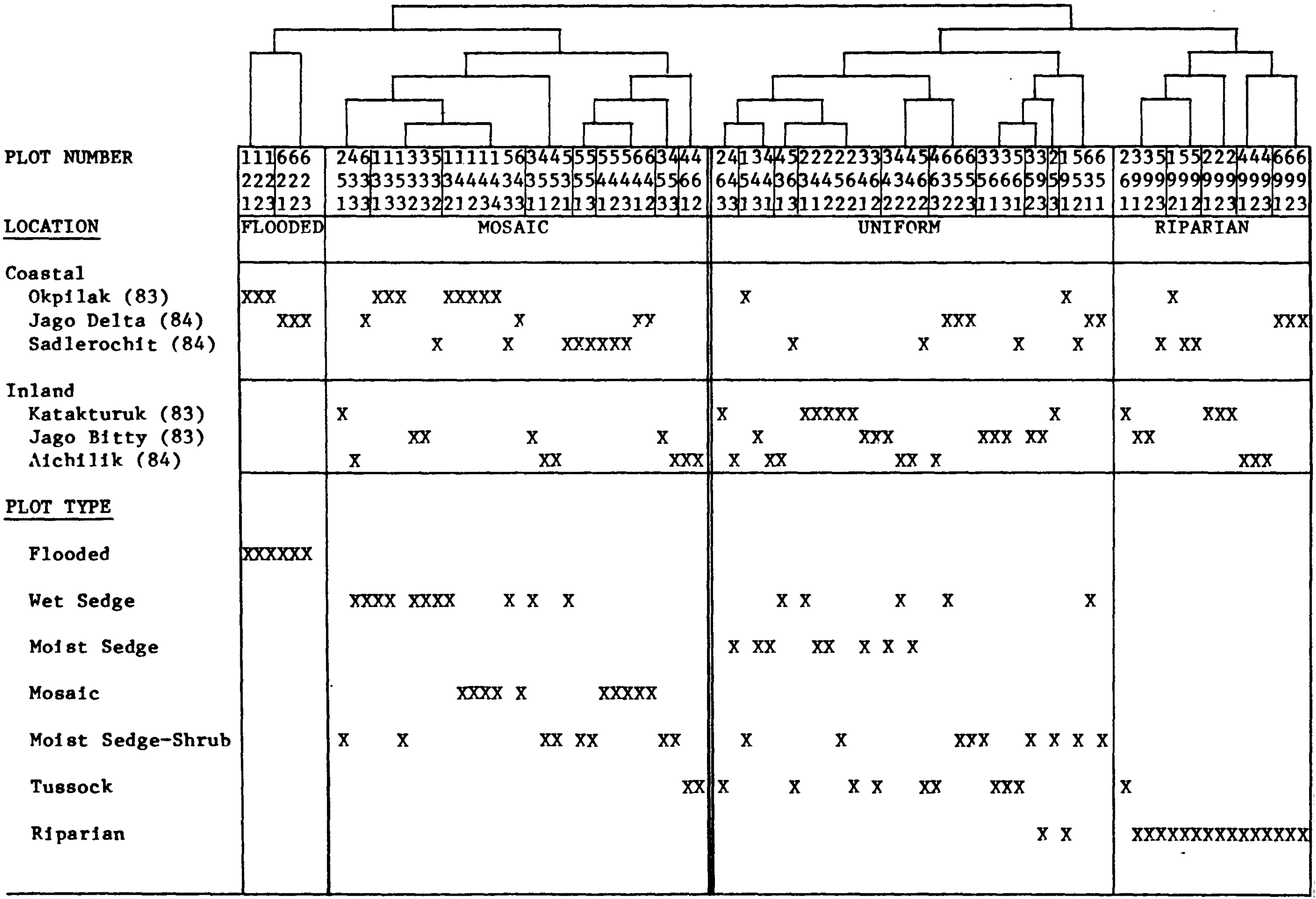

Fig. 20. Ordination of bird census plots by TWINSPAN analysis of breeding season bird densities on 86 10-ha plots at 3 1983 study sites and 3 1984 study sites, coastal plain, Arctic National Wildlife Refuge, Alaska. Dendrogram for plot clustering by 6 divisions of TWINSPAN is shown at top of the figure.

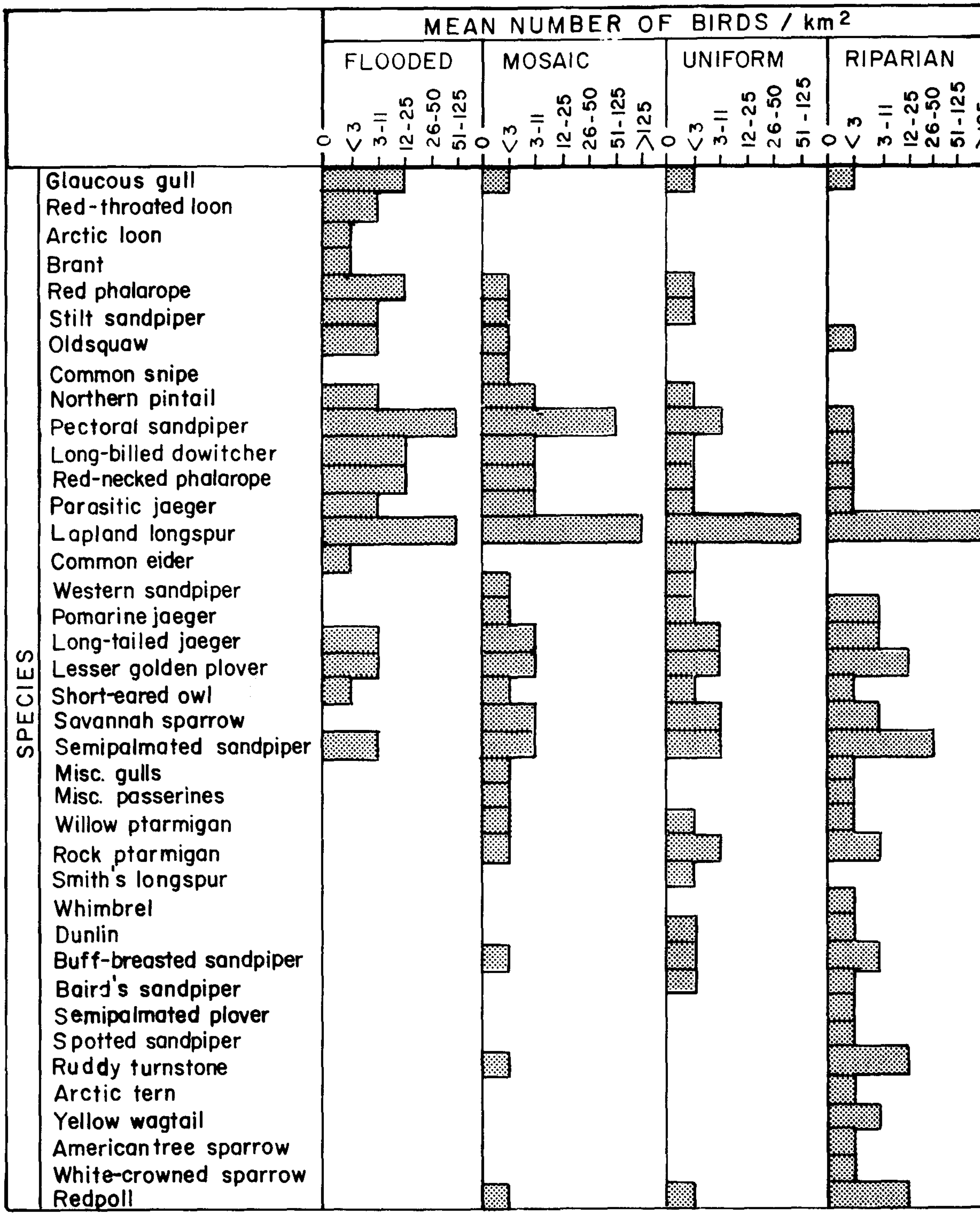

Fig. 21. Ordination of bird species by TWINSPAN analysis of breeding season plot census data for 86 10-ha plots at 3 1983 study sites and 3 1984 study sites on the coastal plain of the Arctic National Wildlife Refuge, Alaska. Mean densities (birds/km^2) are shown for each of four habitat groups derived from the two primary divisions of TWINSPAN.

Most of the Landsat type VI (Tussock) plots fell in the "low pectoral" portion of the ordination, but did not form a distinct grouping. Landsat types III (Wet Sedge) and V (Moist Sedge-Shrub) showed the least recognizable pattern in the ordination, being scattered from one end to the other of both "high" and "low pectoral" groups. This scattered distribution of plots in the TWINSPAN ordination suggested a similar problem in representing bird habitats with Landsat types III and V as was already encountered with Landsat type IV.

The common characteristic of the "non-Flooded high pectoral" plots was apparently either a dominance of very wet habitat (Wet Sedge) plots, or a high degree of interspersion of wet habitat or ponds with moist or dry habitats (Mosaic plots and Moist Sedge-Shrub plots with ponds). This group was simply designated "Mosaic" on Figs. 20 and 21.

The "non-Riparian low pectoral" plots could best be characterized by their uniformity: uniform Tussock, Moist Sedge, or Moist Sedge-Shrub habitat. Moist Sedge-Shrub plots in this group generally lacked significant amounts of wet habitat or ponds, and thus were more similar to Moist Sedge plots. Wet Sedge plots in this group were generally less saturated than those in the "Mosaic" group, and were more similar to Moist Sedge plots; however, this result was interpreted with caution due to the difference in sampling years for different sites, since saturation of Wet Sedge habitats can vary significantly between years and could affect bird use. Future analysis using plot data from all sites in a single year may help to clarify these distinctions. Another source of confusion in the ordination of Wet Sedge plots was the occurrence of high densities of pectoral sandpipers as transient flocks (noted in Wet Sedge plots at Sadlerochit in June-July 1984) versus high densities of breeding pectorals. Troy (1984) obtained different results in bird habitat preference studies at Prudhoe when omitting flocks from the data set. Future data collection for this study should incorporate a system allowing this distinction in analysis.

The TWINSPAN analysis thus suggested four primary divisions of plots by bird habitat:

(1) plots with a high degree of surface water (Flooded)
(2) plots with a high degree of wet habitats or high interspersion of wet with moist or dry habitats (Mosaic)
(3) plots with relatively uniform moist or dry habitats (Uniform)
(4) plots with a high degree of erect shrub cover (Riparian).

Further subdivisions of this ordination might be recognizable with further analysis of data from more sites in a single year.

The results of the TWINSPAN analysis suggested that factors other than a simple vegetation classification or moisture gradient, as distinguished by Landsat, were important to birds in the selection of habitats. Myers and Pitelka (1980) found that four gradients reflected most strongly the range of conditions seen in different tundra habitats: polygonization, pondiness, vegetation density, and shrubiness. Martin (1983) characterized the differences between three different tundra bird habitats by measuring surface water (which varied seasonally), microrelief, and diversity and "patchiness" of vegetation types.

Results appeared to confirm that interspersion of habitats (patchiness), degree of microrelief, extent of ponds and wet habitats, and shrub height and density were all important factors in determining bird use of tundra habitats, and that these factors were not adequately distinguished by a habitat classification based solely on vegetation types or satellite imagery. Future study should focus on attempts to correlate measurements of these habitat variables with bird use.

The results of the TWINSPAN analysis also suggested that MANOVA analyses of bird habitats based on the modified Landsat classification probably produced ambiguous results. The three types (Flooded, Riparian, and Mosaic) which ranked high in bird use according to the MANOVA and Duncan's tests probably represented important bird habitats, since the TWINSPAN analysis confirmed that these were distinct habitats relative to bird use. However, the MANOVA and Duncan's test results for Wet Sedge and Moist Sedge-Shrub habitats were interpreted with caution, since the TWINSPAN analysis suggested that these types represented a wide range of bird habitats. Further study will be necessary to determine the factors in these habitats which make them more or less important for bird use.

Conclusions

MANOVA analysis revealed significant differences in bird and nest densities between some modified Landsat habitats and between some locations. These results are a first step for characterizing differences in bird use, particularly ranking areas of highest bird use. The TWINSPAN analysis suggested that factors other than those distinguished by the modified Landsat classification system may be important in habitat selection by birds. Future study should focus on augmenting the Landsat system with investigation of specific habitat variables such as microrelief, moisture level, size and type of water bodies, height and density of shrubs, and interspersion of microhabitats. Classification of plots by percent cover of vegetation types (Viereck et al. 1982) was a first step in this direction. Correlation between habitat variables and bird use will help to define more accurately the importance of various bird habitats for nest sites, territories, brood-rearing areas, feeding sites, and migratory staging areas.

Total bird and nest densities and densities of the most abundant species were used in ranking habitats by MANOVA analysis, partly because 10-ha plot size was not large enough to provide meaningful density data for the less common species. Analysis which focuses on total densities and densities of the most abundant species may indicate basic trends in tundra bird populations, but may overlook unique habitat requirements of the less abundant species. It is likely some of these less common species are more selective of specific limited habitats, and thus are more likely to be adversely affected by habitat loss resulting from development activities. Furthermore, some of the less common species have habitat requirements which fall outside the modified Landsat habitat types represented by the study plots and therefore have received limited study. Examples are Baird's sandpiper, which generally nests on lake or river bluffs, and ruddy turnstone, which nests on riparian gravel bars (Martin and Moitoret 1981).

Seasonal variability in bird densities has been shown to be high, particularly in comparison of breeding versus post-breeding use of certain habitats. A greater sampling effort has been devoted to determining breeding season densities, but post-breeding feeding and staging areas may be equally critical habitats to migratory birds. Post-breeding season densities were shown to be highly variable both within and between habitats, suggesting that a greater sampling effort is needed to adequately determine the relative importance of bird habitats in the post-breeding season. Although two censuses were conducted in August 1984, compared to one in 1982 and 1983, these covered a period only a few days longer than was studied in 1983, and ended earlier than some 1982 censuses. More complete post-breeding season coverage at Canning Delta in 1979 and 1980 revealed peak densities of some species for some habitats throughout the entire month of August (Martin 1983). Some species, particularly long-billed dowitchers, black-bellied plovers, and lesser golden-plovers, which migrated later than others such as pectoral sandpipers (Martin 1983), may have been missed with our shorter sample period. These three species were more prevalent in the later censuses (18-26 August) in 1982 than in 1983 or 1984.

An assessment of annual variability of bird populations is a study objective that will be addressed in 1985 with the complete data set for the four year project. Significant differences in bird use between three years were shown at a single study site, Okpilak Delta (Spindler et al. 1984), where variability due to year equaled variability due to habitat, but population changes were not consistent for each habitat. A summary of mean total nest densities by habitat for seven different study areas and six different years on the ANWR coastal plain (Table 19) illustrates the obvious inter-year differences but reveals no consistent pattern. Annual variability is a factor which must be considered in any comparison of bird density data from different sites in different years. Pectoral sandpiper populations are known to fluctuate widely (Holmes 1966), and annual differences may be greater than habitat differences (Pitelka 1959). Since this species is one of the most abundant in the study area, population fluctuations may significantly affect study results. Localized patchiness of pectoral distribution which varies between years makes it difficult to detect wide-spread geographic trends in abundance (Myers and Pitelka 1980). Different species may show opposite trends in population density between years (Martin 1983), and a single species may show differences in habitat selectivity between years (Myers and Pitelka 1980). Thus annual variability is difficult to evaluate, but it is a factor which affects the analysis of all other sources of variability: location, habitat, and season.

Acknowledgements

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Table 19. Summary of mean total nest densities[a] (nests/km^2) observed by habitat for 7 study areas and 6 years on the coastal plain of the Arctic National Wildlife Refuge, Alaska.

Year	Study area	Habitat						
		II	III	IV	IVa	V	VI	IX
1978[b]	Okpilak Delta	61.0	45.0	--	87.0	49.0	--	--
1979[c]	Canning Delta	--	59.0	--	--	51.0	--	--
1980[c]	Canning Delta	--	93.0	--	137.0	78.0	--	--
1982[d]	Okpilak Delta	38.0	64.0	--	81.0	68.0	--	--
	Katakturuk River	--	--	15.0	--	83.0	88.0	141.5
1983[e]	Okpilak Delta	55.0	60.0	--	67.5	62.5	--	92.5
	Katakturuk River	--	30.0	27.5	--	33.3	58.3	135.0
	Jago-Bitty	--	55.0	48.3	--	74.0	60.0	128.3
1984	Aichilik River	--	45.0	43.3	--	131.7	86.7	91.7
	Sadlerochit River	--	65.0	--	146.7	121.0	63.3	132.7
	Jago Delta	85.0	67.0	--	174.2	114.3	--	75.0

[a]Nest density determined from number of nests or territories per 10-, 25-, or 50-ha plot.
[b]Spindler 1978.
[c]Martin 1983.
[d]Spindler and Miller 1983.
[e]Spindler et al. 1984.

to locate plots on village lands at Okpilak Delta and Jago Delta. C. Craynor, University of Alaska, provided computer assistance and Drs. D. Thomas and S. Harbo consulted in development of the sample design and analysis.

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APPENDIX

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Appendix Table 1. Julian dates of first observed flowering for plant species found at three study sites in 1984 and dates for those species during 1978, 1982 and 1983 at three other study sites at Arctic National Wildlife Refuge, Alaska.

	1984			1983			1982	1978
Species	Aichilik	Sadlerochit	Jago Delta	Okpilak	Katakturuk	Jago Bitty	Okpilak	Okpilak
Anemone parviflora	159	163	161	175	174	171	171	185
Artemisia arctica	186	197	175					
Astragalus umbellatus	170	177	172	184	184	180	183	186
Caltha palustris	165	166	168	177	176	177	180	184
Cardamine hyperborea	173	179	184		185			189
Cassiope tetragona	167	171	169	177	177	177		182
Dryas integrifolia	167	170	168	177	177	177		182
Epilobium latifolium	188	188	188	190	189	199		
Lagotis glauca	169	173	171	183	179	177	180	182
Melandrium apetalum	187	188	184		188		183	194
Minuartia arctica	173	173	184	179	184	178		187
Oxytropis borealis	172	175	175		185	180		
Oxytropis nigrescens	164	168	163	175	173	186	180	179
Parrya nudicaulis	165	170	168	175	174	172	180	179
Pedicularis capitata	172	179	177	186	185	186	187	
Pedicularis Kanei	163	166	162	171	170	178	175	173
Pedicularis Langsdorffii	172	171	171	180	185			186
Pedicularis sudetica	188	179	172	185	185	180		
Pedicularis verticillata	195	188	187					
Petasites frigidus	166	171	169	173	176	172	183	182
Polemonium boreale	174	175	172	183	179	183	183	184
Polygonum bistorta	171	190	176	180	185	180		187
Ranunculus nivalis	164	161	160	169		171	175	173
Rubus chamaemorus	171	171	190	187		180		187
Saxifraga hirculus	187	188	180	196				
Saxifraga oppositifolia	159	157	157	163	162	158	159	161
Saxifraga punctata	171	174	180	184	183	177	176	182
Silene acaulis	173	174	166	179		177	183	186
Valeriana capitata	173	188	187	193	188	187		186

Appendix Table 2. Nests, displaying males, and estimated nest densities for breeding birds on 15 10-ha plots in five habitats at the Sadlerochit study site, Arctic National Wildlife Refuge, Alaska, 1984.

Plot No.	Species	Number: Nests found	Number: Displaying males[a]	Estimated nest[b] density (nests/km²): By species	Plot total	Average by habitat[c] (±S.D.)
531	Parasitic jaeger	1		10		
	Pectoral sandpiper			10		
	Red-necked phalarope			10		
	Savannah sparrow	1		15		
	Lapland longspur	4	1	20	65	
532	Long-billed dowitcher	1		10		
	Lapland longspur	3	1	30	40	
533	Pectoral sandpiper		1	20		
	Savannah sparrow	1	1	20		
	Lapland longspur	1	2	50	90	65.0 ± 25.0
541	Northern pintail			10		
	Rock ptarmigan			10		
	Semipalmated sandpiper	3	1	40		
	Pectoral sandpiper	1	1	25		
	Long-billed dowitcher			10		
	Lapland longspur	2	8	55	150	
542	Oldsquaw	1		10		
	Lesser golden-plover	1		10		
	Semipalmated sandpiper	1	1	10		
	Pectoral sandpiper	1	1	30		
	Long-billed dowitcher			10		
	Red-necked phalarope			10		
	Lapland longspur	3	10	55	135	
543	Lesser golden-plover	1		20		
	Semipalmated sandpiper	3	2	30		
	Pectoral sandpiper	2	2	25		
	Long-billed dowitcher			10		
	Red-necked phalarope			10		
	Lapland longspur	2	9	60	155	146.7 ± 10.40
551	Semipalmated sandpiper	2		20		
	Pectoral sandpiper	1	2	20		
	Lapland longspur	2	4	70	110	
552	Semipalmated sandpiper			10		
	Pectoral sandpiper			10		
	Red-necked phalarope			10		
	Savannah sparrow		1	3		
	Lapland longspur	5	8	80	113	
553	Lesser golden-plover			10		
	Semipalmated sandpiper	3	1	30		
	Pectoral sandpiper		1	10		
	Red-necked phalarope	1		10		
	Lapland longspur	3	3	80	140	121.0 ± 16.5
561	Rock ptarmigan			10		
	Pectoral sandpiper			5		
	Lapland longspur	2	3	30	45	
562	Rock ptarmigan	1	1	10		
	Lesser golden-plover	1		10		
	Pectoral sandpiper	1		10		
	Lapland longspur	3	4	40	70	
563	Northern pintail	1		10		
	Rock ptarmigan			10		
	Pectoral sandpiper	1		10		
	Long-tailed jaeger	1		10		
	Lapland longspur		3	35	75	63.3 ± 16.1
591	Common eider	1		10		
	Lesser golden-plover	1		10		
	Semipalmated sandpiper	1	3	20		
	Lapland longspur	1	1	30		
	Redpoll sp.			10	80	
592	Ruddy turnstone			10		
	Semipalmated sandpiper		2	20		
	Lapland longspur	1	3	40		
	Redpoll sp.			10	80	
593	Lesser golden-plover			10		
	Ruddy turnstone			3		
	Semipalmated sandpiper	8	2	80		
	Pectoral sandpiper	1		10		
	Savannah sparrow	1	1	15		
	Lapland longspur	4	6	110		
	Redpoll sp.			10	238	132.7 ± 91.2

[a]Maximum number counted on a single census, 10-30 June 1984.
[b]Includes nests found, probable nests as determined by behavioral observations; mapped activity clusters of displaying males, other territorial data and additional sightings from censuses 1-4, 10 June - 16 July 1984.
[c]Habitat type is given as middle digit of plot number: 3 = Wet Sedge, 4 = Mosaic, 5 = Moist Sedge-Shrub, 6 = Tussock, 9 = Riparian.

Appendix Table 3. Nests, displaying males, and estimated nest densities for breeding birds on 15 10-ha plots in five habitats at the Aichilik study site, Arctic National Wildlife Refuge, Alaska, 1984.

Plot No.	Species	Number: Nests found	Number: Displaying males[a]	Estimated nest[b] density (nests/km^2): By species	Plot total	Average by habitat[c] (±S.D.)
431	Pectoral sandpiper			10		
	Lapland longspur	2	1	40	50	
432	Pectoral sandpiper			10		
	Long-tailed jaeger	1		10		
	Lapland longspur	1	5	25	45	
433	Pectoral sandpiper	1		20		
	Lapland longspur	2	1	20	40	45.0 ± 5.0
441	Pectoral sandpiper			5		
	Lapland longspur	1	4	20	25	
442	Rock ptarmigan			10		
	Lesser golden-plover	2		20		
	Lapland longspur	2	3	25	55	
443	Lesser golden-plover	1		10		
	Lapland longspur	3	8	40	50	43.3 ± 16.1
451	Pectoral sandpiper	1		40		
	Long-billed dowitcher			10		
	Red-necked phalarope			10		
	Savannah sparrow			10		
	Lapland longspur	4	7	80	150	
452	Pectoral sandpiper			30		
	Lapland longspur	2	8	65	95	
453	Semipalmated sandpiper			10		
	Pectoral sandpiper			20		
	Red-necked phalarope			10		
	Long-billed dowitcher			10		
	Savannah sparrow	1		30		
	Lapland longspur	1	10	70	150	131.7 ± 31.8
461	Rock ptarmigan	1		10		
	Lesser golden-plover	2		20		
	Pectoral sandpiper	2		40		
	Lapland longspur	2	6	70	140	
462	Pectoral sandpiper	1		20		
	Lapland longspur		5	40	60	
463	Pectoral sandpiper			10		
	Lapland longspur	3	8	50	60	86.6 ± 46.2
491	Lesser golden-plover	2		20		
	Buff-breasted sandpiper			10		
	Savannah sparrow			15		
	Lapland longspur		9	60		
	Redpoll sp.	1		15	120	
492	Lesser golden-plover	1		20		
	Ruddy turnstone	1		10		
	Semipalmated sandpiper	1		15		
	Buff-breasted sandpiper	1		10		
	Lapland longspur	1	6	55		
	Redpoll sp.			10	120	
493	Lesser golden-plover			5		
	Buff-breasted sandpiper	1		10		
	Lapland longspur	1	2	25		
	Redpoll sp.			10	50	91.7 ± 3.92

[a]For Lapland longspurs, maximum number counted on a single census, 10-30 June 1984.
[b]Includes nests found, probable nests as determined by behavioral observations, and mapped activity clusters of displaying males, other territorial data and additional sightings from censuses 1-4, 10 June - 16 July 1984.
[c]Habitat type is given as middle digit of plot number: 3 = Wet Sedge, 4 = Moist Sedge, 5 = Moist Sedge-Shrub, 6 = Tussock, 9 = Riparian.

Appendix Table 4. Nests, displaying males, and estimated nest densities for breeding birds on 15-10 ha plots in five habitats at Jago Delta study site, Arctic National Wildlife Refuge, Alaska, 1984.

Plot No.	Species	Number: Nests found	Number: Displaying males[a]	Estimated nest[b] density (nests/km^2): By species	Plot total	Average by habitat[c] (±S.D.)
621	Pectoral sandpiper	2		20		
	Red phalarope	1		10		
	Lapland longspur	2	5	35	65	
622	Oldsquaw			10		
	Pectoral sandpiper			20		
	Stilt sandpiper			10		
	Red phalarope	1		20		
	Lapland longspur	3	2	45	105	
623	Oldsquaw	1		10		
	Lesser golden-plover			10		
	Pectoral sandpiper	1		25		
	Stilt sandpiper			10		
	Red phalarope	1		10		
	Lapland longspur	2	2	20	85	85.0 ± 20.0
631	Semipalmated sandpiper	1		10		
	Lapland longspur	1	2	35	45	
632	Semipalmated sandpiper	1		10		
	Lapland longspur	3	7	65	75	
633	Semipalmated sandpiper	1		10		
	Stilt sandpiper	1		10		
	Lapland longspur	3	6	60	80	67.0 ± 19.0
641	Semipalmated sandpiper	1		10		
	Pectoral sandpiper	3		50		
	Red-necked phalarope	1		10		
	Lapland longspur	3	10	105	175	
642	Oldsquaw			10		
	Semipalmated sandpiper	1		20		
	Pectoral sandpiper	4		43		
	Red-necked phalarope			10		
	Lapland longspur	1	11	100	183	
643	Northern pintail	1		10		
	Pectoral sandpiper	5		60		
	Lapland longspur	6	16	95	165	174.3 ± 9.0
651	Northern pintail	1		10		
	Semipalmated sandpiper	1		10		
	Pectoral sandpiper	1		20		
	Buff-breasted sandpiper			10		
	Lapland longspur	2	8	63	113	
652	Rock ptarmigan			5		
	Semipalmated sandpiper	1		10		
	Pectoral sandpiper	1		20		
	Buff-breasted sandpiper	1		10		
	Lapland longspur	1	14	80	125	
653	Pectoral sandpiper			10		
	Dunlin	1		10		
	Lapland longspur	5	7	85	105	114.3 ± 10.1
691	Ruddy turnstone	1		20		
	Buff-breasted sandpiper			10		
	Lapland longspur	2	6	65		
	Redpoll sp.			5	105	
692	Ruddy turnstone			5		
	Semipalmated sandpiper			10		
	Buff-breasted sandpiper			10		
	Lapland longspur		4	35	60	
693	Northern pintail	1		10		
	Semipalmated plover	1		10		
	Ruddy turnstone	1		10		
	Lapland longspur		3	30	60	75.0 ± 26.0

[a]For Lapland longspurs, maximum number counted on a single census, 10-30 June 1984.
[b]Includes nests found, probable nests as determined by behavioral observations; mapped activity clusters of displaying males, and other territorial data and additional sightings from censuses 1-4, 10 June - 16 July 1984.

[c]Habitat type is given as middle digit of plot number: 2 = Flooded, 3 = Wet Sedge, 4 = Mosaic, 5 = Moist Sedge-Shrub, 9 = Riparian.

Appendix Table 5. Mean total bird densities (birds/km^2)[a] by habitat of 5 species at 3 locations during the breeding season 1984, coastal plain, Arctic National Wildlife Refuge, Alaska.

Species Location	Habitat[b] II	III	IV	IVa	V	VI	IX
Lesser golden-plover							
Aichilik	--	4	10	--	12	22	38
Sadlerochit	--	0	--	15	7	5	24
Jago Delta	9	2	--	3	4	--	4
Red-necked phalarope							
Aichilik	--	0	0	--	18	4	0
Sadlerochit	--	8	--	5	8	0	3
Jago Delta	4	0	--	6	0	--	0
Semipalmated sandpiper							
Aichilik	--	0	0	--	11	1	15
Sadlerochit	--	2	--	38	37	2	85
Jago Delta	4	13	--	22	10	--	13
Pectoral sandpiper							
Aichilik	--	21	3	--	72	47	3
Sadlerochit	--	54	--	52	13	28	7
Jago Delta	47	8	--	77	22	--	0
Lapland longspur							
Aichilik	--	68	82	--	218	178	136
Sadlerochit	--	110	--	181	203	117	199
Jago Delta	84	144	--	228	163	--	123

[a]Sample size is 12 (4 censuses on 3 10-ha plots) for each mean.
[b]Habitat names are given in Table 1.

Appendix Table 6. Mean total nest densities (nests/km^2)[a] by habitat of 5 species at 3 locations during the breeding season 1984, coastal plain, Arctic National Wildlife Refuge, Alaska.

Species	Habitat[b]						
Location	II	III	IV	IVa	V	VI	IX
Lesser golden-plover							
Aichilik	--	0	10	--	0	7	15
Sadlerochit	--	0	--	10	3	3	7
Jago Delta	3	0	--	0	0	--	0
Red-necked phalarope							
Aichilik	--	0	0	--	7	0	0
Sadlerochit	--	3	--	7	7	0	0
Jago Delta	0	0	--	7	0	--	0
Semipalmated sandpiper							
Aichilik	--	0	0	--	3	0	5
Sadlerochit	--	0	--	27	20	0	40
Jago Delta	0	10	--	10	7	--	3
Pectoral sandpiper							
Aichilik	--	13	2	--	30	23	0
Sadlerochit	--	10	--	27	13	8	3
Jago Delta	22	0	--	51	17	--	0
Lapland longspur							
Aichilik	--	28	28	--	72	53	47
Sadlerochit	--	33	--	57	77	35	60
Jago Delta	33	53	--	100	76	--	43

[a]Nest densities were determined from number of nests or territories on 3 10-ha plots.
[b]Habitat names are given in Table 1.

Appendix Table 7. Mean total bird densities (birds/km^2)[a] by habitat of 5 species at 3 locations during the post-breeding season 1984, coastal plain, Arctic National Wildlife Refuge, Alaska.

Species Location	Habitat[b] II	 III	 IV	 IVa	 V	 VI	 IX
Lesser golden-plover							
Aichilik	--	4	14	--	1	9	20
Sadlerochit	--	0	--	13	4	2	18
Jago Delta	4	18	--	10	19	--	36
Red-necked phalarope							
Aichilik	--	0	0	--	8	3	0
Sadlerochit	--	6	--	7	1	0	1
Jago Delta	3	0	--	2	0	--	0
Semipalmated sandpiper							
Aichilik	--	0	0	--	1	0	10
Sadlerochit	--	2	--	3	0	0	52
Jago Delta	2	7	--	0	1	--	13
Pectoral sandpiper							
Aichilik	--	26	71	--	161	76	12
Sadlerochit	--	159	--	32	38	2	159
Jago Delta	70	121	--	93	56	--	42
Lapland longspur							
Aichilik	--	87	120	--	207	146	203
Sadlerochit	--	62	--	96	104	89	200
Jago Delta	72	153	--	124	192	--	208

[a]Sample size is 9 (3 censuses on 3 10-ha plots) for each mean.
[b]Habitat names are given in Table 1.

Appendix Table 8. Mean total bird densities (±S.D.) on 45 study plots, Arctic National Wildlife Refuge, Alaska, for different census periods[a], June - August 1984.

Plot	Census Periods 1-4	1-5	6-7	1-7
431	13.0± 1.4	10.4± 5.9	24.5±10.6	14.4± 9.5
432	10.3± 2.8	8.6± 4.4	13.5± 7.8	10.0± 5.4
433	12.0± 6.7	9.8± 7.6	20.5± 4.9	12.9± 8.4
441	6.8± 3.2	6.0± 3.2	56.5± 7.8	20.4±25.0
442	14.0± 9.0	12.2± 8.8	29.5±29.0	17.1±16.2
443	16.5± 8.2	14.6± 8.3	11.5±14.8	13.7± 9.2
451	46.8±14.3	46.0±12.5	47.5± 6.4	46.4±10.5
452	36.0± 6.8	34.6± 6.7	51.0± 5.7	39.3± 9.9
453	46.0±17.3	46.6±15.0	41.5± 0.7	45.1±12.5
461	39.5± 6.2	35.0±11.4	29.5± 4.9	30.6±14.3
462	26.0± 7.4	25.4± 6.5	30.5± 4.9	26.9± 6.2
463	22.3±10.9	20.6±10.2	36.0±22.6	25.0±14.5
491	46.3±12.1	45.4±10.7	42.0±28.3	44.4±14.6
492	38.3±15.3	39.2±13.4	19.5± 6.4	33.6±14.8
493	25.0± 3.9	28.4± 8.3	27.5± 6.6	28.1± 7.3
531	23.3±10.2	21.8± 9.4	34.0±11.3	25.3±10.8
532	17.0± 8.1	17.4± 7.1	24.5± 7.8	19.4± 7.4
533	15.8± 9.0	17.4± 8.6	22.0± 2.8	18.7± 7.5
541	30.5± 5.2	28.2± 6.8	9.0± 4.2	22.7±11.0
542	30.5± 8.3	27.6± 9.7	18.5± 7.8	25.0± 9.6
543	41.0± 9.2	35.2±15.2	32.0±31.1	34.3±17.8
551	32.0± 4.1	27.8±10.0	9.0± 7.1	22.4±12.6
552	23.5± 2.4	21.2± 5.5	13.0± 7.1	18.9± 6.7
553	35.0± 7.8	31.0±11.2	31.0±15.6	31.0±11.1
561	14.5± 2.4	12.4± 5.1	21.5±21.9	15.0±10.8
562	17.0± 5.2	14.8± 6.7	28.5±24.7	18.7±13.3
563	16.3± 2.4	14.4± 4.6	21.0±17.0	16.3± 8.5
591	25.3± 7.6	22.6± 8.8	66.0±17.0	35.0±23.4
592	28.7± 4.0	32.8± 8.8	48.0±11.3	37.8±11.6
593	66.0± 8.2	64.6± 7.8	60.0±35.4	63.3±15.9

Appendix Table 8. (Continued).

Plot	Census Periods 1-4	1-5	6-7	1-7
621	23.0± 6.1	22.8± 5.3	14.5± 7.8	20.4± 6.7
622	19.8± 6.1	19.4± 5.4	19.5±10.6	19.4± 6.2
623	13.3± 5.7	14.6± 5.8	22.0±14.1	16.7± 6.0
631	16.3± 4.5	13.2± 7.9	36.5± 7.8	19.9±13.4
632	16.0±11.9	19.4±12.8	39.5±16.3	25.1±15.8
633	20.0±10.1	16.6±11.6	43.5±37.5	24.3±22.3
641	36.3± 6.7	31.8±11.5	32.0± 2.9	31.9± 9.5
642	39.3±11.1	34.2±14.8	23.5± 7.8	31.1±13.6
643	33.3± 9.5	28.4±13.6	42.5±14.8	32.4±14.4
651	22.8±11.2	20.2±11.2	42.5±14.8	26.6±15.5
652	23.8±13.7	20.8±13.6	32.0± 9.9	24.0±13.0
653	20.0± 9.0	18.4± 8.6	33.0± 2.8	22.6±10.1
691	28.0± 9.6	29.4± 8.9	54.5±27.6	36.6±18.2
692	17.5±12.1	19.6±11.5	37.5±33.2	24.7±18.7
693	16.0±13.2	17.6±12.0	33.0±31.1	22.0±17.7

[a]Census dates: 1 = 10-14 June; 2 = 17-21 June; 3 = 24-30 June; 4 = 5-10 July; 5 = 12-16 July; 6 = 10-15 August; 7 = 16-19 August.

Appendix Table 9. Mean total bird densities (±S.D.) on 7 censuses in 7 habitats, Arctic National Wildlife Refuge, Alaska, 1984[b].

Habitat[b]	Variable	Census Period						
		1	2	3	4	5	6	7
II	Total birds	20.3± 6.1	20.0± 8.7	18.7± 5.7	15.7± 9.6	20.0± 2.0	23.3± 3.5	14.0± 6.2
	Shorebirds	9.0± 2.6	8.0± 3.6	11.7± 3.5	9.7± 4.0	14.7± 3.1	8.7± 3.8	11.0± 7.2
	Passerines	10.7± 3.2	11.0± 4.6	6.3± 3.5	5.7± 5.0	5.3± 2.3	13.3± 6.5	3.0± 1.0
III	Total birds	16.1± 5.9	19.8± 8.4	17.8± 7.5	13.8±10.9	11.0±12.3	25.3±11.5	32.1±17.6
	Shorebirds	4.2± 2.8	3.8± 3.3	2.0± 0.7	6.6±10.2	3.9± 4.3	10.6±12.3	20.7±16.4
	Passerines	10.7± 5.3	15.0± 5.8	14.4± 7.8	6.2± 5.7	6.9± 8.8	14.4± 9.4	9.7± 6.4
IV	Total birds	12.7± 3.5	15.0±11.3	16.0± 9.8	6.0± 3.6	5.0± 2.0	24.0±33.2	41.0±16.5
	Shorebirds	1.0± 1.0	2.0± 2.0	1.7± 0.6	1.3± 1.2	2.7± 2.5	8.3±12.7	16.0± 6.2
	Passerines	9.3± 3.8	9.7± 7.2	10.7± 9.1	3.7± 2.9	1.3± 1.2	14.7±19.5	20.0±10.6
IVa	Total birds	41.3±11.3	37.2± 3.2	32.8± 3.9	29.0± 9.7	14.0± 3.4	19.8±10.6	32.7±18.3
	Shorebirds	16.5± 4.8	12.0± 3.7	9.3± 3.1	9.0± 8.4	6.5± 3.6	7.0± 9.5	13.7±11.7
	Passerines	21.8± 6.0	21.7± 6.9	22.2± 3.4	19.0± 4.9	7.0± 2.0	12.2± 8.7	13.8± 6.1
V	Total birds	30.7± 9.8	28.9± 8.1	37.6±12.4	29.9±20.5	21.1±15.4	34.2±17.0	32.6±14.8
	Shorebirds	9.8± 3.7	5.0± 2.5	6.9± 3.1	12.1±11.6	6.2± 5.9	9.3± 8.4	13.9± 8.5
	Passerines	17.2± 6.7	22.4± 5.4	28.6±12.0	16.6± 8.6	13.4± 8.5	22.0±13.5	16.6± 9.1
VI	Total birds	21.2±11.3	27.7±12.0	22.5±11.5	19.0± 7.0	11.8± 7.4	17.7±10.8	38.0± 9.4
	Shorebirds	5.8± 6.0	4.8± 4.5	3.8± 5.5	5.7± 4.0	4.7± 5.3	3.8± 4.7	5.8± 6.4
	Passerines	11.0± 4.1	20.7± 8.3	15.5± 4.9	12.3± 3.3	6.7± 2.9	11.2± 4.4	17.7± 7.2
IX	Total birds	30.3±19.0	26.7±16.2	35.2±21.3	38.3±13.6	36.7±13.7	34.1±16.8	52.1±26.1
	Shorebirds	11.1± 7.8	7.9± 5.7	9.6± 5.0	13.6± 6.3	7.1± 7.0	13.7±10.4	29.9±25.2
	Passerines	15.0± 9.7	17.1±12.1	22.7±16.4	22.6±10.5	27.4± 8.8	16.4± 6.1	21.2±10.3

[a]Habitat names given in Table 1.
[b]Sample sizes as follows: N = 3 for II, IV; N = 6 for IVa, VI; N = 9 for III, V, IX.

Appendix Table 10. Results of MANOVA analyses testing for differences in mean total bird densities and mean nest densities[a] due to study area location within 3 habitat types, coastal plain, Arctic National Wildlife Refuge, Alaska, 1984.

	Habitat		
Variable	Wet Sedge(III)	Moist Sedge-Shrub(V)	Riparian(IX)
Bird densities - Breeding season			
Total birds	P = 0.013	P = 0.006	P = 0.273
Total species	P = 0.051	P = 0.008	P = 0.000
Shorebirds	P = 0.004	P = 0.015	P = 0.211
Passerines	P = 0.076	P = 0.070	P = 0.496
Lesser golden-plover	P = 0.174	P = 0.390	P = 0.040
Red-necked phalarope	P = 0.084	P = 0.006	P = 0.422
Semipalmated sandpiper	P = 0.000	P = 0.109	P = 0.037
Pectoral sandpiper	P = 0.004	P = 0.007	P = 0.394
Lapland longspur	P = 0.031	P = 0.058	P = 0.539
Bird densities - Post-breeding season			
Total birds	P = 0.009	P = 0.002	P = 0.077
Total species	P = 0.001	P = 0.048	P = 0.001
Shorebirds	P = 0.018	P = 0.009	P = 0.016
Passerines	P = 0.127	P = 0.105	P = 0.957
Lesser golden-plover	P = 0.178	P = 0.155	P = 0.725
Red-necked phalarope	P = 0.095	P = 0.046	P = 0.422
Semipalmated sandpiper	P = 0.001	P = 0.630	P = 0.006
Pectoral sandpiper	P = 0.030	P = 0.002	P = 0.009
Lapland longspur	P = 0.091	P = 0.123	P = 0.988
Nest densities			
Total nests	P = 0.340	P = 0.631	P = 0.525
Total species nesting	P = 0.422	P = 1.000	P = 0.340
Shorebird nests	P = 0.729	P = 0.524	P = 0.445
Passerine nests	P = 0.255	P = 0.681	P = 0.619

[a]Nest densities were determined from number of nests or territories per 10-ha plot.

Appendix Table 11. Weather conditions at three study sites, Arctic National Wildlife Refuge, Alaska, 3-30 June, 1-21 July, 6-20 August. Wind and cloud cover recorded twice daily.

	Aichilik			Sadlerochit			Jago Delta		
	June	July	August	June	July	August	June	July	August
Temperature (C°)									
minimum	-1.7	0.0	-1.7	-1.1	0.0	-1.7	-1.1	-0.5	-1.7
mean minimum	3.7	3.7	4.1	1.6	2.2	3.9	1.1	1.6	2.6
maximum	29.4	25.6	25.0	26.7	22.8	21.7	13.9	18.9	27.8
mean maximum	16.3	16.1	12.9	12.6	14.0	11.9	7.8	12.0	10.4
Wind speed (km/h)									
mean	5.3	6.6	6.4	8.8	9.4	7.1	13.4	14.6	12.8
% observations									
0-8(km/h)	49.0	43.9	51.8	26.0	43.9	57.7	19.6	17.5	29.6
9-16(km/h)	51.0	43.9	34.4	48.2	46.3	38.5	60.8	52.5	48.1
17+(km/h)	0.0	12.2	13.8	5.4	9.8	3.8	19.6	30.0	22.2
Wind direction (%)									
N	2.0	0.0	0.0	1.9	3.0	4.5	3.8	2.7	8.0
NE	28.0	7.9	11.1	40.4	12.1	4.5	13.2	13.5	12.0
E	42.0	23.7	18.5	23.1	24.2	9.1	47.2	18.9	16.0
SE	0.0	0.0	3.7	1.9	0.0	13.7	16.9	5.4	8.0
S	0.0	2.7	0.0	0.0	6.1	4.5	0.0	0.0	0.0
SW	2.0	10.5	7.4	1.9	3.0	0.0	0.0	2.7	4.0
W	18.0	44.7	51.9	13.5	45.5	50.0	3.8	37.9	28.0
NW	8.0	10.5	7.4	17.3	6.1	13.7	15.1	18.9	24.0
Cloud cover (%)									
clear	7.5	10.0	6.9	21.8	19.5	3.7	12.9	20.0	3.5
scattered	28.3	17.5	0.0	20.0	4.9	7.4	16.6	12.5	10.3
broken	20.8	12.5	13.8	14.6	24.4	18.5	22.3	5.0	13.7
overcast	43.4	60.0	79.3	43.6	51.2	70.4	48.2	62.5	72.5
Precipitation (days)									
none	19	12	8	13	13	4	16	9	6
rain	4	5	4	6	5	9	4	7	5
snow, sleet	2	2	2	4	1	2	2	2	3
fog	6	5	3	8	3	1	6	3	1

Appendix 12. 1984 Weather Summary for three study sites, Arctic National Wildlife Refuge, Alaska.

Weather data were recorded at the three study areas twice daily at approximately 0800 and 2000h. Taylor maximum-minimum thermometers were used for measurement of current as well as daily maximum-minimum temperatures. Wind velocities were measured with hand-held Dwyer portable wind meters for speeds less than 8 km/h and Sims anemometers for speeds 8 km/h and above. Wind direction was determined by Silva Ranger compass. Cloud cover was recorded in the following classes: clear 0-9%; scattered 10-49%; broken 50-89%; overcast 90-100%. Type of precipitation was also recorded. Weather data are listed in Appendix Table 11.

The inland site (Aichilik) was generally warmer than the two coastal sites. It had higher mean minimum and maximum temperatures with the largest range between these for all months except August. Jago Delta had the coolest weather, likely due to its location on a point which protruded into the Beaufort Sea and formed the eastern edge of the weather zone which surrounds Barter Island. Arctic regional temperatures tended to be warmer than normal in June, near normal in July and colder than normal in August (Arctic Climate Center 1984b)

Prevailing winds were from the east at Aichilik and Jago Delta and northeast at Sadlerochit in June. In July and August west winds were most common at all sites, a divergence from past records of prevailing easterlies through July (Spindler 1978, Spindler and Miller 1983, Spindler et al. 1984).

Wind speeds averaged higher at Jago Delta, followed by Sadlerochit, then Aichilik, throughout the season. Fastest monthly mean speeds and largest proportion of speeds greater than 16 km/h occurred at all sites in July and lowest speeds were recorded in August for all areas except Aichilik. Strongest winds were usually accompanied by snow or rain and were from the west. During storms on 18 July and 11 August wind speeds were lower at Sadlerochit (11-16 km/h, 16-32 km/hr respectively) than at Jago Delta (37-48 km/h, 32-35 km/hr). Strong easterly winds with clear weather were recorded on 2-3 July at all sites.

Weather was relatively mild in June and July with days of high winds, precipitation, or fog alternating with days of clear skies or milder weather. There were the fewest overcast days in June and the highest proportion in August. For the Arctic region, precipitation levels were substantially below normal in June, but above normal in July (Alaska Climate Center 1984b). On the coastal plain it seemed to be drier than normal, with major rivers such as the Tamayariak completely dry, and many of the wet tundra areas and small ponds completely dry by mid-July. The trend changed with light to heavy rain nearly constant from 30 July- 11 August which filled major rivers nearly to the tops of the banks and nearly flooded our adjacent camps. Snow fell during each month with a light covering on 4 and 27 June and 14 July. Measurable (3-10 cm) snow accompanied high winds on 18 July and 11 August. There were more foggy days at Sadlerochit than the other areas in June and more at Aichilik in July. Fog was less common in August in 1984 than in 1983.

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SPECIES ACCOUNTS OF MIGRATORY BIRDS AT THREE STUDY AREAS ON THE COASTAL PLAIN OF THE ARCTIC NATIONAL WILDLIFE REFUGE ALASKA, 1984

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Key words: Anseriformes, Charadriiformes, waterfowl, shorebirds, tundra, wetlands, species accounts, habitat use, status and distribution, Arctic-Beaufort, north slope

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Species accounts of migratory birds at three study areas on the coastal plain of the Arctic National Wildlife Refuge, Alaska 1984.

The following species accounts describe status, breeding chronology, migration and habitat use of 71 bird species at 3 areas on the coastal plain of the Arctic National Wildlife Refuge (ANWR) where intensive investigations of terrestrial bird populations and habitat use occurred during June-August 1984 (Moitoret et al. 1985). Information is given for 46 species of birds at Aichilik River study area, 60 species at Sadlerochit River Delta study area, and 54 species at Jago River Delta study area. Status is also given for species observed while surveying these sites in late July- early August 1983 (Spindler et al. 1984).

Study area maps and descriptions are given in Moitoret et al (1985). Bird breeding chronology, behavior, status, and distribution data were recorded daily during the field season. Field work in the study areas was carried out between approximately 2 June and 20 August with one break when researchers visited 4 other areas. Therefore first and last dates of observations and first dates of hatching of young may not be all inclusive. Bird observations from the 4 new study areas surveyed in late July- early August are summarized in Table 1. More complete species account information for the Canning River Delta site for 1979-80 may be found in Martin and Moitoret (1981).

Status and abundance terminology for birds follows Kessel and Gibson (1978) using these categories: abundant, common, fairly common, uncommon, rare, casual, accidental, resident, migrant, breeder, visitant. Species accounts are presented in phylogenetic order with nomeclature following American Ornithologist's Union (1983). The 2 redpoll species (common redpoll and hoary redpoll) were lumped for the purposes of this report due to confusion in field identification and because several investigators have considered them to be conspecific (Williamson 1961, and Troy 1980). Habitat types follow Walker et al. (1982) with modifications described in Moitoret et al. (1985, Table 1).

Table 1. Bird species observed at Marsh Creek, Canning River Delta, Niguanak, and Tamayariak study areas, Arctic National Wildlife Refuge, Alaska, 21 July to 5 August 1984 [Presence (x), breeding (B), and probable breeding (prob- B) are indicated].

Species	Marsh Creek	Canning River delta	Niguanak River	Tamayariak River
Red-throated loon		x-B		
Arctic loon		x-B	x-B	
Tundra swan		x-B	x-prob-B	
Green-winged teal	x			
Northern pintail	x-B	x	x	
Common eider			x-B	
King eider		x-B		
Harlequin duck	x			
Oldsquaw		x-B	x-B	
Red-breasted merganser		x		
Rough-legged hawk	x			
Willow ptarmigan	x			
Rock ptarmigan	x-B	x	x-B	x-B
Black-bellied plover		x		
Lesser golden-plover	x-B	x-B	x-B	x-prob-B
Wandering tattler	x-B			
Ruddy turnstone	x-B	x	x	
Semipalmated sandpiper	x-B	x-B	x-B	
White-rumped sandpiper		x		
Baird's sandpiper		x	x	
Pectoral sandpiper	x-B	x-B	x-B	
Dunlin		x-B		
Stilt sandpiper			x-B	
Long-billed dowitcher		x-B	x-B	
Red-necked phalarope		x-B	x-B	
Red phalarope		x	x	
Parasitic jaeger	x	x-B	x	
Long-tailed jaeger	x		x	
Glaucous gull		x-prob-B	x	
Sabine's gull		x-B		
Arctic tern		x-prob-B	x	
Snowy owl		x		
Common raven			x	
Yellow wagtail	x	x		
American tree sparrow	x			
Savannah sparrow	x			
White-crowned sparrow	x			
Lapland longspur	x-B	x-B	x-B	x-prob-B
Redpoll sp.	x-B			

RED-THROATED LOON

Aichilik

Uncommon spring migrant. Only a single observation of a single loon flying northeast along the river on 8 June. It landed briefly in the river, then continued flying northeast.

Sadlerochit

Fairly common breeder. The first observation of a red-throated loon was on 8 June when one flew east over the Sadlerochit River. On 9 June one was seen swimming in the ocean near Anderson Point. On 12 June a pair was first seen on a pond near camp, and extensive vocalizations were heard on this date. Red-throated loons were present at the Sadlerochit study area from this time until crew departure on 19 August. They were seen singly and in pairs (occasionally three together) on ponds in Wet Sedge near camp, and flying overhead vocalizing. Three nests were found in 1984. Two of these each produced 2 young which had hatched by 19 July. In the third nest, only one of 2 eggs hatched, at a later date. In 1983 4 pairs of red-throated loons each produced 2 young. After hatching of the young, adult loons were frequently seen flying inland from the ocean with fish in their beaks. Adults with young were present on the nest ponds until our departure 19 August. Small groups of up to 4 loons were observed flying over camp during the month of August.

Jago Delta

Fairly common breeder. Red-throated loons were present in Flooded tundra from 8 June to 19 August. Courtship and defensive calling was first heard on 10 June and continued throughout the season. A single nest found on 2 July with 2 eggs had a complete clutch by 18-23 June or earlier based on back-dating from the sighting of a downy chick in the nest on 16 July (Harrison 1978). Evidence of 2 other nests was shown by observations of single adults, each with two young, swimming in different ponds on 15 and 18 August.

ARCTIC LOON

Aichlik

Uncommon summer visitant. Birds were seen and heard irregularly during 30 June - 18 August, flying both directions along the river. Four loons were seen feeding in the Aichilik approximately 13 km upriver from camp.

Sadlerochit

Rare migrant. Four arctic loons were seen flying northeast on 4 June and two were seen swimming in the ocean on 22 June.

Jago Delta

Fairly common breeder. Arctic loons were first observed on 6 June and were present in Flooded tundra, ponds, and lakes throughout the duration of field work, until 20 August. Flocks of 3 and 12 loons flew east over camp on 10 and 11 June. Elaborate courtship display among 3 loons, with an uninvolved fourth individual in the vicinity, occurred in a large lake on 23 June. Throughout the season 7 pairs were repeatedly observed in large lakes in the study site. Two nests were found on small islands at the edge of large lakes on 28 June and 4 July. First chicks were seen on 19 July in the presence of a defensive adult at a third nesting site. Flocks of 2-4 loons were seen and heard vocalizing in flight on 16 and 19 August.

YELLOW-BILLED LOON

Jago Delta

Rare summer visitant. A flock of 3 was seen flying east on 3 June. Single loons in flight were sighted on 8 June, 10 July, and 12 August.

TUNDRA SWAN

Aichlik

Uncommon spring migrant. Two swans were first observed on 25 June, flying west over camp. On 27 June, 3 immature swans landed on a small pond 1 km southwest of camp, but stayed only a short while before flying north.

Sadlerochit

Uncommon summer visitant. Tundra swans were seen occasionally throughout June and July, usually in groups of 2 or 3, with the first sighting on 5 June. They were most often seen flying, but were also seen resting on Wet Sedge and Moist Sedge-Shrub, and also swimming in ponds near the coast and in the ocean near the river mouth. A pair was seen on 22 June in a coastal lake 5 km west of camp. Single birds were seen on 17 and 18 August standing on Wet Sedge and flying east along the coast.

Jago Delta

Uncommon breeder. Tundra swans were seen almost daily from 2 June to 18 August in Riparian, Flooded and Wet Sedge tundra. A pair was commonly seen from 2 June-7 July near camp in Riparian habitat with standing water in old stream channels. They may have been deterred from nesting by repeated aircraft and human disturbances due to proximity to the camp. Courtship displays were performed by a pair in Flooded tundra 4 km southeast of camp on 10 June. First young, a group of 5 with an adult pair, were sighted on 7 July in Flooded tundra 3 km north of camp. Other broods consisted of 3 young nearly adult size attended by an adult pair in a pond 3 km east of camp on 8 August and a pair with one cygnet in Flooded tundra 5 km northeast of camp on 14 August. Loosely flocked pairs were observed along the Jago River mostly on gravel bars or exposed mud: 10 on 4 July 1.6 km north of camp, 15 on 7 July 3.5 km north of camp, and 7 on 13 July near camp. A molting pair was observed in Flooded tundra 3.5 km east of camp on 15 August.

GREATER WHITE-FRONTED GOOSE

Aichilik

Uncommon spring migrant. First observed on 5 June, when 13 were seen flying west. Two were seen on 7 June, flying north over the river, and 7 were seen flying west on 19 June. On 26 June, 12 geese were seen flying southeast approximately 2 km west of camp.

Sadlerochit

Uncommon migrant. There were 8 sightings in June of 1-6 greater white-fronted geese flying north or west over the study area, with the first sighting on 5 June. On 23 June 3 were seen grazing on Riparian plot 591. One was seen flying west on 12 August.

Jago Delta

Uncommon spring migrant and rare fall migrant. Several flocks flew north or east over the study area in June: 6 on 3 June; 5, 8 and 55 on 6 June; 8 on 7 June; 1 and 4 on 10 June; a pair on 16 June; 5 on 28 June. A pair was observed on Wet Sedge tundra on 12 and 23 June. A group of 4 pairs was involved in courtship display in Moist Sedge on 6 June. Flocks of 4, 11 and 14 geese were seen flying eastward on 15 August.

SNOW GOOSE

Sadlerochit

Uncommon spring migrant. There were 8 sightings of groups of snow geese ranging from 2 to 25 birds, flying east or southeast, between 7 and 18 June. Three seen on 8 June were flying east with a flock of 40 brant.

Jago Delta

Uncommon spring migrant and rare summer visitant. Flocks were seen flying westerly: 7 geese on 2 June, 8 on 3 June, and 29 on 14 June. Eastward migrating flocks numbered 6 and 24 on 6 June, 41 on 7 June, 24 on 19 June, 21 on 20 June and 7 on 23 June. Three snow geese were seen feeding with Canada geese in Flooded habitat on 7 July.

BRANT

Aichilik

Rare spring migrant. One brant was seen flying northeast along the Aichilik river on 18 June.

Sadlerochit

Common spring migrant. Numerous flocks of 20-150 brant were observed daily from 2 to 17 June, flying east along the coast. One was observed 29 July 1983 sitting at the tip of the barrier island spit at Anderson Point.

Jago Delta

Fairly common spring migrant and rare breeder. Most observations were of flocks ranging in size from 4 to 250 (with an average of about 70) during eastward spring migration from 2-13 June. Brant uncommonly used tundra wetland habitats: a pair was in Wet Sedge on 10 June, and one was in Flooded tundra on 23 June. A single brant nest being incubated by an adult was found on 4 July, located on a small mossy island surrounded by Arctophila at the edge of a deep lake. Another adult was swimming next to the nest and a third was in the vicinity. The nest was found abandoned on 11 July with no brant seen in the area. The remains of 3 eggs, broken at one end, were probably predated upon by glaucous gulls or parasitic jaegers present in the nest vicinity when it was first visited.

CANADA GOOSE

Sadlerochit

Uncommon migrant. On 5 June a flock of 50 Canada geese flew east over camp. On 7 June six were seen flying, and one was observed flying on 19 June. Eight flew east over camp on 18 August.

Jago Delta

Uncommon breeder. The majority of observations consisted of 1-3 pairs seen flying over Riparian habitats from 5 June to 2 July. On 6 June a single Canada goose accompanied a flock of 8 migrating white-fronted geese. Pairs were sighted on Wet Sedge tundra on 6 June and on Mosaic tundra on 16 June. A pair was suspected to be nesting in Flooded tundra 3.5 km north of camp on 23 June and was confirmed by the presence of 5 young with the adults on 7 July. Single flocks of 7-12 geese were seen flying over the Jago River and delta 4-8 July. A single flock of 5 geese was observed in eastward migration, flying low over Mosaic tundra on 18 August.

GREEN-WINGED TEAL

Sadlerochit

Rare summer visitant. On 14 June 2 male green-winged teal were observed swimming in a creek near Tussock plot 563.

Jago Delta

Rare summer visitant. Two sightings were made in Mosaic tundra 4-5 km northeast of camp: a pair flushed from plot 643 on 8 June, and a male flushed several times on 16 June.

NORTHERN PINTAIL

Aichilik

Common spring and fall migrant. Birds were seen singly or in small groups during 2-18 June, either flying or feeding on the small ponds in Moist Sedge-Shrub approximately 1.5 km west of camp. On 9 June, several males were seen chasing a single female over the Aichilik River. Only 1 pintail was seen (on 26 June) during 19 June - 8 August. Small groups of pintails (2 or 3) were seen on 9, 13, and 18 August, again feeding in the small ponds in Moist Sedge-Shrub.

Sadlerochit

Common breeder. Pintails were observed daily from arrival until departure of observers (2 June to 19 August). They were seen in all habitats as well as flying overhead, but were most common among the small ponds on Mosaic and Moist Sedge-Shrub plots. A pair of pintails was observed copulating on 9 June on a small inlet near Anderson Point. In August 1983 2 broods of 3 and 5 ducklings were observed with adult females on small ponds in Wet Sedge near camp. In 1984 no nests were found in this habitat, but 1 nest was found in a Tussock plot near a small stream, on 29 June. The nest had 7 eggs but was subsequently depredated, probably by the long-tailed jaegers which had a nest about 30m away. Two females with broods of at least 4 ducklings were seen in

Mosaic habitat on 10 and 12 July. A female with 7 ducklings was seen in Mosaic habitat on 16 August, and 2 other large ducklings were also seen on this date. A female with 4 ducklings was seen on a pond in Wet Sedge near camp 17 August.

Jago Delta

Fairly common breeder and fall migrant. Singles, pairs, or small flocks were seen almost daily in all habitats from 2 June to 18 August. Males seen singly or in flocks of 2-11 predominated the observations 5-18 June. The first female with a suspected nest was seen in Flooded tundra 12 June. Four pintail nests were found. The first nest was found on 17 June located between tussocks in a dry area of Moist Sedge-Shrub habitat 4 km southeast of camp. Seven eggs were being incubated by the female, and a male was also in the area. This nest was found depredated a week later. Another pintail nest was found depredated, with scattered egg shells and down, in Mosaic tundra 5 km northeast of camp on 19 June. A nest with 8 eggs was found on 2 July under low Riparian willows about 14 km south of camp. A long-tailed jaeger and common eider nest were present in the vicinity of this nest. The latest date a nest was found was 13 July with a female incubating 8 eggs. This nest was in a crack on the ground on the Dryas river terrace near camp and was found depredated on 17 July. No broods were observed. Females in flocks numbering 5-7 were observed in Flooded tundra 5 -7 July, and a flock of 10 was seen feeding on Jago delta mudflats on 16 July. A male was seen in molt plumage in Flooded tundra on 7 July, and a flock of 4 females were in flightless molt condition on 19 July. Small flocks (5-20 birds) were observed flying over the study area 7, 13, 14 August.

NORTHERN SHOVELER

Jago Delta

Rare spring migrant. A pair was observed flying east on 6 June near camp. A single male was seen flying west over Mosaic tundra 4 km northeast of camp on 8 June.

GREATER SCAUP

Sadlerochit

Rare spring migrant. Two males and one female were seen on 7 June swimming and feeding in the ocean near Anderson Point.

Jago Delta

Rare spring migrant. There was a single sighting of 2 pairs swimming in a pond 3 km east of camp on 8 June.

LESSER SCAUP

Jago Delta

Rare spring migrant. A single individual was observed in Flooded tundra about 3 km east of camp on 11 June.

COMMON EIDER

Sadlerochit

Fairly common breeder. Common eiders were first observed 7 June when at least 25 males and 16 females were seen swimming and feeding in the ocean near Anderson Point. Gradually diminishing numbers of eiders remained in this area until 2 July, when a single male was observed with 4 females. Small groups and pairs were seen flying up and down river, and resting on gravel bars on Riparian plots throughout June. Males were observed courting females on the river near camp on 21, 24, and 30 June. A depredated eider nest was found on a willow clump on Riparian plot 591 on 18 June. On 30 June an eider nest was found on the river bank near Riparian plot 592, but the female abandoned her 4 eggs. Two female common eiders were observed sitting on nests, with 4 and 5 eggs respectively, on the gravel beach near the tip of the barrier island spit at Anderson Point. These females were last observed incubating on 11 July, and on 19 July the nests were empty. In 1983 a female was found on a nest with 5 eggs on Riparian plot 591 on 6 August. A female with 2 ducklings was seen on the barrier island spit at Anderson Point 29 July, and a female with 1 duckling was seen along the shoreline on 7 August, 1983.

Jago Delta

Fairly common breeder. Common eiders (primarily breeding females) were observed from 12 June to 19 August. There were only two sightings of males, a single male with 3 females flying east near the coast on 12 June and a single male with 2 females flying low over Flooded tundra on 7 July. The 3 common eider nests located were subsequently found depredated or abandoned. Two nests were in Wet Sedge tundra: the first was found with 5 incubated eggs on 17 June 2.5 km southeast of camp and had been destroyed by the time it was relocated on 24 June; a second was discovered on 7 July with 6 incubated eggs, was still active when checked on 13 July, but had been abandoned by 17 July. One nest was found in Riparian habitat with some sedges and willows on a river gravel bar 1 km north of camp on 16 July. The nest contained 5 incubated eggs, but a few hours after discovery the female was found dead with wounds near the sternum. Presence of additional nests was indicated by observation of 2 broods: a female with 4 young in a pond 5 km southeast of camp on 13 August; and 2 young accompanied by a female in a pond on 19 August.

KING EIDER

Sadlerochit

Rare spring migrant. Four males and 3 females were seen swimming and feeding in the ocean at Anderson Point on 7 June.

Jago Delta

Uncommon spring migrant. The majority of sightings of king eiders were of birds flying over the study area in westward migration: 2 pairs on 6 June; 1 pair on 8 June; a flock of 19 on 8 June; a flock of 6 and 2 pairs on 10 June; and a pair on 16 June. Sightings were made in Flooded tundra 3 km northeast of camp of a pair (14 June; 16 June) and 2 pairs (20 June).

HARLEQUIN DUCK

Aichilik

Uncommon summer visitant. One female harlequin was seen flying over and feeding on the Aichilik river approximately 8 km southwest of camp, on 30 June.

OLDSQUAW

Aichilik

Uncommon spring visitant. Two oldsquaw, a male and female, were seen on a small pond in Wet Sedge habitat, approximately 1 km southwest of camp on 14 June. A male was seen in the same pond on 16 June, but no nest was found and no birds were seen thereafter.

Sadlerochit

Common breeder. A pair was observed on the Sadlerochit River on 2 June, and pairs and singles were frequently observed throughout June and July in the river and on ponds in Wet Sedge and Mosaic habitat. There was also a large concentration of oldsquaw swimming, sleeping, feeding, and calling in the leads among the ice floes along the shoreline at Anderson Point, observed throughout the summer from 9 June to 18 August. One female oldsquaw was found on a nest with 7 eggs on a Mosaic plot on 25 June. By 2 July there were only 5 eggs and parasitic jaegers were frequently observed in the vicinity. The remaining eggs were depredated by jaegers on 3 July when the female left the nest following several failed attempts to capture her for a radio-telemetry study. In early August 1983 2 females were observed with broods of 2 and 5 ducklings respectively in the vicinity of Anderson Point.

Jago Delta

Common breeder and fall migrant. Oldsquaw were observed almost daily from 2 June to 19 August in all habitats. Pairs were primarily observed during the first half of this period. A male in winter plumage was observed on 10 June in Mosaic tundra. Three oldsquaw nests were found and an additional 4 were indicated by presence of broods. The first nest found contained one egg on 19 June in Flooded tundra, and was not relocated. One nest was discovered with 7 eggs on 30 June in Wet Sedge tundra and was empty with the outcome uncertain on 10 July. A nest with 7 eggs was found on 2 July under Riparian willows 14 km south of camp, near a long-tailed jaeger nest. First young were observed on 11 July, a brood of 5 with a female, swimming in a pond 2.5 km north of camp. Four other broods were seen in Flooded tundra ponds: a brood of 5 on 19 July 3 km north of camp; a brood of 5 on 6 August 4 km east of camp; a brood of 3 on 13 August 4 km southeast of camp; 3 on 14 August 3 km east of camp. A flock of approximately 500 molting oldsquaw were seen in Tapkaurak Lagoon on 15 August.

SURF SCOTER

Sadlerochit

Fairly common spring migrant. Many were observed swimming and feeding in the ocean near Anderson Point on 7, 9, and 22 June. On 22 June a group of 20 appeared to be mostly males.

WHITE-WINGED SCOTER

Sadlerochit

Uncommon spring migrant. Two were swimming and feeding in the ocean at Anderson Point on 7 June, and a group of 10 was seen there on 22 June.

Jago Delta

Rare spring migrant. A single observation was made on 17 June of 1 male and 2 females flying low over Flooded tundra 2 km east of camp.

COMMON GOLDENEYE

Sadlerochit

Rare spring migrant. Two males were seen swimming and feeding in the ocean at Anderson Point on 7 June.

RED-BREASTED MERGANSER

Aichilik

Uncommon summer visitant. Pairs or small groups were seen on the Aichilik river during 4-28 June. Two females were seen on the river near our Riparian plot (1 km northeast of camp) on 9 July. Small groups were also seen on the river on 13 July and 15 August.

Sadlerochit

Uncommon summer visitant. Two pairs were seen swimming and feeding in the ocean at Anderson Point on 7 June. Pairs and single females were seen flying over the river on 11, 15, 18, 23, 26 June and 6 July. One female landed on the river on 15 June, two on 26 June, one on 7 July, three on 17 July, and five on 18 July. One female was swimming in the ocean near Anderson Point on 19 July. In 1983, 4 pairs flew upriver on 29 July.

Jago Delta

Rare summer visitant. There were seven sightings of red-breasted mergansers from 5 June to 19 July. Most were in ponds or Flooded tundra: 2 pairs on 5 June; a flock of 3 feeding on 10 June 3-4 km southeast of camp; single females on 23 June and 19 July 3-5 km north of camp. Mergansers were seen flying over the study area: a single bird on 24 June; a pair traveled over the Jago River on 25 June; a single female moved upstream on 4 July.

NORTHERN HARRIER

Sadlerochit

Rare fall visitant. One was seen 31 July 1983 flying over Moist Sedge-Shrub 6 km inland. An immature was seen sitting on a mound near the river and flew to the bluff on 12 August 1984. An immature bird was seen near the bluff on 15 August 1984 and it flew away across the river.

Jago Delta

Rare summer visitant. A single female plumaged bird hunted over Wet Sedge tundra 1.5 km northeast of camp on 20 June.

ROUGH-LEGGED HAWK

Aichlik

Rare spring visitant. One hawk was seen on 7 June, soaring near camp.

Sadlerochit

Rare summer visitant. One rough-legged hawk was seen flying over the Sadlerochit delta on 30 and 31 August 1983.

Jago Delta

Rare summer visitant. A single rough-legged hawk hunted in Tussock tundra near the Jago River 14 km south of camp on 2 July.

GOLDEN EAGLE

Aichlik

Fairly common summer visitant. One eagle seen on 5 June soaring over the river approximately 2 km south of camp. On 12 June, 1 eagle was seen sitting in and flying low over Moist Sedge-Shrub habitat (there were caribou with calves in the area). On 18 June an immature eagle was seen 3 km south of camp, sitting on the ridge west of the river. It crossed the river, flying very low, and sat on the bluff east of the river, then continued east. During 1-3 July 4 eagles were seen in the foothills 20 km south of camp, hunting and soaring.

Sadlerochit

Rare summer visitant. An immature golden eagle was seen flying over Tussock plots, 6 km inland, on 5 June 1984. Another was seen flying over the river on 1 July 1984.

Jago Delta

Rare spring migrant. A single golden eagle soared over the Jago River 8 km south of camp on 10 June.

MERLIN

Jago Delta

Rare fall migrant. There were 2 sightings of single merlins near camp on 16 August and 19 August. On the later date the merlin was chasing shorebirds in Riparian habitats.

WILLOW PTARMIGAN

Aichilik

Common resident, fairly common breeder. Almost all sightings of willow ptarmigan were in Moist Sedge-Shrub and Tussock habitats. On 2 occasions, 14 June and 19 August, birds were seen in Wet Sedge. On the latter date, a group of 15 were observed, including adults and young-of-the-year. Male ptarmigans had a rusty red head and neck and white body on 4 June, and by 26 June they had essentially completed their molt. They remained in summer plumage through 20 August. Display flight and vocalizations by males were seen during 4-18 June. On 14 July, a pair of ptarmigan were found in Moist Sedge-Shrub (approximately 1.6 km west of camp) with 2 hatchlings which appeared to be only 3-4 days old. On 13 August several large groups (with up to 11 birds in a group) were seen feeding and flying in Moist Sedge-Shrub. On 20 August, a group of 15 were seen feeding and flying in Tussock habitat.

Sadlerochit

Uncommon breeder. A pair and a male were seen on 5 June on Moist Sedge-Shrub habitat. Males were observed on 12, 14, 21, 27 June and 14 July on Moist Sedge-Shrub habitat, standing, vocalizing, and displaying. On 16 July a pair with 11 flight-capable young were seen on Moist Sedge-Shrub. A pair with about 15 juveniles were seen in the same habitat on 14 August. A group of about 12 were standing in Riparian willow near the river on 15 August. Groups of 15, 6, and 4 were seen on Tussock plots on 19 August.

ROCK PTARMIGAN

Aichilik

Common resident, fairly common breeder. Rock ptarmigan were seen in Riparian, Wet Sedge, Moist Sedge, and Tussock habitats. Birds were seen during 2 June - 16 August. Most display and vocalization flights occurred during 8-13 June, and by 17 June the birds were hiding/sitting on the ground. On 4 June, the males seen were still in full winter plumage, but the females had full summer plumage. Dark feathers were first noticed on the heads of males on 8 June. A male with an essentially complete summer plumage was seen on 28 June. A single rock ptarmigan nest was found in Tussock plot 461 (approximately 1.6 km west of camp) on 28 June; the female did not flush until touched, and the nest had 11 eggs. When the nest was again checked on 10 July, it appeared that some eggs had hatched (presence of egg caps) but that some others were left in the nest and had been eaten by jaegers. On 16 July, a female with 9 chicks (some with pin feathers) was seen in Riparian Willow habitat. Young observed on 19 July in Riparian, Wet Sedge, and Tussock habitats were flight-capable. On 12 August, groups of 10, 11, and 12 birds were seen on Riparian plot 491, approximately 1 km northwest of camp. All birds could fly. On 16 August 15 birds were seen on Moist Sedge plot 442. It was noticed that some of these birds were beginning to molt head feathers back to winter plumage.

Sadlerochit

Fairly common breeder. Rock ptarmigan were seen in the study area throughout the summer from 4 June until crew departure 19 August, in all habitats except Wet Sedge. Male displays were most conspicuous through 15 June; after this males began molting and were more often seen hiding in the tundra rather than flying and vocalizing. A male in full summer plumage was observed 4 July. Females were observed with males in Mosaic, Tussock, and Riparian habitat in June. A female flushed from a nest with 12 eggs on a Tussock plot on 29 June; the nest was empty on 9 July. Chicks were first observed on 9 July in Riparian and Tussock habitat (3 broods, one with flight capable chicks). In mid-August groups of juveniles with adults were seen in Riparian and Mosaic habitat, but the greatest concentration was on 19 August when a total of 46 rock ptarmigan in five groups of 6-12 each were seen on 2 Tussock plots. In 1983, pairs with 6-8 flight capable chicks were seen in Riparian and Moist Sedge-Shrub habitat on 30 July.

Jago Delta

Uncommon breeder. There were 1-2 pairs in Riparian habitat near camp of on 3 and 4 June, but there were no subsequent observations in this habitat. Male ptarmigan (1-4) were sighted in Wet Sedge tundra 1.5-4 km east of camp on 5 June and 6 June, possibly dispersing from the Riparian habitat. The majority of observations were in Mosaic and Moist Sedge-Shrub habitats 2-4 km from camp 5 June-18 August. Courtship displays were conducted by males in winter plumage in Riparian habitat on 3-4 June and by males in transition or courtship plumage from 10-17 June in Mosaic tundra. The first male in summer plumage was seen on 24 June. No nests were found but a female flushed suspiciously from Wet Sedge tundra on 30 June. The first young was observed on 13 August, a single ptarmigan in Moist Sedge-Shrub habitat. A brood of 5 flight-capable young with an adult was observed on 16 August in Mosaic tundra and a flock of 5 juveniles was recorded in Wet Sedge tundra on 18 August.

SANDHILL CRANE

Aichilik

Rare spring migrant. A single crane was observed flying southwest over the Aichilik river near camp on 11 June.

Sadlerochit

Uncommon summer visitant. Vocalizations were heard on 2 June. A pair was seen feeding on Wet Sedge near camp on 13, 15, and 16 June and a pair flew over camp on 23 June and 12 August. In 1983, vocalizations were heard from camp on 30 July and 4 August.

Jago Delta

Uncommon spring and rare fall migrant, fairly common summer visitant. The first observation was on 3 June of a pair feeding in Riparian habitat near camp and a pair was subsequently heard vocalizing in this vicinity on 6 June and 28 June. A pair was seen on 7 July in Flooded tundra 3 km northeast of camp. Single birds were seen or heard in Mosaic tundra on 12, 16, 17, and 24 June and in Wet Sedge on 20 June and 15 July. Migratory flocks were observed in the spring: 6 circling over Wet Sedge tundra on 6 June and 13 feeding in Flooded tundra on 7 June. In the fall a single migratory flock of 4 cranes was seen flying east on 15 August.

BLACK-BELLIED PLOVER

Aichilik

Uncommon spring migrant. Two black-bellied plovers were seen, 1 on 5 June and 1 on 8 June, upriver from camp approximately 2 km, in Riparian habitat.

Sadlerochit

Uncommon fall migrant. A single bird was seen feeding on the mudflat at the base of the spit at Anderson Point on 29 July, 1983. A flock of 6 and a flock of 12 flew over Moist Sedge-Shrub 6 km inland on 31 July, 1983. In 1984 single birds were observed on 7, 12, 13, and 14 August flying over Wet Sedge and feeding on gravel bars in Riparian habitat.

Jago Delta

Rare breeder and fall migrant. The first observation was on 3 June of 1 black-bellied plover in Riparian habitat near camp, with another sighting in this habitat on 8 June. The first documented black-bellied plover nest for the ANWR coastal plain was located in Flooded tundra, 2 km east of camp, on a low ridge 25 m from a pond. Three plovers were first observed in this vicinity on 14 June, and there were sightings of a pair or single bird in the area until 19 August. The nest was found 1 July with 4 eggs, pipping began on 11 July, and hatching occurred on 14 July. Back-dating (Harrison 1978) indicates a clutch initiation date of 14 June. Juveniles attended by the adult pair were observed on 14 August near the nest. Another nest was suspected 4 km south of camp in *Dryas* river terrace adjacent to the Jago River. A pair was observed there on 2 July and an adult with 3 downy young was seen on 13 August in nearby Wet Sedge habitat. Single flocks of 4-6 were seen flying eastward in fall migration on 8 and 20 August.

LESSER GOLDEN PLOVER

Aichilik

Common summer resident, fairly common breeder. Lesser golden plovers were seen in all habitats during 2 June - 19 August. Birds were in summer plumage on 2 June, and vocalizations, territorial confrontations and wing displays were observed during 2-9 June. Two nests with 4 eggs each were found on 25 June in Riparian plots. Two more nests, one with 4 eggs and the other with 3 eggs and 1 nestling, were found in that habitat on 6 July. With an incubation period of 27-28 days (Harrison 1978), incubation on the latter nest began around 9 June. This nest had 2 infertile eggs when rechecked on 13 July. One of the nests found on 25 June had hatched by 6 July; both the others had eggs on 13 July and had hatched when rechecked on 19 July. One of the nests found on 6 July had 4 young in the nest on 17 July. With a 27-28 day incubation (Harrison, 1978), this would mean incubation probably began around 20 June. Two nests with 4 eggs each were found in Tussock habitat on 28 June, and both had hatched by 10 July. Two nests with 4 eggs each were found in Moist Sedge habitat on 5 July, and by 17 July both had either some or all of their eggs hatched. A third nest, which had failed due to predation, was found in this habitat on 12 July. The first fledgling out of the nest was seen in Moist Sedge on 16 July. Two others were seen in Tussock habitat on 17 July. On 13 August, a pair of plovers was seen in Wet Sedge habitat with 2 fledglings that were still down-covered. Whereas most adults had begun molting in to winter plumage approximately 17 July, 1 of these adults was still in summer plumage. On 8 August, which proved to be just prior to a snowstorm accompanied by high westerly winds, large groups of both adult and juvenile plovers (up to 30 in a group) were seen sitting on the Dryas river terraces. Subsequently, only small groups of birds were seen, usually in Riparian habitats.

Sadlerochit

Fairly common breeder. Lesser golden-plovers were seen daily in the study area from crew arrival to departure (2 June to 19 August), in all habitats, but only rarely in Wet Sedge. They were generally seen as pairs or singles, standing and vocalizing, but there was a congregation of eight feeding on Riparian plot 593 on 18 June. Four nests were found; one in Riparian on 18 June, one in Tussock on 29 June, and two in Mosaic on 25 June and 3 July. All nests contained 4 eggs. The Riparian and Tussock nests were empty on 25 June and 9 July respectively, but their fate was unknown. The first Mosaic nest hatched on 20 July when 2 chicks and 1 egg were found in the nest. The second Mosaic nest had not yet hatched at this time, but was empty on 10 August. Additional nests were suspected in Mosaic and Moist Sedge-Shrub. Chicks were first seen 11 July with 2 adults near Anderson Point. Flightless chicks were observed in Mosaic and Riparian habitats through 14 August. Small flocks of 3-8 birds were observed flying east in late July and August.

Jago Delta

Fairly common breeder and common fall migrant. Small numbers of lesser golden-plovers were seen almost daily from 4 June to 20 August in all habitats. Pairs were seen in courtship display and chasing 8-13 June. Interaction with 2 caribou occurred on 17 June, with a pair performing aggressive distraction displays and leading the mammals away from a probable nest site in Moist Sedge-Shrub tundra. Three nests containing 4 eggs each were found on dry microsites in Moist Sedge-Shrub (24 June), Mosaic (28 June) and Wet Sedge (5 July). Distraction display was infrequently observed at the nests, with the incubating bird typically flushing unobtrusively, flying to a distance of 100 m, then sneaking back to the nest site. Feigning display was observed only at a nest with eggs near hatching. Pipped eggs were seen at one nest on 2 July and at another on 12 July. The first chicks out of the nest were seen with a pair of adults on 14 July in Wet Sedge but adults were defensive with chicks probably present in Riparian habitat from 4-12 July. The first flight capable juveniles were seen on 10 August in Riparian areas. Small post-breeding flocks (5-7 birds) were sighted in Dryas forb tundra on 16 July. Small migratory flocks largely comprised of juveniles were seen in all habitats 11-20 August with largest groups (10-20 plovers) present in Riparian and Wet Sedge habitats.

SEMIPALMATED PLOVER

Aichilik

Uncommon summer visitant. A single bird was in Riparian habitat near camp on 3 June. Another single bird was seen in Riparian habitat along the Aichilik river approximately 10 km southwest of camp on 30 June.

Jago Delta

Rare breeder. Most semipalmated plover sightings were of a pair which nested on a gravel bar near camp, first observed on 3 June. The nest with 4 eggs was found on 18 June. The adult was evasive until the nest site was found whereupon it conducted injury-feigning distraction display without any vocalizations. Hatching occurred on 29 June and back-dating (Harrison 1978) gave an estimated clutch completion date of 7 June. One chick was seen with an adult pair on a gravel bar at the edge of the Jago River on 8 July. Last sighting was of a defensive adult on 20 July.

SPOTTED SANDPIPER

Aichilik

Rare spring migrant. One bird was seen in Riparian habitat near camp on 5 June.

WHIMBREL

Aichilik

Uncommon summer visitant. On 25 June, a pair of whimbrels landed near camp in Riparian habitat, but remained only a short while. During 6-13 July, however, flocks were seen feeding in Tussock, Wet Sedge, and Moist Sedge-Shrub habitats. The largest of these flocks was 15 birds, and this period was probably the beginning of the migration to their wintering grounds. No whimbrels were seen after 13 July.

Sadlerochit

Rare summer visitant. Two whimbrels were seen on Moist Sedge-Shrub habitat, 6 km inland, on 9 July. One was flying and vocalizing along the bluff and over Wet Sedge habitat near camp on 20 July.

Jago Delta

Rare summer visitant. A flock of 3 whimbrels flew west over Flooded tundra 2.5 km east of camp on 19 July.

BAR-TAILED GODWIT

Sadlerochit

Rare spring migrant. A pair landed on a gravel bar on the Sadlerochit River near camp 11 June, and 1 godwit was seen standing in Moist Sedge-Shrub 15 June.

Jago Delta

Rare spring and fall migrant. A single bar-tailed godwit was observed flying over Flooded tundra 1.5 km east of camp on 12 June. One godwit was feeding in Wet Sedge tundra 1 km east of camp on 18 August.

RUDDY TURNSTONE

Aichilik

Common summer resident, fairly common breeder. Turnstones were seen in Riparian habitat (almost exclusively) during 3 June - 12 August. Vocalizations and territorial behavior were noted on 10 June, and 1 nest was found with 4 eggs on 18 June. The eggs were pipping on 25 June, and the young were out of the nest by 27 June. With a 21-23 day incubation period (Harrison 1978), incubation began approximately 3 June. The only observations of turnstones in a habitat other than Riparian were those of birds flying over the Dryas river terrace at camp.

Sadlerochit

Fairly common breeder. A ruddy turnstone was first observed 4 June flying and calling over a Mosaic plot, and turnstones were present in the study area until our departure 19 August. They were primarily observed in Riparian habitat, but one was observed in Moist Sedge-Shrub on 27 June. Two nests were found; one in Moist Sedge on the river bank had 4 eggs on 16 June but was empty on 23 June, possibly depredated; the second on a gravel bar by Riparian plot 593 had 4 eggs on 1 July but was empty on 6 July. Adults were very defensive and were observed chasing gulls and jaegers. Juveniles were observed in Riparian habitat on 16 July and 17 July, and only one was not flight-capable. Four juveniles were feeding on mud bars along the river on 13 August.

Jago Delta

Common breeder. Ruddy turnstones were observed daily from 2 June to 2 August, with greater nesting densities than have been recorded for other sites on ANWR, except possibly Canning Delta. Most sightings were in gravel bar or Dryas river terrace areas of Riparian habitats, although turnstones were less frequently sighted in Moist Sedge habitats adjacent to the river and in Mosaic tundra near the coast. Aerial display by a group of 3 turnstones was observed on 8 June. Defensive behavior suggesting presence of nests was seen on the earliest sighting. Distraction displays and vocalizations were usually performed at a nest site by the pair of turnstones, or occasionally the single incubating bird. On 13 June a turnstone which had been incubating flew into the shoulder of a biologist. Turnstones commonly chased jaegers and sandpipers from their nest sites. Eight turnstone nests were found between 10 and 23 June, all containing 4 eggs except one which held 3. The majority of nests were in Riparian habitat, placed in bare sand (1), gravel (2), partially vegetated Dryas terrace (2), and dwarf willows (2). A single nest was found in sedge, willow, and moss (Moist Sedge habitat) 50 m from the river bank. One nest was apparently abandoned on 16 June. The first nest with pipped eggs was seen on 22 June.Hatching was recorded on 23 June (2 nests), 25 June, 2 July, and 7 July. Back-dating from hatching (Harrison 1978) indicated estimated clutch completion dates ranging from 1-3 June to 13-15 June. Chicks attended by adults were seen 7-20 July in Riparian areas. A chick was eaten by a common raven 17 July. Many defensive pairs were observed in Mosaic habitat 4-5 km northeast of camp on 4 July, although nests or young were not revealed. Small flocks (3-7 birds) were observed from 17 July to 20 August in Riparian areas.

SEMIPALMATED SANDPIPER

Aichilik

Common summer resident, uncommon breeder. Semipalmated sandpipers were seen regularly during the summer in Riparian and Moist Sedge-Shrub habitats. Birds were seen on 1 occasion each in Tussock and Wet Sedge habitats, on 6 and 8

June, respectively. One nest with 4 eggs was found in Riparian plot 492 on 11 June. The adult used the "rodent-run" distraction display. On 27 June, this nest had 1 hatchling, 1 pipping egg, and 2 eggs. With a 17-19 day incubation period (Harrison 1978), incubation began around 9 June. All eggs had hatched, and the nestlings were gone, by 6 July. Several fledglings were found (in Riparian) on this date, still being protected by adults. A nest was suspected in Moist Sedge-Shrub habitat, but never located. On 7 August, groups of up to 10 birds were seen feeding in the fine mud that had recently been deposited by high water levels in Riparian Willow habitat. Only a few individuals were seen after that, and none after 12 August.

Sadlerochit

Common breeder. The first observation was on 3 June and thereafter semipalmated sandpipers were seen daily in the study area throughout June and July. They were observed primarily in Riparian, Mosaic, and Moist Sedge-Shrub, and rarely in Wet Sedge or Tussock habitats. Display flights were observed 5 through 15 June. There were 24 nests found between 8 and 29 June: 11 in Riparian habitat, 7 in Mosaic, 6 in Moist Sedge-Shrub. The highest density occurred on Riparian plot 593 with 8 nests in 10 ha. All nests had 4 eggs but 1 nest lost 1 egg mid-way through incubation. Based on back-dating from known hatching dates the majority of nests were initiated 5-9 June, considering a 17-19 day incubation period (Harrison 1978) commencing with laying of the third egg (Norton 1972). Five nests were initiated 10-1[illegible] June and 1 nest was initiated as late as 23 June. First hatching was observed 27 June, and all but 1 nest had hatched by 7 July. Newly hatched chicks from the late nest were observed on 15 July. Adults were vocal in defending nests and chicks. Many flight-capable juveniles were observed in Riparian habitat on 17 July. Small flocks of semipalmated sandpipers were observed beginning 3 July. In 1983 numerous flocks of up to 30 birds were seen flying and feeding along the coastal shoreline on 29 July. Semipalmated sandpipers were less numerous in August and were seen only in Riparian and coastal habitats, flying and feeding on mudflats, until crew departure on 19 August.

Jago Delta

Fairly common breeder and fall migrant. Semipalmated sandpipers were noted from 4 June to 19 August. They were equally common in all habitats until 6 July, when they were recorded primarily in Riparian and Flooded habitats. Courtship display flights were noted 4-12 June. Defensive alarm calling was noted when observers were at nest sites 14-28 June. Nine nests were found between 10 June and 2 July, all with 4 eggs except one which had 3 eggs. Nests were found in Wet Sedge (3), Mosaic (2), Moist Sedge-Shrub (2), Flooded (1) and coastal *Dryas*-forb (1). The first hatching was noted on 24 June with 2 chicks hatched in a nest in Moist Sedge-Shrub. Other known hatching dates were 1 July and 4 July, with pipped eggs in another on 2 July. Clutch completion dates ranged from 5-7 June to 16-18 June based on back-dating from hatching dates (Harrison 1978). Persistent brood calling by pairs and groups of pairs was observed 1-12 July with a single later example on 19 July, primarily in Riparian habitats. The first defended chicks were observed with adult pairs on 6 July in Riparian habitat at the edge of an old river channel pond. Occasional small flocks of semipalmated sandpipers (3-9 birds) were seen feeding on mudflat and wet sedge areas along the river 10-19 August.

WESTERN SANDPIPER

Sadlerochit

Rare fall migrant. Two were seen feeding on Riparian plot 591 on 17 August.

WHITE-RUMPED SANDPIPER

Sadlerochit

Rare fall migrant. One was seen feeding on a mud bar near Riparian plot 592 on 13 August. It vocalized once.

Jago Delta

Rare fall migrant. This species was not observed in 1984. In 1983 there was a single white-rumped sandpiper in Flooded tundra on 1 and 2 August.

BAIRD'S SANDPIPER

Aichilik

Uncommon spring migrant. Birds were seen in Riparian habitat on 6 and 11 June (1 and 2 birds, respectively). Three birds were seen in Wet Sedge habitat, in 3 separate observations, on 8 June.

Sadlerochit

Uncommon summer visitant. There were 5 sightings of 1-6 birds in June and early July on Riparian plots, and one along the coast on 15 June. A few were seen in late July 1983 in the same habitats.

Jago Delta

Uncommon summer visitant, probable breeder, and spring and fall migrant. Small numbers of Baird's sandpipers were observed from 2 June to 19 August in Riparian areas, primarily in mud along the river or old channel ponds and on gravel bars. Largest flocks (6-10 birds) were observed feeding along the river from 2-4 June. Aerial courtship display was observed on 3 June. It is probable that 3 pairs nested in Riparian habitat: 1 km south of camp, 1 km northeast of camp and 4 km north of camp. Defensive alarm calling and chasing by pairs in these areas was noted from 23 June to 5 July. Other sightings were made of pairs feeding together in these areas during this period. On 4 July a flock of 5 was seen with semipalmated, pectoral, and buff-breasted sandpipers on a barren sandy area of Jago delta 4 km north of camp. A flock of 7 fed on delta mudflats 4 km north of camp on 16 July. Small flocks (3-4 birds) were seen feeding along the river channel on 10, 12, and 19 August and one foraged with a flock of semipalmated sandpipers on 19 August.

PECTORAL SANDPIPER

Aichilik

Fairly common breeder. Observed in all habitat types during 2 June - 20 August, with nests found in Wet Sedge, Moist Sedge, Tussock, and Moist

Sedge-Shrub habitats. Male courtship vocalizations were heard during 2-11 June, and very infrequently after that. On both 19 and 27 June, single nests were found in Wet Sedge habitat. A nest was located in Moist Sedge on 24 June, and another in Moist Sedge-Shrub on 26 June. Two nests were found in Tussock habitat on 28 June. Each of these nests had 4 eggs being incubated. Also on 28 June, a nest was found with 3 hatchlings and 1 egg, in Tussock habitat. With a 21-23 day incubation period (Harrison 1978), incubation began approximately 6 June. This single egg proved to be infertile, a d was apparently the only pectoral egg found that did not hatch. During July groups of adults flocked together, acting defensively on Moist Sedge-Shrub, Tussock, Moist Sedge, and Wet Sedge habitat. On 9 and 14 July, fledglings were found in Riparian and Moist Sedge-Shrub habitat, respectively. Many small groups of 3-5 birds were seen during 7-9 August, feeding in the fine mud recently deposited by high water in Riparian Willow areas, and resting on Dryas Forb terraces. On 13 and 16 August groups of up to 11 birds were seen feeding in Moist Sedge-Shrub and Moist Sedge, respectively. On 17 August nly a few birds were noted in Riparian habitat.

Sadlerochit

Common breeder, and abundant fall migrant. Pectoral sandpipers were present in the study area from crew arrival until departure (2 June to 19 August), and were observed in all habitats. Male displays were most frequent over Wet Sedge 2-6 June, and some males were seen displaying until 16 June. Twelve nests were found in the study area between 9 and 29 June. Four nests were in Mosaic, four were in Wet Sedge, two in Moist Sedge-Shrub, and two in Tussock habitat. All nests had 4 eggs. Females were elusive, usually flushing at a considerable distance from the nest. Based on back-dating from known hatching dates, assuming a 21-23 day incubation period (Harrison 1978), most clutch completion dates were estimated between 4 and 10 June, with none later then 18 June. The first known hatching date was 28 June when 4 chicks were found in a nest on Wet Sedge, and all nests were empty by 5 July. Fl..ks of 10 or more birds began to appear around 5 July circling, vocalizing ,d resting on Wet Sedge, and defensive adults were common along the bluff edge through mid-July. In August, flocks including many juveniles were frequently observed in all habitats, but especially feeding along the river and on coastal Wet Sedge. The highest densities were observed in Wet Sedge on 15 August ($237/km^2$) and in Riparian on 18 August ($357/km^2$).

Jago Delta

Common breeder and abundant fall migrant. Pectoral sandpipers were common from 2 June to 19 August in all habitats. Male courtship displays were common 2-14 June in all habitats except Riparian, infrequent 17-21 June, and single displays were heard on 26 and 28 June. On 6 June half of the males were seen paired with females and the peak of courtship behavior (display flights , chasing and territorial behavior) occurred on this date. Pre-copulatory display and copulation was noted on 10 and 11 June. Males were most commonly seen in Wet Sedge and Flooded habitats from 17 June to 5 July, with small flocks of 6-10 males recorded on 26 June and 2 July. The last male was seen on 5 July.

The first nest was suspected 8 June due to female distraction-lure behavior. The first nest was found on 10 June, an earlier date than recorded for previous years of this study. One cold egg was found out of the nest 1.5 m away and 3 incubated eggs within it. Fox predation w s evident when this ne was subsequently relocated. Of 27 nests found between 10 June and 2 July the majority were in Mosaic habitat (17) with smaller numbers found in Flooded (2), Wet Sedge (2), and Moist Sedge-Shrub (2). Clutch size was 4 eggs for all nests except two which had 3 eggs. Clutch completion dates were 15 June based on sighting of an incomplete clutch; 15-17 June and 19-21 June based on back-dating from probable hatching dates assuming an incubation period of 21-23 days (Harrison 1978). Three nests were still being incubated on 16 July. First hatching may have occurred by 19 and 24 June when nests were found empty. Pipped eggs were noted on 2 and 5 July. Hatched young were observed with defensive females in the vicinity of nest sites on 28 June, 5 July, and 8 July. Female brood calling and defensive behavior was noted until 17 July. There was interspecific flocking by pectorals with phalaropes, stilt and semipalmated sandpipers, and long-billed dowitchers in defense of young primarily in Wet Sedge, Flooded, and Riparian habitats. Small flocks of females were seen flying over the wetter habitats 8-16 July.

Fall migratory flocks consisted of some small groups from 11-15 August and larger and greater numbers of flocks present 16-19 August. Pectoral sandpipers were more numerous in Riparian, Wet Sedge, and Flooded habitats during fall migration than during the breeding season.

DUNLIN

Sadlerochit

Uncommon summer visitant and common fall migrant. One dunlin was seen flying low over the coast on 6 June and two were seen feeding on Riparian plot 591 on 8 June. There were 2 sightings in July of a single bird feeding on a gravel bar near Riparian plot 593. On 7 August 2 dunlins flew and vocalized along the river 5 km south of camp. In 1983 2-3 dunlins were observed feeding along the river during the first week of August. In 1984 14-20 dunlins, mainly juveniles or molting adults, were observed feeding on mud and gravel bars of Riparian plots 591 and 592, from 13 to 18 August.

Jago Delta

Rare breeder and common fall migrant. Small numbers (1-9) of single and paired dunlins were seen almost daily from 8 June to 15 August and migrating flocks were seen 16-20 August. Dunlins were most commonly observed in Moist Sedge-Shrub, Mosaic, and Riparian habitats. Courtship flight displays peaked on 12 June, but were observed 6-20 June. Suspicious behavior suggested presence of a nest on 12 June. Three nests with 4 eggs each found on 26 June (2) and 28 June (1) represent the only verified dunlin nests found on the ANWR coastal plain east of the Canning Delta. Nests were located in flat sedge or dry centers of low-center polygons dominated by sedge (60-70%), willow (20-30%), and moss (10-20%). Two were in Mosaic habitat (one 5 km northeast of camp on a ridge, one 3 km east of camp near Flooded tundra) and one was in Moist Sedge-Shrub 5 km east of camp. Aerial and ground distraction displays were observed at nest sites. Two other nest sites were suspected based on presence of displaying and defensive adults in Flooded and Mosaic habitats 3-5 km from camp. At 2 nests which were relocated on 30 June and 2 July the incubating adult flushed from the observers when they were only 1-3 m from the nest. Hatching was observed in progress (3 chicks, 1 pipped egg) on 2 July and 9 July. A banded chick was observed with a pair of adults in Flooded tundra approximately 1 km from its nest site in Mosaic habitat on 14 July. A defensive pair in Riparian habitat was suspected to have been attending chicks on 15-16 July and 3 chicks were located on 17 and 19 July in the same vicinity. Small migratory flocks (6-10 mostly juvenile dunlin) were commonly observed in Riparian and less frequently in Wet Sedge habitats from 10-20 August. The peak of migratory activity was noted on 16 August when larger flocks with up to 60 dunlin fed in Riparian habitat , largely on Dryas river terraces, along stream channels, and at pond edges.

STILT SANDPIPER

Sadlerochit

Uncommon summer visitant. Two stilt sandpiper adults were feeding in a shallow pond near the bluff on 19 July, 1984. Four were feeding at the edge of the inlet at the base of Anderson Point on 29 July, 1983. Two were seen on 13 August and one on 14 August 1984, feeding in shallow water and on mudflats near Riparian plots 591 and 592.

Jago Delta

Uncommon breeder. Singles, pairs and small flocks were observed from 8 June to 18 August in Wet Sedge and Flooded tundra. Courtship flight displays and vocalizing were recorded 10-26 June. A nest was suspected on 8 June because of defensive adult behavior. One nest was found in the center of a low-center polygon in Wet Sedge tundra 2 km northeast of camp on 13 June. When this nest was checked on 20 and 27 June the incubating adult flushed at a distance of 1-3 m and a second adult circled observers with defensive alarm calls. The nest was found empty on 30 June, with chicks presumably hatched and in presence of defensive adults. Four other stilt sandpiper nests or broods were suspected in Flooded tundra based on behavioral observations from 30 June to 14 July. Flocks of up to 7 stilt sandpipers along with other species including pectoral sandpipers and phalaropes were seen in defensive behavior of probable chicks. The first flight capable chicks were attended by an adult in Flooded tundra on 16 July. The first independent young was seen feeding with pectoral sandpipers in Wet Sedge on 17 August. Other observations during the fall were of a single stilt sandpiper flying with a flock of dunlin (11 August), a flock of 5 stilt sandpipers flying low to the west (12 August) and one standing in Riparian habitat (18 August). In 1983 a flock of six was seen feeding in Riparian habitat (4 August) and a total of 16, which included a flock of 10, were recorded feeding in Wet Sedge habitat in early August.

BUFF-BREASTED SANDPIPER

Aichilik

Uncommon breeder. Single birds were first seen on 5 June feeding near small ponds in both Tussock and Moist Sedge-Shrub habitats. On 10 June, a single bird was seen feeding in Moist Sedge. Subsequent sightings were all in or very near Riparian habitat. A wing-display was seen on 11 June, and 2 nests (with 4 eggs each) were found in or near Riparian plot 492 on that day also. Both of these nests had eggs on 27 June, but were empty on 6 July. A third nest, with 4 eggs, was found in Riparian plot 493 on 18 June, in an area of Sedge-Dryas complex. This nest was believed to be unsuccessful due to avian predation when rechecked on 25 June. Two groups of 4 fledglings were found in Riparian plot 492 on 13 July. Subsequently, single birds were seen on 19 July and 14 August, in Riparian and Dryas Forb, respectively.

Sadlerochit

Uncommon summer visitant. Two were seen walking on Riparian plot 592 on 6 July 1984. Two were seen standing in Mosaic habitat on 2 August 1983. One was standing on Riparian plot 591 on 17 August 1984.

Jago Delta

Fairly common breeder. Singles or small flocks (2-9 birds) were seen almost daily from 5 June to 17 August, most frequently in Riparian habitat, but less often in Dryas- sedge tundra and Moist Sedge habitat near the river banks and in Moist Sedge-Shrub 3.5 km from the river.

Male courtship displays were observed 10-30 June. The peak of displaying occurred on 13 June at a lek in Wet Sedge 1 km northeast of camp with 5 males engaged in wing flap ground displays, aerial chasing and display , and pre-copulatory behavior with a single female. Less intense display activity was noted for 3-6 birds at a second lek located in Dryas-sedge and Riparian 2.5 km south of camp 10-25 June. From 18 June to 7 July sporadic and less concentrated displays by flocks of 2-7 birds were observed in Riparian habitat adjacent to the leks.

A nest was suspected on 5 June because of suspicious behavior of a female in Dryas-sedge tundra 1.5 km south of camp, but the nest was not located. Nests were later found at most sites where first sightings of single birds were made. Three nests containing 4 eggs each were found: one in Moist Sedge-Shrub (19 June); one in a dry area of Wet Sedge (28 June); and one in a Dryas- sedge area of Moist Sedge habitat (23 June). One nest may have hatched by 27 June when it was found empty. Hatching was seen at one nest on 10 July. Two chicks becoming feathered were attended by an adult in Riparian habitat on 17 July.

Flocks of 2-7 birds, which probably included some juveniles, foraged in Riparian areas, primarily Dryas terrace and gravel areas, 2-14 July. On 4 July mixed flocks with pectoral, semipalmated and Baird's sandpipers were noted in Riparian. Singles occasionally flushed from Mosaic, Wet Sedge and Riparian habitats 7-17 August. On 13 August small flocks (2-3 birds) were noted near camp in Riparian.

LONG-BILLED DOWITCHER

Aichilik

Fairly common summer resident, probable uncommon breeder. On 7 and 9 June, pairs were seen feeding and preening in Moist Sedge and Wet Sedge habitats, respectively. Subsequently, all sightings were in Moist Sedge-Shrub. Several birds were seen regularly on censuses in this habitat, and during late June and July dowitchers acted as if they had nests or young in the area. They would flock with pectoral sandpipers and circle the biologists, calling loudly. No dowitchers were seen after 20 July.

Sadlerochit

Uncommon breeder. Dowitchers were first observed on 4 June in Mosaic habitat. They were present in low numbers throughout June and July in Mosaic and Wet Sedge habitat, and were also seen feeding along the river. There was one sighting in Tussock habitat on 9 July. One nest was found on 13 June in Wet Sedge with 4 eggs. The first egg pipped on 28 June, and an adult was brooding 4 chicks near the nest on 30 June. Defensive adults indicated that other nests and chicks were probably present in Wet Sedge and Mosaic habitat. Small groups were seen flying around in early July. A few molting adults or juveniles were seen along the river and in Mosaic habitat in mid-August.

Jago Delta

Fairly common summer visitant and fall migrant, rare breeder. There were fairly frequent observations of singles, pairs, and small flocks (3-7 birds) from 5 June to 19 August, most commonly in Flooded tundra, but also in Wet Sedge and Mosaic habitats. Courtship displays were noted 5-12 June. No nests were found, but at least one was suspected in Wet Sedge 2.5 km southeast of camp. Pairs of adults conducted aerial displays and alarm calls and flocked with other shorebird species in defense of probable young in Flooded tundra 2-14 July. The first flight capable juvenile attended by a pair of adults was observed on 15 August, and 2 groups of 2 independent juveniles were seen on 16 August feeding in Moist Sedge.

Small migratory flocks (3-14 birds) were seen flying east on 30 June and 8 July. In August, flocks consisting largely of juveniles were commonly seen feeding in Flooded and Wet Sedge habitats. A large influx of flocks of 4-15 birds occurred on 18 August and continued through 19 August, the last field day.

COMMON SNIPE

Aichilik

Uncommon summer resident, probable uncommon breeder. Snipe were not seen as often as heard; their winnowing could be heard at camp from across the river, where they flew above the bluff, which was Tussock habitat. They were also regularly heard over Moist Sedge-Shrub. Vocalizations were heard during early June to early July. There were probably only a few birds in the area.

Sadlerochit

Rare possible breeder. A snipe was frequently heard winnowing over Mosaic habitat from 6 June to 5 July. There were sightings of single birds in Mosaic habitat on 15, 17, and 25 June and one in Wet Sedge on 27 June.

RED-NECKED PHALAROPE

Aichilik

Uncommon summer resident, probable rare breeder. Single pairs of red-necked phalaropes were seen in Wet Sedge and Riparian habitats on 5 and 6 June, respectively. Subsequent sightings in June (to 29 June) were usually in Moist Sedge-Shrub and Tussock habitats, with some in Riparian. No birds were seen in early July, but they were seen in Moist Sedge-Shrub during 14-20 July. Some of these birds acted as if they had nests or young. A single bird was seen on 10 August in Moist Sedge-Shrub.

Sadlerochit

Fairly common breeder. Red-necked phalaropes were first seen 5 June when two were swimming on a pond in Moist Sedge-Shrub. They were observed throughout the summer in all habitats except Tussock, with the last sighting on 15 August. Most observations were pairs and single males in early June. Groups of up to 7 females appeared in late June. Most observations were of birds flying and vocalizing or swimming and feeding on small ponds or the river. One nest was found on 27 June with a male incubating 4 eggs. The nest was empty by 7 July. Several other nests were suspected due to behavior of adult males 2-6 July on Mosaic habitat and ponds near the coast. A male was leading and brooding 4 chicks near a pond below the bluff 2 km south of camp on 9 July. Red-necked phalaropes were seen frequently in small groups throughout July on ponds in Mosaic and Wet Sedge and along the river near the coast. In 1983, many were seen feeding along the barrier island spit at Anderson Point on 28 July. They were less numerous in August, with only 8 individuals sighted in August 1984.

Jago Delta

Uncommon breeder, fairly common summer visitant. Singles, pairs and small flocks (3-15 birds) were observed from 5 June to 17 August, primarily in Flooded tundra, less frequently in Mosaic tundra, and rarely in Wet Sedge and Riparian areas. Pairs were observed from 5 June to 7 July, but males were more common after 16 June. The last observation of a female was on 7 July. Courtship behavior and aerial chasing by paired phalaropes were noted on 7 and 14 June. Only one nest was found, although the presence of others was evident by sightings of chicks. The nest was found on 17 June containing 4 eggs incubated by the male, and presumably hatched by 5 July when it was found empty. Defensive behavior was observed from 2-19 July by singles and flocks of 2-7 red-necked phalaropes, often mixed with red phalaropes, semipalmated, stilt and pectoral sandpipers, due to likely or confirmed presence of chicks. The first downy chick was observed in Flooded habitat on 5 July, and subsequent sightings of chicks were made on 11 and 16 July and 13 August in Flooded habitat and in the river. The first flight capable juvenile was still being defended by a male on 19 July in Flooded habitat. Greatest concentrations of defensive flocks and pairs were noted in an area of Mosaic habitat with pronounced micro-relief 3.5 km north of camp, near the coast, on 4 July. In the fall, flocks of 2-15 phalaropes fed in Flooded, Wet Sedge, Mosaic and a slow channel of the river.

RED PHALAROPE

Aichilik

Rare spring migrant. One pair of red phalaropes was seen on 6 June in a small pond in Moist Sedge-Shrub. Birds were in breeding plumage.

Sadlerochit

Uncommon summer visitant. Two pairs were observed, one on a pond and one sitting in sedge, on a Mosaic plot near the coast on 4 June. One flew over a Mosaic plot on 5 July, and two were observed on Mosaic plots on 8 July: one flying, swimming on ponds, and feeding with a group of 4 red-necked phalaropes, and one sitting on the tundra, vocalizing.

Jago Delta

Fairly common breeder. Red phalaropes were observed from 2 June to 16 August, primarily in Flooded tundra, but less frequently in Mosaic, Wet Sedge, and river channels. Pairs were noted 3-26 June, males were more often observed after 12 June, and the last female was sighted on 4 July . Of 7 nests found between 12 June and 11 July, 3 contained 3 eggs and the remainder had 4 eggs, and all were incubated by males. Most nests (6) were in Flooded tundra and 1 was in Mosaic habitat. The first chicks were seen on 28 June; 1 brood was attended by the adult out of the nest and another had just hatched in the nest. Pipped eggs were noted on 2 July and hatching occurred on 10 July at other nests. Other chicks were defended by males in Flooded tundra on 30 June and 11 July. Flocks of red phalaropes (2-10 birds), red-necked phalaropes, semipalmated sandpipers, and pectoral sandpipers defended probable chicks 4-16 July. The first independent flight capable juvenile was observed in Mosaic habitat on 14 August. A post-breeding flock of 7 birds flew east on 10 July. Red phalaropes were infrequently sighted in August; mostly singles (7, 14, 16 August) and one flock of 5 (15 August).

POMARINE JAEGER

Aichilik

Common spring migrant. Pomarine jaegers were seen during 2-18 June, over all habitat types. These birds were usually seen when caribou were present.

Sadlerochit

Fairly common spring migrant and rare summer visitant. There were daily sightings of 1-5 pomarine jaegers flying and hunting over all habitats throughout most of June, with the first sighting on 4 June and last on 26 June. A single pomarine jaeger flew over Moist Sedge-Shrub with a long-tailed jaeger on 14 July.

Jago Delta

Fairly common spring migrant. Pomarine jaegers were observed on most days from 2 June to 8 July. Singles or small flocks (3-14 birds) were most often seen flying in eastward migration from 5 - 15 June, and subsequently westward movement of 1 - 4 jaegers was recorded. Hunting occurred in Wet Sedge and Riparian habitats, with single jaegers occasionally chased by ruddy turnstones and once by a lesser golden-plover.

PARASITIC JAEGER

Aichilik

Uncommon summer resident, probable rare breeder. Small groups of jaegers (up to 4) could be seen in early June, usually over Moist Sedge-Shrub and Tussock habitats, though some were seen over Moist Sedge. On 19 July 3 birds (1 dark phase and 2 light), apparently a pair and a single, had an aggressive aerial interaction. The birds locked claws and tumbled to the ground. Throughout the rest of the summer, a pair consisting of 1 dark phase and 1 light phase were seen regularly in Moist Sedge-Shrub and Tussock habitats. On 8 August a single jaeger was seen hunting over Dryas Forb habitat, and a pair (presumably the same pair described above) was seen hunting over Moist Sedge on 15

August. This pair caught and killed a pectoral sandpiper in Moist Sedge-Shrub habitat on 18 August; this pectoral did not appear to be a juvenile.

Sadlerochit

Uncommon breeder. There were daily sightings of 1-4 parasitic jaegers flying and hunting over all habitats throughout the summer from 4 June to 19 August. Most sightings were of a light phase/dark phase pair which nested on a Wet Sedge plot near camp. An identical pair was defensive in the same area in early August 1983, but no nest or young were observed in that year. In 1984, the nest was found on 9 June with 2 eggs, although the pair had been observed in the area since 4 June. The pair was extremely defensive of the nest, becoming more aggressive as incubation progressed. They divebombed and danced on observers heads as they approached the nest. Occasionally they did a broken-wing act. They were also seen chasing pomarine, long-tailed, and other parasitic jaegers, glaucous gulls, a snowy owl, and a herd of caribou. They, in turn, were chased by ruddy turnstones when flying near the river. On 2 July a parasitic jaeger harassed an oldsquaw on her nest and she chased it away, but subsequently the oldsquaw eggs were eaten. Parasitic jaegers were seen chasing and eating numerous small birds, including Lapland longspurs, semipalmated sandpipers, and pectoral sandpipers. Both members of the parasitic jaeger pair were observed incubating their nest, and the first egg began hatching on 2 July. The chick was banded on 3 July. Hatching of the second egg was not observed, but the nest was empty on 8 July. The adults remained in the area, defensive but less aggressive, but young were not observed again until 12 August, when the flight-capable banded juvenile was seen with the light phase adult near camp. This juvenile was then seen daily, learning to hunt and to be aggressive, with one or both adults, until 17 August.

Jago Delta

Uncommon breeder, common summer visitant. Parasitic jaegers were observed daily from 5 June to 19 August in all habitats. Courtship display was noted for a pair of birds in Flooded tundra 3 km east of camp on 13 June. A nest containing 2 eggs was found at this site on 14 June. Dive-bombing by the pair of birds occurred during all visits to the nest. The nest was hatched by 8 July when it was found empty, with defensive adults still in the area. Flight capable juveniles were seen with an adult on 15 August in Flooded tundra 1.5 km from the nest site. A flock of 5 juveniles hunted in Riparian habitat on 18 August. Singles and small flocks observed hunting in Riparian habitat were frequently chased by ruddy turnstones. A shorebird was taken by a jaeger in this habitat on 19 August.

LONG-TAILED JAEGER

Aichilik

Common summer resident, fairly common breeder. Long-tailed jaegers were seen during 2 June - 20 August. During early June, pairs were seen hunting over Moist Sedge, Dryas river terraces and Riparian habitats. A nest with 2 eggs was found on 13 June, about 1 km west of camp on the moss mounds between Wet Sedge and Tussock habitats. The bird sitting on the nest was very protective. On 5 July, this nest had 1 pipping egg, and on 6 July there was 1 hatchling and 1 pipping egg. Using a 23-day incubation (Harrison 1978) for backdating, incubation began approximately 13 June. On 8 July both young were off the nest, but the actions of the adults indicated they were still in the area. A second nest, found on 4 July, contained 1 egg and 1 hatchling. This nest was also on a moss mound, and incubation began around 11 June. On 23 and 24 June, very large groups of jaegers were seen hunting over and loafing in Dryas Forb and Riparian habitats along the river. These groups had up to 20 birds, and may have been hunting newly hatched and/or fledged young in passerine and shorebird nests. These large groups were not observed during July, but during 6-8 August pairs and groups up to 5 were noted hunting over Wet Sedge, Moist Sedge, Dryas Forb, and Riparian. Throughout the summer, birds were mainly seen in these habitats, but were also seen (in lesser numbers) in Moist Sedge-Shrub and Tussock.

Sadlerochit

Uncommon breeder. There were daily sightings of 1-6 long-tailed jaegers flying and hunting over all habitats from 4 June to 19 August. A nest with 2 eggs was found on 14 June on a Tussock plot. This nest was empty on 9 July, when the adults were observed feeding a large chick about 100 m from the nest. A second nest was found containing 1 egg on 15 June, in Mosaic habitat near Anderson Point. This nest subsequently contained 2 eggs. The first egg was pipping on 8 July, but the first chick was not seen when the second egg was pipping on 10 July. One small chick was seen near the nest on 11 July. Each nest was attended by 2 adults, which were defensive but much less aggressive than the parasitic jaegers. Long-tailed jaegers were observed harassing ptarmigan and a snowy owl, and being chased by ruddy turnstones and a lesser golden-plover. On 26 June, a flock of about 25 long-tailed jaegers were observed circling over a musk-ox herd 2 km southeast of camp. An adult with a juvenile was seen flying over and standing on a Moist Sedge-Shrub plot on 19 August.

Jago Delta

Rare breeder, fairly common spring, summer and fall visitant. Singles, pairs, and occasionally small flocks (3-5 birds) were observed hunting or flying every few days from 4 June to 13 August. They were seen in all habitats, but long-tailed jaegers tended to occur more frequently in the drier types in contrast with the parasitic jaegers. A pair of long-tailed jaegers flushed a common eider from a nest on 8 July. One long-tailed jaeger nest was found on a Dryas terrace 15 km south of camp. The pair of adults fiercely defended the nest, which had 1 egg.

MEW GULL

Aichilik

Uncommon summer resident, probable rare breeder. First observation was on 7 June, when a single mew gull was seen mobbing a glaucous gull over the Aichilik river, approximately 2 km northeast of camp. Mew gulls were occasionally seen in this area during June and July, and on 6 July a bird was described as "acting parental" when biologists were in the area. It was believed to have had a nest on the gravel between river braids, east of plot 493. The last observation of a mew gull was on 17 July.

Sadlerochit

Rare summer visitant. Six were seen flying over the Sadlerochit River on 9

June, and one was flying over the ocean near Anderson Point on 3 July.

Jago Delta

Rare spring migrant. There were 3 sightings of mew gulls flying over Riparian areas: a flock of 4 on 2 June; 5 on 3 June; and 1 on 5 June.

HERRING GULL

Aichilik

Rare summer visitant. Herring gulls were seen only twice, first on 8 June when a single gull was seen sitting next to a glaucous gull on a gravel bar, and on 6 July when 1 gull was seen feeding and flying along the Aichilik, southeast of camp.

Sadlerochit

Rare summer visitant. One flew north over Anderson Point on 7 June 1984, and one flew south up the Sadlerochit River on 30 July 1983.

GLAUCOUS GULL

Aichilik

Uncommon summer resident. Glaucous gulls were regularly seen in low numbers along the Aichilik river near camp during 2 June - 20 August. The highest number of birds seen together was 4 observed on 7 and 8 August. Usually only 1 or 2 gulls were seen, and they were rarely seen outside Riparian habitat.

Sadlerochit

Fairly common summer resident, probable breeder. Glaucous gulls were present in the study area throughout the summer from 4 June to 18 August. They were observed flying over all habitats, but were most commonly observed along the river and coast. Flocks of 19 and 14 were seen flying east over camp on 4 and 5 June, a flock of at least 10 was seen near Mosaic plots on 10 June, and a flock of 10 flew east along the coast on 22 June. Many were seen flying, vocalizing, swimming, and standing on ice and on shoals in the ocean north of camp and near Anderson Point on 15 June, 3 July, and 16 July. Pairs were seen along the river and on gravel islands near its mouth behaving defensively on 1, 2, and 3 July, and 7 and 12 August, indicating possible nests or chicks. Glaucous gulls were observed fishing in the river on 26 June and 7 August.

Jago Delta

Uncommon breeder; common spring, summer and fall visitant. Daily observations of glaucous gull were made from 1 June to 10 August. Gulls were seen in flight over all habitats, but most commonly occurred in the wetter tundra types and Riparian areas. One nest containing 2 eggs was found on 12 June 4 km southeast of camp. Other evidence of breeding consisted of 2 downy chicks seen swimming in a pond 3 km north of camp on 11 July and one juvenile with 4 adults in a lake 3.5 km east of camp on 18 August.

SABINE'S GULL

Jago Delta

Rare spring migrant. There were 4 sightings of Sabine's gulls flying over Flooded tundra in early June: 2 on 5 June; singles on 5, 8 and 10 June.

ARCTIC TERN

Aichilik

Uncommon summer resident. Small numbers of terns, usually 1 or 2, were seen irregularly during the summer, from 8 June - 17 August. Almost all observations were of hunting birds over the Aichilik river. One tern was seen flying over a Tussock plot on 19 July. On 12 August, 2 flocks (of 8 and 5 birds) were seen flying north over Dryas Forb and Riparian, presumably migrating. The last observation was of a single bird hunting over the river on 17 August.

Sadlerochit

Uncommon summer resident, possible breeder. There were observations of 1-4 arctic terns seen frequently throughout June (first observed 2 June) and less frequently in July, usually flying and vocalizing over the Sadlerochit, or fishing in the river; occasionally along the coast or flying over Wet Sedge near the river. There were 2 sightings of terns sitting on gravel islands in the river, on 18 and 26 June, but no confirmed nests. The only August sightings were 1 tern fishing on the river on 13 August and 5 terns vocalizing and flying upriver on 14 August.

Jago Delta

Fairly common spring migrant, uncommon summer and fall migrant. Singles, pairs and small flocks (3-10 birds) were observed hunting and flying between 5 June and 13 August. Most sightings were over Flooded tundra. The largest flock (10 birds) was seen on 7 June, and terns were most common during the first half of June. A tern displayed defensive behavior in Flooded tundra 4 km northeast of camp on 12 June, but no nests were found in the study area.

BLACK GUILLEMOT

Sadlerochit

Casual summer visitant. Two black guillemots were seen standing at the tip of the barrier island spit at Anderson Point on 29 July 1983.

SNOWY OWL

Aichilik

Rare spring visitant. A single snowy owl was seen sitting in Wet Sedge habitat approximately 1 km southwest of camp on 4 June.

Sadlerochit

Rare summer visitant. On 7 June a snowy owl sat on the bluff above the Wet

Sedge plots; it flew south and was harassed by a parasitic jaeger. There were 2 sightings on 15 June, possibly the same bird, one in Tussock habitat 6 km southwest of camp, and one on a mound in Mosaic habitat 1 km west of camp. There were 3 sightings of a single bird on 6, 7, and 8 August, on Riparian and Mosaic habitat and sitting on the bluff near camp. This bird was harassed by parasitic jaegers. On 12 August a snowy owl was sitting on a tussock 3 km southwest of camp.

Jago Delta

Uncommon spring migrant and rare summer visitant. A single snowy owl was observed almost daily 2-13 June, usually standing on mounds or ridges within all habitat types. A single owl was seen on 2 July.

SHORT-EARED OWL

Aichilik

Rare spring visitant. A single short-eared owl was flushed off the ground in Moist Sedge-Shrub habitat on 12 June. The remains of what appeared to be a Lapland longspur were found where it was sitting.

Sadlerochit

Rare spring migrant. One flew east over Mosaic plots on 9 June, and one sitting on Riparian plot 593 on 11 June flew west.

BARN SWALLOW

Aichilik

Rare summer visitant. A single swallow was seen flying east over Moist Sedge habitat on 27 June.

COMMON RAVEN

Aichilik

Uncommon resident. Ravens were seen frequently in June and August, but in July were only noted on 9 and 10 July. Sightings were typically of lone birds flying, generally along the river. The largest group seen included 4 birds seen on 9 July. The first sighting was on 2 June, the last on 17 August.

Sadlerochit

Uncommon summer visitant. Ravens were seen regularly but not daily throughout the summer from 2 June to 19 August. Most sightings were of a single bird flying and vocalizing, but occasionally two were seen together, and a flock of 5 flew southwest over the Tussock plots on 14 June. Ravens were seen flying over all habitats, but most frequently over the river. One landed on the bluff near Moist Sedge-Shrub plots on 27 June and appeared to be eating an egg. Three ravens landed in Riparian willow on 13 August.

Jago Delta

Fairly common summer visitant. Singles or pairs were noted flying over all habitats on 6, 10, 13, 15, 19, 20, 24, 30 June; 9, 10, 12, 13, 16, 19 July;

and 14, 17, 20 August. Flocks were observed hunting in Riparian habitat: 6 on 6 July, 4 on 20 July. A raven which hunted in Riparian habitat was chased by ruddy turnstones on 9 July and one raven in a flock of 7 captured a ruddy turnstone chick on 17 July.

BLUETHROAT

Aichilik

Casual spring visitant. A single male bluethroat was seen Riparian Willow habitat (on plot 491) on 8 June. The bird flew up, singing, in what appeared to be a display. It moved northeast along the willows and river.

NORTHERN WHEATEAR

Aichilik

Casual fall migrant. A single adult in winter plumage (or a female in summer plumage) was seen at camp on 15 August, moving along the Riparian Willow from south to north.

AMERICAN ROBIN

Sadlerochit

Casual spring migrant. One flew south along the Sadlerochit River on 9 June.

VARIED THRUSH

Sadlerochit

Casual summer visitant. One was sitting on the shoreline bluff near Anderson Point on 29 July, 1983.

YELLOW WAGTAIL

Aichilik

Rare fall migrant. One juvenile wagtail was seen near camp on 15 August. The bird was feeding at river's edge and on the *Dryas* river terrace.

Sadlerochit

Uncommon probable breeder. Yellow wagtails were seen infrequently, but were suspected to be nesting in Riparian willow habitat upriver from camp. One female flew and vocalized over a Moist Sedge-Shrub plot near the river on 19 June. Defensive pairs of adults were seen flying and vocalizing over Riparian habitat upriver from camp on 1 and 4 July. Four flight capable young were seen on gravel bars in the middle of the Sadlerochit River on 17 July, near an island where a defensive pair of adults had been previously observed. There were sightings of 1-3 yellow wagtails on 7, 10, and 12 August, flying and vocalizing over the river near camp. Four juveniles were seen on Riparian plot 592 on 18 August, sitting, vocalizing, and flying among willows and on gravel bars.

Jago Delta

Rare fall migrant. No wagtails were observed in 1984. In 1983 a single wagtail was seen flying over Riparian habitat near camp on 5 August.

WILSON'S WARBLER

Sadlerochit

Casual fall migrant. A single female was observed flying and perching on willows in Riparian plot 593 on 7 August.

AMERICAN TREE SPARROW

Aichilik

Rare fall migrant. Two adults were seen on Riparian plot 491 on 17 August.

Sadlerochit

Casual fall migrant. A single bird was observed flying, perching on willows, and vocalizing in Riparian plot 593 on 17 August.

SAVANNAH SPARROW

Aichilik

Uncommon breeder. These birds were seen almost exclusively in Moist Sedge-Shrub, Riparian Willow, and Riparian habitats. The first observation of a savannah sparrow was on 6 June, and they were seen regularly through 16 July. A single male was seen feeding in Wet Sedge on 10 June. Only one nest was found, containing 6 eggs on 19 June, in Moist Sedge-Shrub habitat. This nest had 6 nestlings on both 26 and 29 June, and the young had fledged by 8 July. On 6 July, large fledglings were seen in willow thickets in Riparian. Adults were nearby and protective, and juveniles could fly well. The only bird seen in August was a single adult seen in Riparian willow on 17 August.

Sadlerochit

Fairly common breeder. The first Savannah sparrow was seen singing on a mound in Wet Sedge near camp on 5 June. Savannah sparrows were commonly seen in Riparian willow and Wet Sedge areas along the river and coast, and less commonly in Mosaic and Moist Sedge-Shrub habitat near the bluff edges. Males sang from conspicuous perches (such as plot stakes) throughout June, and one was singing on 8 July. Four nests were found 16 and 20 June, all well concealed in sedge clumps on the ground. Preferred nest sites appeared to be associated with dense willow-sedge vegetation on Wet Sedge plots or along the river. Nests were distinguished from Lapland longspur nests by the lack of feather lining. One nest with 4 eggs on 19 June was empty on 26 June, probably depredated. Two nests each with 5 eggs on 16 and 17 June had 4 and 3 downy chicks on 26 and 28 June, respectively. The remaining eggs in these nests did not hatch. The chicks had pinfeathers by 1 and 2 July and the 2 nests were empty on 6 and 8 July. The fourth nest had 6 eggs on 20 June, 6 large chicks on 28 June, and the nest was empty on 8 July. Based on a 12 day incubation (Harrison 1978), earliest nest initiation was probably around 4 June. Adults and fledlgings were seen and heard flying and vocalizing ("chipping") in Riparian and Wet Sedge throughout July, but the only observation in August was a pair on Riparian plot 593 flying, perching, vocalizing, and chasing longspurs on 17 August.

Jago Delta

Rare fall migrant. Savannah sparrows were not observed in 1984. A single bird was seen standing at the tide line of Tapkaurak Lagoon on 2 August 1983.

LAPLAND LONGSPUR

Aichilik

Abundant breeder. Longspurs were seen every day that biologists were present at this site during 2 June - 20 August. Nests were found in all habitat types. Eleven nests were found in Moist Sedge, 8 in Moist Sedge-Shrub, 7 in Tussock, 7 in Wet Sedge, and 3 in Riparian. Average clutch size for all nests (n=36) was 4.59 eggs. Eighty-six percent of the nests were successful. Courtship display flights were common when biologists arrived on 2 June, and decreased in frequency thereafter. The last display flight noted was on 28 June. The first nests were found on 9 June; 1 in Tussock-Dwarf Shrub and 1 in Wet Sedge. All nests visited during 9-17 June had eggs. The first hatchlings were found on 18 June, in Riparian habitat. The latest known hatching date was 5 July, in Moist Sedge habitat. During 20-29 June, most nests visited had nestlings. A few nests still contained young on 8, 12, and 14 July. Nestlings large enough to band were first found on 25 June in Riparian habitat. The first fledglings were seen in Dryas Forb habitat on 28 June. Male feeding groups, containing 2-7 birds, were noted during 21-24 June. By 6 July, most juveniles were flight-capable, and were found in willow thickets in Riparian habitat. Adults were still protective of these young, and these groups sometimes contained more than 10 adults and juveniles. Use of Riparian habitat by longspurs increased markedly after this date, with a commensurate decrease of use in all other habitats. Premigratory flocks of both adult and juvenile longspurs were noted throughout August. During 7-13 August, groups of up to 8 birds were seen in Riparian, Riparian Willow, Dryas Forb, and Moist-Sedge Shrub habitats. On 17 August, groups containing up to 16 birds were seen feeding in Riparian habitat.

Sadlerochit

Abundant breeder. Longspurs were present in all habitats throughout the observation period 2 June-19 August. In early to mid-June highest longspur densities were found in Moist Sedge-Shrub and Mosaic habitats(170-230/km^2). In late June to early July these were surpassed by longspur densities in Riparian habitat (227-253/km^2). In mid-July densities declined in all habitats except Riparian, where they remained high (187-217/km^2) through August. Male longspurs gave song and flight displays frequently 2-14 June and less frequently through 29 June.

A total of 44 nests were found 7-28 June: 12 in Moist Sedge-Shrub, 10 in Mosaic, 9 in Riparian, 8 in Wet Sedge, and 5 in Tussock habitat. Clutch size was 5 eggs for all but 7 nests. There were 6 nests with 4 eggs and 1 nest with 3 eggs: at least 4 of the nests with smaller clutch sizes may have been renest attempts as suggested by later than normal initiation dates (10, 14, 23, and 27 June). Based on 10-14 day incubation from last egg (Harrison 1978) the majority of nests were probably initiated 1-5 June and hatched 15-19

June. Excluding 3 nests abandoned or depredated before hatching, hatching success was 92%. Nests were most frequently located on the south side of a tussock mound, or polygon rim. Adults were frequently seen collecting food for nestlings 18-27 June. First fledglings were observed 27 June and were numerous through 19 July. Small flocks of longspurs, primarily juveniles, were seen flying around and feeding, especially in Riparian habitat, in August.

Jago Delta

Abundant breeder. Longspurs were present in all habitats from 2 June to 20 August. Male courtship displays were common from 2-10 June, with a peak in Mosaic on the latest date but earlier in other habitats. Courtship displays were infrequent from 12-30 June. Pairs were commonly seen together from 5-14 June. Copulation was observed on 10 June. Nest building by females was observed on 11 June (carrying grass) and 19 June (carrying white ptarmigan feather). Fifty-two nests were found from 5 June to 8 July in all habitats studied: 9 in Flooded; 13 in Wet Sedge; 16 in Mosaic; 12 in Moist Sedge-Shrub; 2 in Riparian which were in depressions in sprasely vegetated ground. The earliest clutch completion date was 1-4 June and the latest was 27 June based on back-dating (Harrison 1978) from known hatching dates. Nest initiation began earlier and occurred over a longer period than in previous years studied. Clutch sizes ranged from 2-6 with a mode of 5 and average of 4.6 eggs. Known hatching dates were from 14 June to 5 July and latest estimated date was 7-11 July. Outcome of nesting attempts for which information was available (n=39) was 90% successful (35 nests), 7% abandoned before hatching (3 nests), 3% depredated (1 nest). Hatching success of 132 eggs in nests with sufficient information available (and not abandoned or depredated) was 95%. The majority of nests had hatched by 17 June. The first young with feathers were seen in a nest on 21 June. The first independent young out of nests were seen on 26 June. By 27 June most nests had had fledged young. The first flight capable fledglings were seen on 30 June.

Post-breeding flocking by adults was seen in Flooded habitat on 2 July, and in Riparian on 7, 13, 17 July. From 6-20 August flocks of 5-100, consisting primarily of juveniles, were seen in all habitats.

SNOW BUNTING

Sadlerochit

Uncommon summer visitant, possible breeder. Pairs and small groups were seen along the coastal shoreline on 7, 15, 22 June and 1, 3, 19 July, 1984. Pairs and individuals were seen near the camp and on the Sadlerochit River on 11, 15, 16, and 19 June, 1984. At least 10 were observed 29 July 1983 along the coast and barrier island spit, and two were on the spit on 7 August 1983.

Jago Delta

Uncommon breeder and summer visitant. Most sightings were near the coast. The first observation was of 7 mostly paired, in *Dryas* - forb tundra on ocean bluffs on 16 June. A total of 5 pairs in Riparian habitat 1 km from the coast seen on 23 June constituted the highest count. A single bunting was observed singing and displaying in camp from 25 June to 3 July. Evidence of nesting was seen only in coastal sites: 3 adults and 1 juvenile on 4 July; a nest in a barrel on a sandy spit contained at least one chick on 16 July; a juvenile was observed in Mosaic habitat 1.5 km from the coast on 18 August.

REDPOLL

Aichilik

Fairly common breeder. Virtually all sightings of redpolls were in Riparian habitats. Exceptions were on 6 June, when pairs were seen in Moist Sedge-Shrub and Tussock habitats. The first nest was found on 3 June. It had 5 eggs and was in a low willow, approximately 15 cm above running meltwater. When rechecked on 5 June, the female did not flush. When rechecked on 11 June, the nest had been destroyed by predators. A second nest, found on 10 June, contained 4 very young hatchlings. On 17 June, these young birds were large enough to band and had primary flight feathers. The nest was empty on 24 June. On 11 June, a female was observed carrying nest materials to a nest. By 18 June the bird was incubating 5 eggs, and she did not flush on 25 June. On 6 July the nest contained 3 hatchlings large enough to band, and on 10 July the nest was empty. During early July groups of adults and juveniles were found in the willow thickets in Riparian habitat. Only 2 birds were seen in August; a juvenile in Riparian habitat on 15 August, and an adult in Riparian habitat on 17 August.

Sadlerochit

Uncommon breeder. Redpolls were first seen on 5 June when a small flock flew over Moist Sedge-Shrub, vocalizing. Redpolls were seen throughout the rest of June and until mid-July. They were seen occasionally flying and vocalizing in small groups over all habitats, but were most numerous in Riparian willow, where the most recorded in one census was 23 in 30 ha on 18 June. On this date they were observed flying in small groups of 3-5 birds and feeding on insects in the willow flowers. The pollen from the willow flowers had stained the upper breasts of some of the redpolls bright yellow. A nest was found 15 June in a dwarf willow near the Sadlerochit River, about 30 cm above the ground. It contained 5 eggs which were all hatched by 26 June. Five young were in the nest 29 June and 2 remained on 4 July, but at least one of these was flight capable. Another nest was found 30 June in the base of a dwarf willow on the bank of a river channel, with 2 eggs. the female was incubating on 6 July, but the nest containing 4 eggs was later abandoned. There were no sightings of redpolls after 16 July 1984, but in 1983 a flock of 5 was seen feeding in Moist Sedge Shrub on 30 July, and a flock of 25 was observed flying and feeding in Riparian on 3 August.

Jago Delta

Rare breeder. Redpolls were observed from 11 June to 15 July, usually flying over Riparian habitat 1-2 km from camp but infrequently over Moist Sedge-Shrub 4 km from camp. Most sightings were of single birds, but flocks of 3-4 redpolls were present on 11,17, and 26 June. Most sightings in Riparian were probably associated with one nest located approximately 1 km south of camp. The nest was in an erect willow (15 cm tall) on a sandy mound next to a river channel. It contained four young nearly ready to fledge on 7 July and was empty by 13 July.

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MICROTINES AND GROUND SQUIRRELS OF THE COASTAL PLAIN OF THE ARCTIC NATIONAL WILDLIFE REFUGE: NOTES ON DISTRIBUTIONS, DENSITIES, AND GENERAL ECOLOGY

Christopher A. Babcock

Key words: Microtine rodents, *Microtus miurus*, *Microtus oeconomus*, *Dicrostonyx torquatus*, *Spermophilus parryii*, *Lemmus sibericus*, population density, demography, habitat selection, predation, Arctic National Wildlife Refuge, north slope.

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Microtines and ground squirrels of the coastal plain of the Arctic National Wildlife Refuge: notes on distributions, densities, and general ecology.

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Abstract: A microtine rodent trapping survey was done at three locations across an altitude/coastal influence gradient in the Arctic National Wildlife Refuge from 31 May - 25 August 1984. Each location was trapped three times at monthly intervals. A similar trapping program was done in 1983. Densities of *Microtus oeconomus* decreased at the more inland study areas between years. *Dicrostonyx torquatus* and *Lemmus sibericus* species were more common towards the coast. *Microtus miurus* occurred only at the most inland study site. Analysis of raptor pellets indicated that *Dicrostonyx* and *Lemmus* populations at the two more coastal sites may cycle or fluctuate. These populations appear to be in the second consecutive low density year. Habitat selection and partitioning by microtines appears to occur at low densities. Distribution of arctic ground squirrels (*Spermophilus parryii*) depends primarily on suitable burrowing conditions and forage quality. Herbivory by, and predator use of microtines and ground squirrels suggests their integral importance in the arctic ecosystem.

Microtines and ground squirrels of the coastal plain of the Arctic National Wildlife Refuge: notes on distributions, densities, and general ecology.

Microtine rodents are extrmely important components of the tundra ecosystem as they may account for most of vertebrate herbivory on the tundra (Batizli et al. 1981) and are an important prey resource for a wide variety of predators. Arctic ground squirrels are also of considerable importance as prey animals as well as being interesting in terms of their habitat selection and population dynamics. The brown lemming (Lemmus sibericus), collared lemming (Dicrostonyx torquatus) and tundra vole (Microtus oeconomus) are the most common microtines of the coastal plain of the Arctic National Wildlife Refuge (ANWR). The singing vole (Microtus miurus) occurs primarily in the foothills and mountains, and the redbacked vole (Cleithrionomys rutilus) occurs only farther into the mountains at lower elevations (Bee and Hall 1956). Arctic ground squirrels occur throughout the ANWR and their distribution seems to correspond to that of permafrost free substrates suitable for burrows. The material presented in this report represents data from the second season (1984) of a two year study program, and also some comparisons with results from the first season (Babcock 1984). The objectives of the study were as follows:

1. Estimate the distributions and densities of ground squirrels and of all microtine rodent species occurring within the coastal plain of ANWR.

2. Determine habitat use and population dynamics of ground squirrels and microtine species.

3. Note predator use of microtines and ground squirrels.

Method and Materials

Study Areas

The second field season of the study was done from 31 May through 25 August 1984 and includes some information from and comparisons with the previous field season (2 June through 18 August 1983). The study sites were chosen to give a latitude/altitude transect across the coastal plain and to reflect differences between coastal and mountain influences. Transportation logistics also influenced site locations. The study sites were located on the Kongakut and Katakturak rivers and also near the Okpilak river delta (Fig. 1). Each study site was visited three times over the field season at approximately one month intervals; stays at each site lasted about ten days. See Babcock (1984) for detailed descriptions of study areas.

Microtine Trapping

In the first field season at each study site a live trapping grid was surveyed and staked using a compass and chain. Trap points were located a 10 m intervals on the 130 x 130 m grid, giving a total of 196 trap locations and a total grid area of approximately 2 ha. A large size (7.6 x 7.6 x 23 cm) folding Sherman live trap was placed near each grid point and was stuffed with indigenous vegetation as insulation. Traps were not baited. The grid was checked at 4-6 hr intervals (dependent on temperature and precipitation) for 5 days (120 hr). All captured animals were identified to species, sexed, weighed, and reproductive state/maturity was noted. Animals were marked using the toe clip method of Melchior and Iwen (1965). Each grid was run for a 5-day trapping period at monthly intervals for a total of three periods at each site. These grids were left marked over the winter and were used in the same way in the 1984 field season.

Opportunistic snap trapping was done at each visit to each site (using Museum Special traps) to collect stomachs for dietary analysis. The various microtine species were trapped in a variety of habitats in attempts to sample from a broad population of each species. Reproductive and demographic information was also gathered from snap trapped animals. Quantitative vegetation sampling was done in each habitat that was trapped.

Raptor and jaeger pellets were collected from the Katakturuk and Okpilak study areas during the 1983 and 1984 field seasons. The pellets were analyzed to aid estimates of the proportion of microtine species at these areas. Only skulls found in pellets were used, since the pellets were of variable age and condition.

Ground Squirrel Collecting

Squirrels were collected with a shotgun during each visit to each site, and reproductive, weight and age information was gathered. Squirrel stomachs were collected and stored in 80% ethanol for later dietary analysis. Squirrels were collected from the same specific area during each visit and quantitative vegetation sampling was done on the collecting areas.

Quantitative Vegetation Sampling

Vegetation was systematically sampled on each live trapping grid and also on areas where squirrels were collected and where snap trappings of microtines were done. A circular 0.25 m^2 quadrat was placed at regular intervals and all species occurring within the quadrat were assigned a cover class based on percent canopy cover. In 1983, vegetation was sampled at each point of the live trapping grids and these quadrat samples were arranged to refine the broad vegetation community type of the grid area into more narrowly defined microhabitat classes. These microhabitat classes on the grids were compared for indications of differential trapping success which would indicate microhabitat preferences of the microtines species.

On areas where snap trapping or squirrel collection was done, vegetation quadrats were placed at 10 m intervals along a transect and species cover classes were recorded. This information will be used to calculate an index of relative biomass of the plant species and in conjunction with diet analysis of the resident animals may give an indication of the food plant preferences of the different rodent species.

Results and Discussion

Microtine rodents of the north slope have been studied extensively at Barrow (Pitelka 1973, Batzli et al. 1981) and also at Atquasuk (Batzli and Jung 1980)

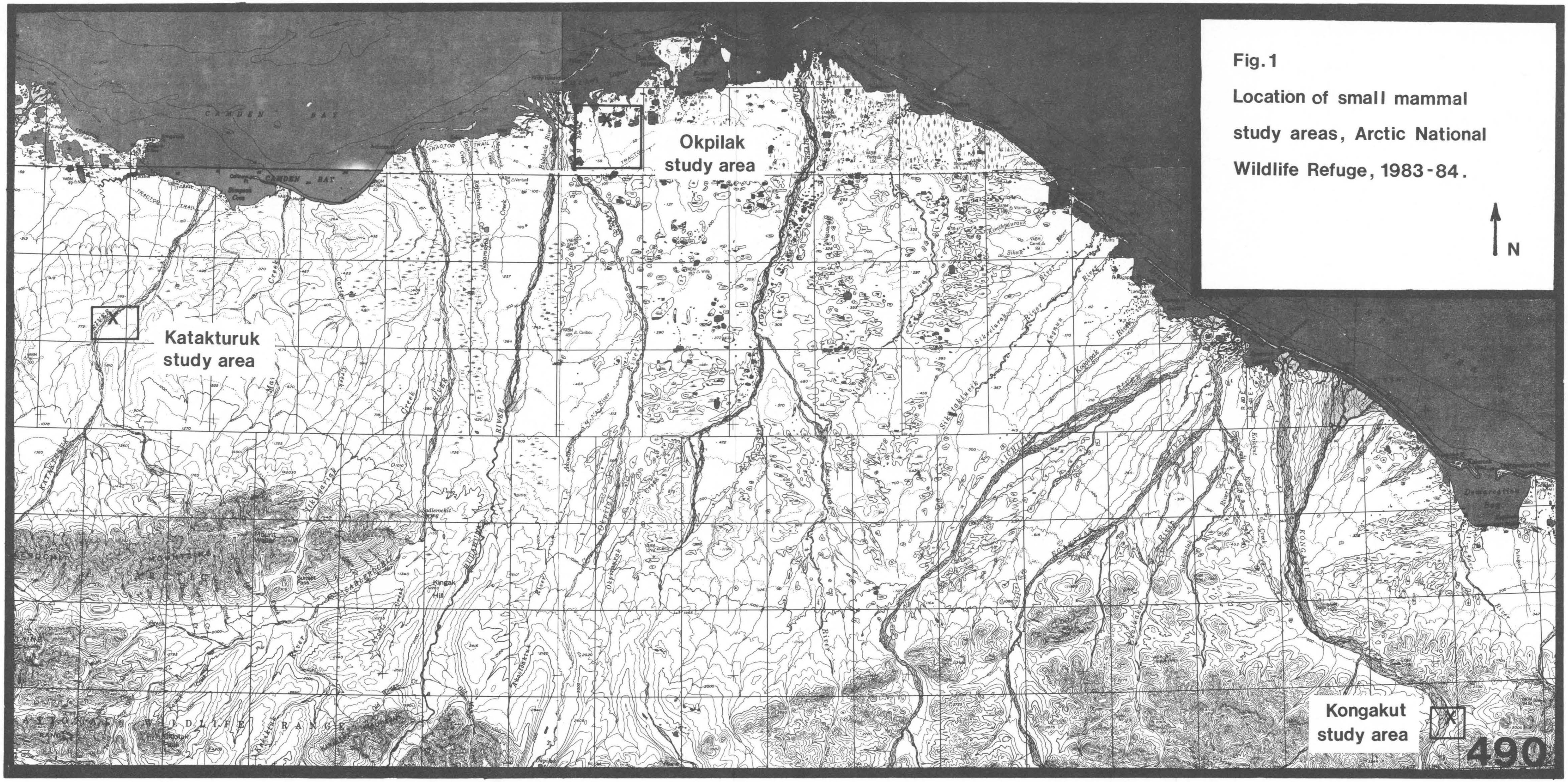

Fig. 1
Location of small mammal study areas, Arctic National Wildlife Refuge, 1983-84.

and Prudhoe Bay (Feist 1975). General distributions and ecological notes on microtines were recorded by Bee and Hall (1956). There are only a few detailed studies in the literature from other locations on the north slope. Some information on microtine species of the coastal plain of ANWR is summarized by Babcock (1984).

Four species of mircotines were captured over the 1984 season and approximate densities and habitat use relationships were calculated. The species differ widely in abundance both geographically and temporally. Captures on the live trap grids of all species of microtines combined were lower in 1984 compared to the capture success of 1983 (Table 1). The largest decrease in microtine density between the seasons was on the Kongakut grid where the 1983 high of about 15 trappable animals per ha declined to 1.5 trappable animals per ha.

Table 1. Number of captures for all microtine species on live trap grids in 1983 and 1984 seasons (Number of individuals in parentheses).

		Trapping Period		
Study Area	Year	1	2	3
Kongakut	1983	28 (19)	43 (20)	54 (31)
	1984	1 (1)	2 (2)	6 (3)
Kaktakturuk	1983	24 (12)	17 (12)	36 (19)
	1984	14 (5)	6 (3)	3 (2)
Okpilak	1983	8 (3)	16 (11)	4 (3)
	1984	3 (2)	6 (3)	6 (5)

On the Katakturuk gird, microtine density appeared to decrease across the 1984 season while at the coastal Okpilak grid densities remained fairly uniform across the season and between years (Table 1). Snap trapping in 1984 accumulated 1043 trap-nights at the Kongakut area, 699 at Katakturuk and 1082 at the Okpilak area yielding captures (for all microtine species combined) of 66, 45, and 114 respectively. For comparison, at Kongakut there were 0.63 captures and at Okpilak 1.11 captures per 10 trap-nights. Microtus oeconomus was the only species captured on the Katakturuk and Kongakut live trap grids in 1984, and this species was the most common both on and off the Okpilak grid. Only 2 Lemmus were captured on the Okpilak grid in 1984.

Microtus miurus (singing vole): This species was captured only at the Kongakut study area. It occurred commonly in restricted habitats and these habitats tended to be scattered throughout the area. M. miurus was found at higher elevations, especially ridge slopes that were moist, vegetated with shrub willows and forbs, and that had other than directly south facing aspects. In snap trapping transects down slope, M. miurus and M. oeconomus were trapped in distribution exclusive of each other, with M. miurus using only the upper slope and M. oeconomus only the more poorly drained, flatter and more sedge dominated end. Murie (1954, pp. 117-118) and others have noted that M. miurus collects vegetation in the fall and uses these food storage piles as a winter food resource. Several fresh storage piles were collected on 25 August from the Kongakut/Caribou Pass area. These piles appeared to be unfinished, and ranged in weight from 8 to 94 gm dry weight. Lupinus arcticus contributed most weight to the piles, followed by Hedysarum spp., and then shrubs (Salix spp.). Storage piles remaining from the previous winter were also noted to contain large proportions of Lupinus and other forbs. At Tulik Lake in the central Brooks range, M. miurus storage piles were seen to consist almost entirely of Equisetum spp. (Heikki Hentonnen, pers comm.). Densities of M. miurus appeared to be reduced from 1983 levels, dropping from 1.17 captures per 10 trap-nights to 0.62 captures per 10 trap-nights. Sex ratios of captured animals were even in 1983, but in 1984 the sex ratio was significantly skewed with 9 females and 2 males captured.

Microtus oeconomus (tundra vole): This species tends to use a broad variety of habitats and can be found in association with Lemmus and Dicrostonyx. Batzli and Jung (1980) have described M. oeconomus as a generalist herbivore where it occurs with these lemming species. Tundra voles do however tend to select forage from both woody dicotyledonous and graminoid plant groups. In 1984 highest densities of M. oeconomus were found in areas dominated by almost pure stands of Eriophorum angustifolium. In one such stand of sedges at a lake outflow area at Okpilak, densities were relatively high (1.65 captures per 10 trap-nights), perhaps due to the high nutritional quality of the vegetation in that specifc location. Abundant waterfowl fecal material collected at the lake outflow and appeared to be fertilizing the vegetation in the vicinity. In feeding trials with captive animals the below ground carbohydrate storing portions of the Eriophorum stems were consumed preferentially over the leaf and upper stem. M. oeconomus was trapped on all live trap girds and was collected in habitats away from the grids at each area. The 24 individuals trapped on all combined grids in 1984 had significantly skewed sex ratio of 20 males: 4 females, (x^2 =10.667, $0.001<P<0.005$). The 1983 sex ratio for 83 live trapped animals did not deviate significantly from even. A major factor probably contributing to this change in density and demography was the low accumulation of snow on the ANWR over the winter of 1983 - 1984. Light and patchy snow cover would tend to reduce the amount of protective and suitably insulated winter habitat, and winter mortality due to exposure and predation was likely to have been high. In 1984 there is evidence that the animals snap-trapped at Kongakut were subject to some nutritional stress compared to the animals from Okpilak. The litter sizes of snap trapped young of the year females were calculated by number of embryos or placental scars. Animals from Kongakut had significantly smaller litter sizes than those from Okpilak (Student t-test, one tailed; t = 5.30, $P<<0.001$). Stearns (1977) suggests that genetic, social and behavioral components, in addition to nutrition, may influence litter size in rodents.

Dicrostonyx torquatus (collared lemming): The collared lemming has been reported to have a dietary specialization for deciduous woody dicotyledons, especially Salix pulchra (Batzli and Jung 1980). Dicrostonyx were captured at all three study areas, but densities were low (probably less than two per ha) and appeared to be less than densities estimated from 1983 trapping.

Lemmus sibericus (brown lemming): The brown lemming has been studied extensively, with emphasis on cyclic changes in its population density. At Barrow, peak densities of up to 225 individuals per ha have been recorded, dropping to lows of 0.02 per ha with 3 to 6 years between peaks (Batzli et al. 1981). Causes for the cycle have been ascribed to climatic, nutritional (Schultz 1964, Pitelka 1973), predation (MacLean et al. 1974) and even endocrine, genetic, and social factors (Chitty 1967, Krebs et al. 1973). Clearly, no one factor is the driving force of this phenomenon, but all may contribute in varying degrees.

Relatively few Lemmus were captured or collected at Okpilak in 1983, but in 1984, 20 individuals were snap-trapped from the same Eriophorum stand at a lake outflow where hignest M. oeconomus desities occurred. Only 5 individuals were captured at Katakturuk in both seasons combined and none were seen or captured at Kongakut.

Microhabitat Selection by Microtines

Vegetation sampling was done on all three live trapping grids and sample quadrats corresponded to each grid point/trap location. This quantitative assessment of plant species presences and their cover class values was analyzed using a dichotomously branching sorting computer program (Cornell Ecology Program Series 1979). This program arranged the total set of samples for each grid into classes based on similarity of vegetation. This method provides a more objective classification of samples into microhabitat classes than could be done by inspection. On each grid, samples tended to be arranged across a moisture gradient, with more xerophyllic species groupings on one end and hydrophyllic species groupings on the other. The total set of samples from each grid was divisible into three or four microhabitats. These microhabitats exist as mosaics with xeric and hydric types often occurring in close proximity due to the poygonization of the tundra landscape. Since permafrost lies close to the soil surface, small changes in microtopography can strongly influence the amount of ground water available to plants. It should be realized that the microhabitat classes are based on continuum of samples, and the cut-off points between them are not totally distinct.

Microhabitats of the three live trap grids are characterized by the following plant species and conditions:

Kongakut

- hydric: Eriophorum angustifolium, Salix glauca, Carex aquatilis.
- mesic: Salix arctica, Arctostaphylos rubra, Cassiope tetragona.
- xeric: Dryas integrifolia, Tofieldia coccinea, Carex nardina, Lichen spp.

Katakturuk

- hydric: Eriophorum angustifolium, Carex aquatilis, Pedicularis verticillata, Carex saxatilis.
- mesic: Carex bigelowii, Salix reticulata.
- xeric: Saussurea angustifolia, Astragalus umbellatus, Hedysarum hedysaroides.

Okpilak

- hydric: Large sized Carex aquatilis and Eriophorum angustifolium, Eriophorum russeolum, Juncus biglumis; Polygon troughs.
- subhydric: Salix reticulata, Carex bigelowii, Carex misandra; polygon low centers and shallow troughs.
- subxeric: Salix pulchra, Polygonum viviparum, Carex bigelowii; rims of polygons.
- xeric: Cassiope tetragona, Saussarea angustifolia, Luzula spp., Lichen spp.; high polygon rims and mounds.

Using this assignment of each trap location into a microhabitat class it was possible to test for differential capture frequency between vegetation classes. There was significant selection of certain microhabitat classes over others on all grids though not in both seasons. On the Kongakut grid, where only *M. oeconomus* was captured, there was strong selection ($P<0.001$) for the hydric microhabitat in 1983, but no significant selection in 1984 (Table 2). The combined years showed strong selection as in 1983, and it may be that 1984 results are confounded by low sample size. At the Katakturuk grid, considering only *M. oeconomus*, there was no significant differential selection in 1983, but selection for wet (hydric) microhabitat was significant (0.010 P 0.025) in the 1984 season (Table 3). On the Okpilak grid in 1983, considering the combination of all microtine species, there was significant selection (0.001 P 0.005) for the dry microhabitats (xeric and subxeric; Table 4). In 1984, captures for all species showed no significant selection, although the combined years did ($0.025<P<0.05$). At Okpilak, when both years are combined and captures are broken down by species, there is significant selection of the dry mircrohabitats by *Dicrostonyx* ($0.005<P<0.0001$) and significant selection of the wetter microhabitats by *M. oeconomus* ($0.010<P<0.025$; Table 5). Captures of *Lemmus* were too few to calculate significance. Batzli and Jung (1980) suggest that the food habits of *M. oeconomus* may overlap with *Dicrostonyx*, but it appears that at Okpilak, with the densities seen in 1983 and 1984, this overlap may be insignificant and strong interspecific competition is probably avoided.

Table 2. Kongakut live trap grid, X^2 test of capture frequency in 3 microhabitat classes.

		Microhabitat Class (percent of grid area)			
		Wetter ⟵	⟶	Drier	
	Year	Hydric (31.1%)	Mesic (37.3%)	Xeric (31.6%)	Totals
Observed	1983	58	34	33	125
number of	1984	3	2	4	9
captures	combined	61	36	37	134
Expected	1983	38.91	46.55	39.54	125
number of	1984	2.80	3.35	2.85	9
captures	combined	41.70	49.90	42.63	134
X^2 test	1983	13.831 ($P<0.001$)			
Statistic*	1984	1.022 (not significant)			
(Significance)	combined	13.548 ($0.001<P<0.005$)			

*Critical level ($\hat{\alpha}$ = 0.05) = 5.991 with 2 degrees of freedom.

Table 3. Katakturuk live trap grid, X^2 test of capture frequency (*M. oeconomus* only) in 3 microhabitat classes.

	Year	Microhabitat Class (percent of grid area) Wetter ⟷ Drier: Hydric (12.8%)	Mesic (52.0%)	Xeric (35.2%)	Totals
Observed number of captures	1983	12	37	25	74
	1984	8	10	6	24
	combined	20	47	31	98
Expected number of captures	1983	9.44	38.51	26.05	74
	1984	3.06	12.49	8.45	24
	combined	12.50	51.00	34.50	98
X^2 test Statistic* (Significance)	1983	0.794 (not significant)			
	1984	9.182 ($0.010<P<0.025$)			
	combined	5.169 (not significant))			

*Critical level (α = 0.05) = 5.991 with 2 degrees of freedom.

Table 4. Okpilak live trap grid, X^2 test of capture frequency (for all species combined) in 4 microhabitat classes.

	Year	Microhabitat Class (percent of grid area) Wetter ⟷ Drier: Hydric (24.0%)	Subhydric (25.5%)	Subxeric (34.2%)	Xeric (16.3%)	Totals
Observed number of captures	1983	5	5	6	12	28
	1984	7	2	4	1	14
	combined	12	7	10	13	42
Expected number of captures	1983	6.71	7.14	9.57	4.57	28
	1984	3.36	3.57	4.79	2.29	14
	combined	10.07	10.71	14.36	6.86	42
X^2 test statistic* (significance)	1983	14.480 ($0.001<P<0.005$)				
	1984	5.491 (not significant)				
	combined	8.474 ($0.025<P<0.05$)				

*Critical level (α = 0.05) = 7.815 with 3 degrees of freedom.

Table 5. Okpilak live trap grid, X^2 test of capture frequency by species (both seasons combined) in 4 microhabitat classes.

	Species	Microhabitat Class (percent of grid area) Wetter ⟵ Hydric (24.0%)	Subhydric (25.5%)	Subxeric (34.2%)	⟶ Drier Xeric (16.3%)	Totals
Observed number of captures	Dicrostonyx	2	4	3	8	17
	M. oeconomus	10	1	5	5	21
	Lemmus	0	2	2	0	4
	All species	12	7	10	13	42
Expected number of captures	Dicrostonyx	4.08	4.34	5.81	2.78	17
	M. oeconumus	5.04	5.36	7.18	3.43	21
	Lemmus	not enough captures to perform valid test				4
	All species	10.07	10.71	14.36	16.86	42
X^2 test statistic* (significance)	Dicrostonyx	12.248 ($0.005<P<0.001$)				
	M. oeconomus	9.808 ($0.010<P<0.025$)				
	All species	8.474 ($0.025<P<0.050$)				

*Critical level ($\alpha=0.05$) = 7.815 with 3 degrees of freedom.

Predator Use of Microtines

Microtines are prey for all mammalian predators of ANWR and they are primary prey of short-tailed weasels (*Mustela erminea*) and least weasels (*Mustela nivalis*). Weasel predation may contribute to the cyclic densities fluctuations of lemmings by accelerating mortality in the crash phase of the cycle (MacLean et al. 1974). Most of this predation appears to occur in winter. One short tailed weasel was captured on the Okpilak grid in 1983 and two least weasels were captured in the Kongakut area in 1984. At each study area recent winter nests were examined for evidence of predation. Depredated nests contain fur, bones and often stomachs of animals that were preyed upon within the nest, and usually the nest has been lined with microtine fur as additional insulation by the weasel. The Okpilak area had the highest incidence of nest predation, followed by Kongakut and Katakturuk (Table 6). The actual incidence of predation is probably somewhat higher, since microtines build new nests through the winter as old ones are fouled.

Table 6. Microtine winter nest predation at 3 study areas in 1984.

Study Area	Total Nests Examined	Nests Disrupted by Predation: Number	%
Kongakut	37	5	13.5
Katakturuk	29	2	6.9
Okpilak	74	18	24.3
All combined	140	25	17.9

Microtines are also of considerable importance to avian predators in the ANWR, most notably snowy owls (*Nyctea scandica*) and jaegers (*Stercorarius* spp.). At Barrow and other northern Alaskan locations breeding densities and fledging success of snowy owls and jaegers have been reported to increase with increases in microtine densities (Maher 1970, Maher 1974, Pitelka 1974). Clutch size of rough legged hawks also appears to be related to availability of microtines (Harrison 1978, p. 91). Only one snowy owl was seen in each season at the Okpilak area, although they were a common visitant and were seen hunting there in 1982 (Spindler and Miller 1983). A pair of rough legged hawks nested on the Katakturuk bluff in 1983, laying three eggs (two chicks were surviving on 10 August) and in 1984 one chick was in the nest on 12 July but was not seen on 11 August. Jaegers nested at both Okpilak and Katakturuk in both seasons. Raptor and jaeger pellets were collected from the Okpilak and Katakturuk areas in 1983 and 1984. Proportions of *Lemmus* and *Dicrostonyx* skulls in pellets from the two areas were not significantly different, but the proportion of *M. oeconomus* skulls was significantly higher ($P<0.001$) at Katakturuk (Table 7). *M. oeconomus* comprised only 2% of skulls from Okpilak, but 18% from Katakturk, although the impression from two seasons of trapping was that lemmings were outnumbered by *M. oeconomus* at both sites. The inference that can be drawn from these data is that most avian predation occurs when populations of lemmings are high relative to *M. oeconomus* and that the lemming populations at Okpilak and Katakturuk are cyclic or at least fluctuate widely in density.

Table 7. Chi square contingency table comparing proportions of *Lemmus*, *Dicrostonyx*, and *M. oeconomus* skulls in raptor and jaeger pellets from the Okpilak and Katakturuk study areas.

Study area	*Lemmus*	*Dicrostonyx*	*M. oeconumus*	Totals
Okpilak 1983				
Observed	51	100	3	154
Expected	48.95	89.75	15.30	
X^2 value	0.086	1.171	9.888	
Katakturuk 1983 & 1984				
Observed	45	76	27	148
Expected	47.05	86.25	14.70	
X^2 value	0.890	1.218	10.292	
Totals	96	176	30	302
Totals X^2	0.175	2.389	20.180	22.744
(Significance)	(n.s.)	(n.s.)	(P 0.001)	(P 0.001)

X^2 test statistic critical value = 5.991 with 2 degrees of freedom, ($P<0.001$).

Ground Squirrels

Spermophilus parryii (arctic ground squirrel) were collected in 1984 from all three study areas. Stomachs were preserved for analysis of diet and comparison of diets with estimates of plant species biomasses from the collection areas. At the Kongakut area squirrels lived in extensive colonies on the river bluffs and in rock outcrops at higher elevations. The Katakturuk and Okpilak colonies were limited to river bluffs and dunes. The sex ratios of collected animals were not significantly different from even at all areas. The mean weight of squirrels from Kongakut was 725g, Katakturuk 500g, and Okpkilak 667g. Although these weights are statistically different, the difference is probably not valid because of sampling bias towards smaller (young of the year) individuals later in the season. Young of the year began to disperse from their natal colonies (Carl 1971) about 1 July at Kongakut, and on 11 August the first animals were seen across the river from the Katakturuk bluff colonies. At Okpilak on 17 August and subsequent days a squirrel was seen on the VABM Mars pingo, at least 4 km from the nearest perennial colony. A few observations of feeding squirrels were made at each area, and in all cases the chosen forage was forbs and other herbaceous plants or plant parts.

Grizzly bears (Ursus arctos) were seen digging in squirrel colonies at Kongakut and Okpilak in 1984, and in both cases bears appeared to have achieved success in catching squirrels. Evidence of grizzly predation on the Katakturuk colonies was also common in August. All large raptors are known to take ground squirrels and golden eagle (at Kongakut) and rough legged hawks (at Katakturuk and Kongakut) were seen hunting over colonies throughout the season.

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DISTRIBUTION AND ABUNDANCE OF WOLVERINES IN THE NORTHERN PORTION OF THE ARCTIC NATIONAL WILDLIFE REFUGE

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Key Words: Wolverine, distribution, abundance, food habits, habitat use, Arctic National Wildlife Refuge, Arctic-Beaufort

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Distribution and abundance of wolverines in the northern portion of the Arctic National Wildlife Refuge.

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Abstract:
Preliminary investigations of wolverines (Gulo gulo) associated with the northern part of the Arctic National Wildlife Refuge were initiated in 1984. Objectives and methods for short and long range study are discussed. A total of 11 observations of wolverines were reported in the area during 1984. Single wolverines were observed feeding on a caribou (Rangifer tarandus) and on a brown bear (Ursus arctos) carcass. One wolverine was observed catching and killing a ground squirrel (Citellus parryi). Locations of reported wolverine observations indicate that the species probably occurs throughout the study area; however, due to the small number of observations it is not possible to determine relative importance of one area over another. Considerable effort was expended conducting aerial searches during March, April and June, 1984 for purposes of capture/marking studies, however, no wolverines were found. Aerial surveys for identification and mapping of wolverine tracks/trail systems were tested on 19 and 20 April. Only a restricted area of the southern foothills and northern mountain border contained adequate snow conditions supportive of track surveys. The remainder of the study area contained hard-wind packed snow cover making it difficult to identify wolverine tracks from the air. One wolverine track system measured about 12.8 km long, and included two excavations that contained remnants of caribou calf carcasses. Another wolverine track system measuring 24.8 km was also found. Snowmobile tracks/trails were found in association with one wolverine track, however, it was not possible to determine if hunting was involved. One adult male wolverine was killed by Kaktovik residents using snowmobiles on 2 May 1984 in the southern foothills region. In spite of rather intensive aerial surveys in the study area associated with this study and corresponding wildlife studies, the low number of wolverines observed suggests that the density of wolverines may be less than other areas in arctic Alaska.

Distribution and abundance of wolverines in the northern portion of the Arctic National Wildlife Refuge.

Wolverines (Gulo gulo) are circumpolar in distribution, inhabiting the remote northern coniferous forest and tundra regions of North America and Eurasia. Throughout its distribution, the wolverine is noted for its avoidance of humans, solitary, wide-ranging nature, and sparse densities. These characteristics make the wolverine difficult to study and consequently few ecological studies of the wolverine have been completed.

The wolverine is the largest terrestrial member of the weasel family (Mustelidae). Adult males weigh up to 20.0 kg (average weight for males is about 13.0 kg.), while females average about 9.6 kg. (Rausch and Pearson 1972). Wolverines are noted for their stocky body build and powerful musculature. Tooth structure and composition indicate that the wolverine has evolved primarily as a scavenger, although it functions as a predator as well.

Adult wolverines usually breed in late spring and early summer (Rausch and Pearson 1972). Magoun (In prep.) observed adult wolverines breeding in early June in northwest Alaska. Rausch and Pearson (1972) reported that some female wolverines mature at about one year of age and produce their first litters when they are 2-years old. In northwest Alaska, Magoun (In prep.) observed a young female wolverine (17 or 29 mo. old) breeding in early August; however, no young were produced. Following breeding, the embryos are not implanted until during winter. The average litter size (based on fetuses recovered from carcasses) for 54 Alaskan and Yukon wolverines was 3.5 (Rausch and Pearson 1972). Only 1.8 young/litter based on four observations of 2-3 month old kits with maternal females) were recorded by Magoun (In prep.) in northwest Alaska. The average reproductivity rate of marked wolverines during a four year study in northwest Alaska was 0.7 kits/mature female/year (Magoun In prep).

Young wolverines are born in snow dens during late winter (early March in northwest Alaska) (Magoun 1979). They grow rapidly and usually are able to move out of the den within a month (Magoun In prep.). By fall the young wolverines are nearly full-grown. Based on a limited number of relocations of radio-collared animals in northwest Alaska, it appears that young wolverines disperse from their mothers during the period of January-May (Magoun In prep.).

Food habits of the wolverine reflect an opportunistic feeding behavior. Wolverines have been reported killing large ungulates such as caribou (Rangifer tarandus), moose (Alces alces) and Dall sheep (Ovis dalli)(Burkholder 1962, Haglund 1974, Gill 1978). It is generally thought, however, that in Alaska the wolverine is more often a scavenger than a predator of large ungulates (Rausch and Pearson 1972). Magoun (In prep.) found that food items in the wolverines diet in northwest Alaska varied with season. Arctic ground squirrels (Citellus parryi) were an important food item throughout most of the year. Caribou were utilized in May and June when large numbers were in the study area. During June and July, wolverines also prey on birds and eggs in nests. An important winter food for wolverines in the tundra environment appears to be ground squirrels that are cached during the fall or excavated from their hibernacula (Magoun In prep.). In mixed tundra and boreal forest environments in southcentral Alaska, wolverines fed mostly on ungulate carrion (primarily moose) during winter, and demonstrated little reliance on cached food resources (Gardner In prep).

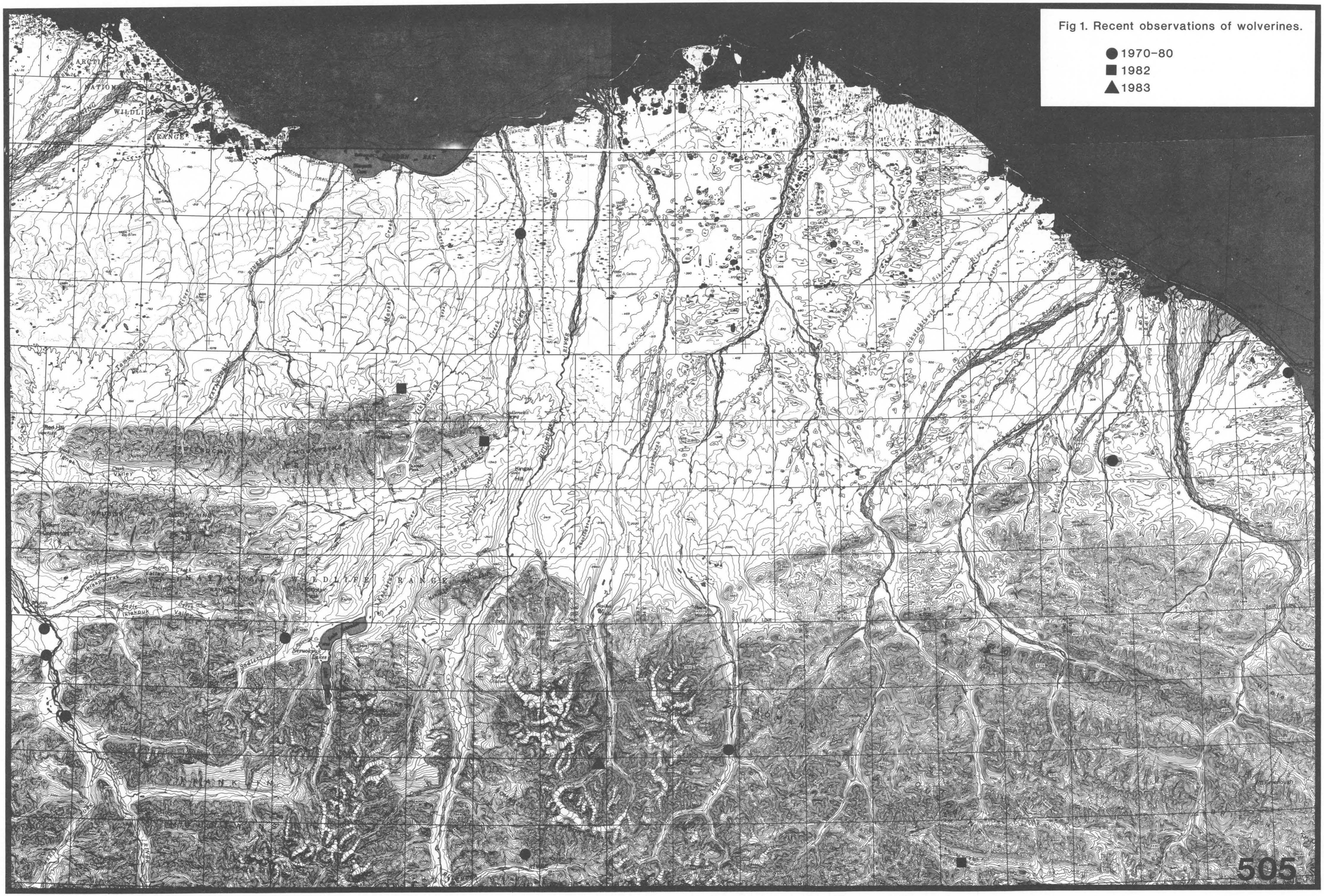
An intensive study of an essentially unharvested population of wolverines in northwest Alaska estimated fall wolverine densities of 1/55 km^2 - 1/74 km^2 in an arctic foothills area (Magoun In Prep). Other reported wolverine densities include 1/65 km^2 in northwestern Montana (Hornocker and Hash 1981) and 1/76 km^2 - 1/143 km^2 in southcentral Alaska (Gardner and Ballard 1983). In northwestern Alaska, the home ranges of male wolverines were considerably larger than those of females and overlapped several female home ranges (Magoun In Prep.) The average annual home range size was 115 km^2 for females and 666 km^2 for males (Magoun In prep.). Lactating females to range over a much reduced area during March and April when young are born and reared.

Based on observations and tracks noted during studies, it is apparent that wolverines frequent all types of terrain found in arctic areas (Quimby and Snarski 1974, Magoun In prep). Features such as rivers and mountains do not inhibit wolverine movements but are frequently associated with territory boundaries (Magoun per. comm.). Snow drifts are important habitat for wolverine den sites (Pulliainen 1968, Magoun In Prep.). In the tundra environment, remnant snow drifts in small drainages with associated meltwater caverns were an important rearing habitat used by maternal females and their offspring (Magoun In Prep.). In northwest Alaska, females with young inhabited three general habitat types (Tussock meadows, vegetated upland tundra, and bare hilltops) 70% of the time. The amount each type was used seemed to depend on the specific setting of each individual territory and the season of the year (Magoun In prep.). In southcentral Alaska radio-collared wolverines demonstrated seasonal habitat preferences (tundra environments during summer and open spruce forest areas during winter), which was probably related to food availability factors (Gardner and Ballard 1983).

Although wolverines are known to inhabit the coastal plain of the Arctic National Wildlife Refuge (ANWR) little is known about their abundance, distribution, movements, home ranges, food habits, or other ecological relationships (U.S. Fish and Wildlife Service 1982). Records of wolverine sightings for the area are sparse. During extensive biological field studies in the early 1970's, only 26 wolverine sightings were recorded in northeastern Alaska, 10 of which occurred north of the continental divide with 1 observation occuring within the coastal plain of ANWR (Quimby 1974, Quimby and Snarski 1974). Recent ongoing biological field studies on the ANWR coastal plain have also resulted in few incidental wolverine sightings. Recent reported wolverine sightings in northeast Alaska are shown in Fig. 1.

Records of wolverine pelts sealed by the Alaska Department of Fish and Game (ADF&G) indicate that an average of about one wolverine per year is harvested from the refuge coastal plain area (USFWS 1982). This figure may actually be higher, however, due to incomplete reporting (Magoun In Prep). Wolverines are occasionally harvested by trappers having traplines near the village of Kaktovik. Sealing records indicate that these animals are mostly sub-adults which may be dispersing on to the coastal plain from the foothills region to the south. According to Jacobson and Wentworth (1982), Kaktovik residents harvested six wolverines in 1979 and seven in 1980. The areas most frequently hunted for wolverines by Kaktovik residents are the foothills and northern mountain areas of the Sadlerochit, Hulahula, and Okpilak River drainages

Fig 1. Recent observations of wolverines.



(Jacobson and Wentworth 1982). These particular areas are also frequently used for other winter subsistence activities such as fishing (Hulahula River), ground squirrel trapping, and hunting for caribou, Dall sheep and wolves (Jacobson and Wentworth 1982). Without further investigation it is not possible to determine if wolverines are more abundant in the preferred hunting areas because potential wolverine food resources (caribou, Dall sheep, ground squirrels) are also abundant in these areas (Magoun In Prep), or if the higher harvest level of wolverines from these areas is merely a function of hunter effort associated with other hunting endeavors.

The relationship between wolverines of the northern portion of ANWR and food resources such as the Porcupine caribou herd are not known. Understanding these and other relationships are essential to assess potential impacts of oil and gas development in ANWR. Furthermore, since there has been no systematic inventory of wolverine abundance, distribution, habitat use, or movement patterns in the ANWR, assessments of impacts cannot be made.

The following study objectives were developed to address information needs relative to wolverines associated with the northern portion of the ANWR and legislative mandates for wolverine studies.

Short Term Objectives:

1) Determine the feasibility of aerial survey techniques to measure wolverine distribution and abundance.

   a) Design a survey strategy which optimizes collection of conclusive data with respect to basic assumptions about wolverine home range size, activity, and movement patterns.

   b) Test and evaluate the survey technique under field conditions in the study area.

2) Initiate radio telemetry studies of up to (four) wolverines in or adjacent to the study area.

3) Obtain information regarding age and sex composition, physical measurements, and breeding status of captured wolverines and from wolverine carcasses collected from hunters and trappers at Kaktovik.

4) Determine food preferences based on analysis of scats and observations of radio-collared wolverines.

Long Range Objectives:

1) Determine the distribution and abundance of wolverines associated with the northern coastal plain and foothills of the Arctic National Wildlife Refuge.

2) Determine the average home range size, movement patterns, and habitat associations of wolverines in the study area.

3) Develop estimates of wolverine density in the study area.

4) Investigate the food habits of wolverines in the study area and relate wolverine abundance and distribution to various available food resources.

5) Determine the effects of current human activities (especially harvesting) on wolverine populations in the study area.

6) Determine the potential impacts of oil and gas development on wolverines in the study area.

The above objectives were originally proposed as a 2 (+) years wolverine field study. Due to funding constraints and unsuccessful efforts to capture and radio-collar wolverines in the ANWR study area, field work (described in this report) only partially addresses some of the short range objectives.

Methods

Study Area:

The study area lies in the extreme northeastern corner of Alaska and generally consists of the northern portion of the Arctic National Wildlife Refuge, from the Canning River on the west to the Canadian border on the east, the Beaufort Sea coast line on the north and the Brooks Range on the south. It includes a 630,000 ha tract of ANWR which is currently subject to Congressionally mandated oil and gas exploration, as well as adjacent lands which may contain portions of wolverine home ranges common to the exploration area. A description and synthesis of existing literature regarding the physical characteristics, geology, climate, soils, hydrology, vegetation, and fish and wildlife resources of the study area is found in USFWS (1982).

Wolverine Observations

Incidental observations of wolverines by a variety of personnel conducting biological studies and management activities in the study area during 1984 were recorded according to date, location (plotted on 1:63,360 and/or 1:250,000 topographic maps), number, and wolverine activity/behavior.

Aerial Survey

Aerial reconnaisance surveys were conducted in late April on a trial basis to identify techniques which could be incorporated into a systematic inventory of wolverine tracks and trails in the study area. Rational for the survey procedure tested included consideration of the following conditions and characteristics:

1) Wolverines are presumably at a low density in the study area (based on existing observations).

2) Wolverine tracks and trail systems can be identified following a fresh snowfall from aircraft at elevations of approximately 200 m above ground level (AGL) (Magoun pers. comm).

3) Wolverines are rarely inactive for longer than 12 hours (Magoun pers. comm).

4) In arctic areas, female wolverines prefer to den in snowdrift areas and embankments associated with drainage courses and swales during March-May (Magoun pers. comm.)

5) Denning females remain near den sites (within 12 km) during the denning period (Magoun In Prep).

6) Average home range size for female wolverines in arctic foothills environments is about 115 km^2(Magoun In Prep).

7) Wolverine often use terrain features such as major drainages, ridges, etc. for territorial boundaries (Magoun pers. comm.).

Ten sample quadrats, 15-20 km on a side, ranging in size from about 225-400 km^2 were delineated on 1:63,360 topographic maps (Fig. 2). In determining approximate quadrat size, the assumption was made that female wolverines in the study area have similar home range sizes as females in northwestern Alaska. Typical features commonly used by wolverines for territorial boundaries were chosen to outline each quadrat. Thus it is reasonable to expect that at least one female wolverine home range or a major portion thereof may occur within each quadrant. Other criteria that were considered in selection of quadrats were geographical location, recent wolverine sightings, traditional wolverine harvest areas, distributions of potential food resources (ground squirrel habitat, caribou calving areas, caribou winter distributions), and logistical considerations.

Aerial searches were conducted in late April from a fixed-wing aircraft (Helio Courier) flying about 200 m AGL at 160 km/hr. Quadrats were systematically searched following parallel flight lines spaced at 3 km intervals. All wolverines or wolverine tracks detected were followed from end to end. Locations of animals, dens, tracks, and trail systems were plotted on 1:63,360 topographic maps and data were recorded on forms.

Results and Discussion

Wolverine Observations

Eleven observations of wolverines were reported by various field personnel during 1984 (Table 1). Ten observations occurred north of the continental divide (Fig. 3), four of which occurred within the 1002 oil and gas exploration area. The remaining observation occurred on an upper tributary of the Coleen River. Observations 1 and 2 occurred at approximately the same time period and may represent the same individual wolverine. Observation 4 occurred near to where an adult wolverine with 2 young were observed in 1982. One wolverine was observed in the act of catching and killing an arctic ground squirrel . Another a wolverine was observed feeding on a brown bear (Ursus arctos) carcass. On a third occasion a wolverine was observed feeding on a caribou carcass. In general, distribution of wolverine observations in 1984 is similar to the pattern of previous recorded observations (Fig. 1) and suggests that wolverines range throughout the coastal plain, foothills and mountain provinces of the study area. The frequency and number of observations recorded have been insufficient to determine if wolverine abundance varies with topographic province or with season. The relatively intense level of observer effort exerted on the study area during various periods of the year, and the corresponding low yield in wolverine observations, suggests that wolverine density may be low in the study area compared to that documented in northwestern Alaska (Magoun in prep). Until more comprehensive studies are conducted, wolverine population levels in the study area will remain largely unknown.

Table 1. Summary of Observations of Wolverines Reported during 1984, Arctic National Wildlife Refuge, Alaska.

Observation[a]	Date	General location	Number	Remarks
1	February 1984	Tamayariak R.	1	
2	February 1984	Tamayariak R.	1	May be same as #1
3	March 1984	Marsh Creek	1	
4	27 May	Marsh Creek	1	Same area as 1982 observation of female + 2 young
5	9 June	Hulahula R.	1	
6	8 August	Carter Creek	1	Large adult near ground squirrel colony
7	15 August	Jago River	1	
8	15 August	Jago River	1	Different individual from #7
9	29 August	Lake Schrader	1	Killed a ground squirrel
10	5 November	Aichilik R.	1	Feeding on dead brown bear
11	19 November	Coleen River	1	Feeding on Caribou carcass

[a] Corresponds to locations numbers in Fig. 3.

Aerial Survey

Reconnaisance survey flights were conducted in the study area on 19 and 20 April 1984. Favorable snow conditions for aerial tracking existed only in the southeastern portion of the study area where relatively fresh, soft snow covered nearly 100% of the ground and was not influenced by winds. This zone of favorable snow cover extended along the northern flanks of the Brooks Range from roughly the Hulahula river eastward to approximately the Egaksrak River (66 km) and covered the adjacent foothills northward for a distance of approximately 10-19 km. Study quadrat 10 and the extreme southern portion of quadrat 9 occurred in the zone of favorable snow conditions (Fig. 2). The remainder of the study area including quadrats (1-8 and most of 9) were covered by very hard, wind-packed snow with numerous areas of exposed ground. These areas were not feasible for aerial track surveys.

Survey methodology described in the above section was initiated on the northeastern corner of quadrat 10 (Fig. 2). The tracks and excavations of one wolverine were detected during the first east-west transect. A landing was made and the excavations were investigated. There were two separate excavations (approximately 50 m apart). Both excavations were about 40 cm wide and extended 30 cm into the soil. Remnants of caribou calf bones and

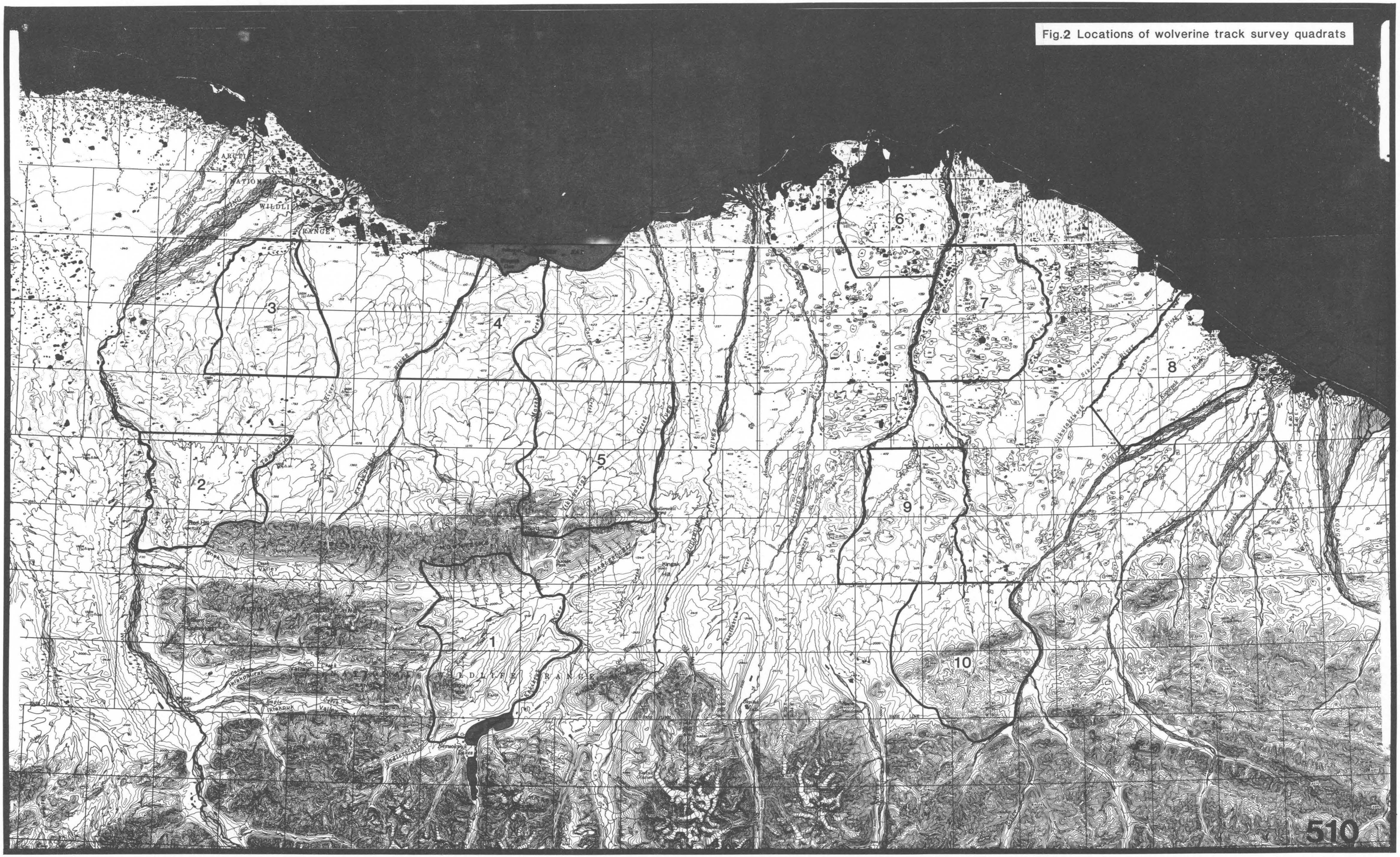
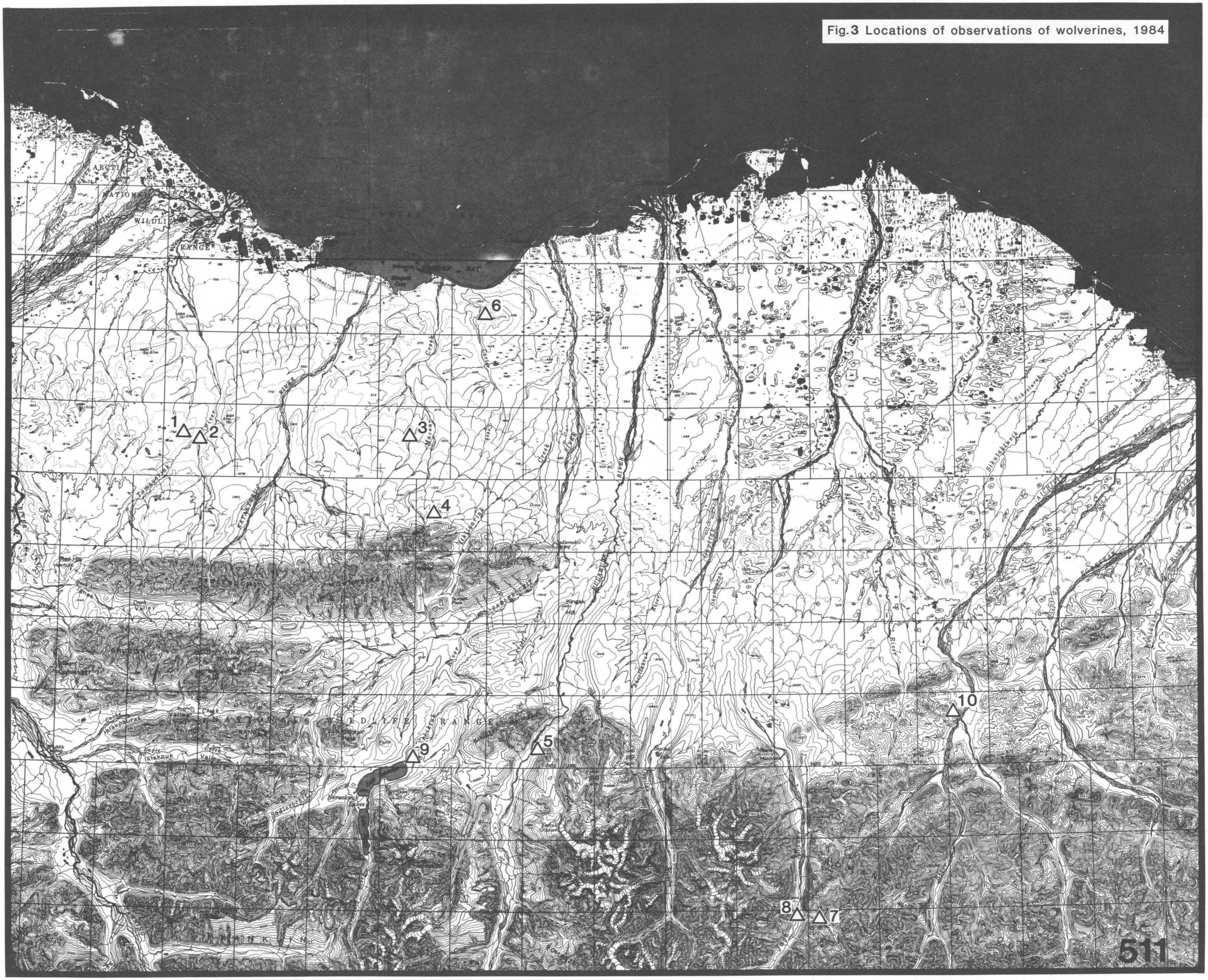


Fig.2 Locations of wolverine track survey quadrats

Fig. 3 Locations of observations of wolverines, 1984



hair were present at both excavations. Two wolverine scats were present as well as an impression in the snow where the wolverine had bedded down. The scats appeared to consist primarily of soil and bone material. Similar scats were found in late winter in northwestern Alaska (Magoun In prep) and indicated a significant reliance on cached food resources. There wolverine tracks and excavations occured within the southern portion of a major calving concentration areäs used by the Porcupine caribou herd in 1983 (Whitten et al. 1984). The wolverine tracks were back-tracked to the north where they became obliterated by wind-influenced snow conditions. The tracks continued south, following a small stream drainage leading to mountainous terrain where they disappeared in areas of exposed terrain. In total approximately 12.8 km of wolverine tracks were investigated.

Mountainous terrain in the southern 2/3's of quadrat 10 prevented survey from a uniform flight elevation throughout. Techniques were modified to search sections of drainage valleys where low-level flight could be safely accomplished. Uneven snow cover on south-facing slopes also reduced survey efficiency in this area.

A short portion of a wolverine track was also found in quadrat 10 near the Aichilik River. The track appeared old and was only partially visible. It was paralleled by a snow machine trail, and may have been followed by the driver. Snow machine tracks/trails were observed along the Okerokovik River, and crossing a low mountain pass into the Aichilik valley where a heavily used snow machine trail led up the Aichilik River.

On 20 April a wolverine track was found in the foothills west of quadrat 10. Both ends of this track system terminated in areas of wind-influenced snow located to the north. The portion of trail which was discernable from the air measured approximately 24.8 km in length. Much of the travel route frequented rock and boulder outcrops occurring in lateral moraine features associated with the Okpilak and Jago valleys, suggesting that the wolverine may have been searching for recently emerged ground squirrels which tend to frequent such areas. A male wolverine was killed by local hunters in the vicinity of this trail on 2 May 1984 (G. Garner pers. comm).

A possible wolverine sighting was reported along the Okpilak River approximately 6 km north of the northern terminus of this trail on 17 April (G. Elison pers. comm.). The observation was made at the entrance of a tunnel in a snow drift. Subsequent observations at this site recorded a red fox at the tunnel entrance.

No other wolverine tracks were observed during the reconnaisance survey. A majority of the study area was covered by wind-packed snow and was not suitable for a track survey. Due to the frequency of of winds associated with the study area, it is probably rare when uniform, fresh snow prevails over the area during a time period of sufficient length to conduct aerial track surveys. Information collected from areas with suitable tracking conditions demonstrated the potential utility of this technique for collecting considerable data on abundance, distribution, movements, habitat use, territories and food habits. Unfortunately the weather and snow conditions of the study area are rarely such that the aerial track survey could be applied in one systematic survey. It can, however, provide substantial data from certain areas during fairly short time intervals.

Subsequent to the wolverine track survey, an extensive wolverine track system was found on 3 May in the northern foothills region of the Egaksrak - Ekaluakat drainages (G. Garner pers. comm.). The tracks were found during wolf capture operations and followed for several km, but no wolverine was ever observed. Numerous, extensive low level searches were conducted throughout the southern portion of the study area in association with wolf and brown bear capture operations which were conducted in mid-late April, early May, early-mid June and during late June. During these operations, observers were also searching for wolverines, however none were found. Considerable low level observation flights were also conducted over the eastern portion of the study during caribou and golden eagle surveys during late May to early July. No wolverines were seen during these flights. Due to the extensive and intensive nature of aerial operations over the study area in 1984, the paucity of wolverine observations suggests that wolverine density may be low.

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ANWR Progress Report Number FY85-17

FALL AND WINTER MOVEMENTS AND DISTRIBUTION, AND ANNUAL MORTALITY PATTERNS OF THE PORCUPINE CARIBOU HERD, 1983-1984

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Key Words: Porcupine caribou herd, movement, mortality, predation, wintering areas, Arctic-Beaufort.

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Fall and winter movements and distribution, and annual mortality patterns of the Porcupine Caribou Head, 1983-1984.

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Abstract: Traditional winter ranges in Alaska (Chandalar Lake- Arctic Village) and in Cananda (Ogilvie basin, Hart basin and Eagle plains) were used by the Porcupine Caribou Herd in fall 1983-1984. Late winter shifts towards northern portions of the winter ranges occurred during February-March in Alaska and possibly earlier in Canada. One radio-collared caribou accompanied by up to 1000 other caribou wintered north of the Brooks Range in the Schrader Lake/Kikitak Mountain area. Based on proportions of radio-collared caribou found, it is estimated that about 40,000 caribou wintered in Alaska and about 100,000 (+) in Canada. First year mortality (based on survival rates of radio-collared calves) was estimated at about 43% for 1983-84. Mortality rates for radio-collared yearlings was slightly higher (11%) than (6%) for radio-collared adults. Most calf mortality occurred in the first 9 days after birth. More calves died during fall migration than during the entire mid-winter period. Adult mortality also was higher during the fall period. Higher densities of wolves in the fall and winter range may account for the increased mortality of caribou.

ANWR Progress Report No. FY85-17

Fall and winter movements and distribution, and annual mortality patterns of the Porcupine caribou herd, 1983-1984.

Intensive studies of the ecology of the Porcupine caribou herd are currently being conducted cooperatively by the U.S. Fish and Wildlife Service, Alaska Department of Fish and Game, Yukon Territory Government, Canadian Wildlife Service, and the University of Alaska. Primary emphasis has been on calving distribution, initial productivity, and neonatal calf survival in relation to petroleum exploration and potential development in the Arctic National Wildlife Refuge (ANWR). Numerous calf and adult caribou have been radio-collared in conjunction with these studies, providing a large sample of individually recognizable caribou. Relocating these marked caribou throughout the year yields valuable information on winter movements and annual mortality rates which can otherwise be gathered only with great expense and/or difficulty using conventional aerial survey and collection techniques. This report summarizes the results of radio-tracking surveys in Alaska during winter 1983-84.

Methods and Materials

Radio-collared caribou were relocated using fixed-wing aircraft and standard techniques and equipment from October 1983 through May 1984. Surveys in Alaska were flown once in October, February, and March, and two surveys each were flown in November and May. In Canada surveys were flown once in October, December, February, April, and May. Movements and distribution were determined primarily from locations of radio-collared caribou, although observations of other caribou seen during tracking flights were also considered in making general conclusions.

Radio collars were equipped with motion-sensing mortality switches (Whitten et al. 1984). Suspected mortalities were investigated on the ground, using helicopters for easy access. Mortality rate calculations include data from summer studies (Whitten et al. 1984) and from tracking flights and field necropsies conducted in Canada.

Results and Discussion

Fall and Winter Movements and Distribution

Caribou of the Porcupine herd used all three primary traditional wintering areas (Whitten and Cameron 1982) during 1983-84: the Richardson and Ogilvie Mountains areas in Canada, and the Chandalar area in Alaska (Fig. 1). As in many past years, there was a mass movement by much of the herd through the Brooks Range toward the Chandalar area during late July and August 1983. Subsequently, most caribou moved to the eastermost Brooks Range in Alaska or to the British Mountains and Old Crow Flats in the Yukon Territory. Unfortunately, tracking and survey flights were insufficiently frequent to provide more details on these late summer movements. A migration into the Chandalar area occurred in October, probably just after the rut, and caribou then remained in Alaska for the duration of the winter.

By late October, caribou in the Chandalar wintering area had reached as far southwest as Chandalar Lake, although most remained farther north between Ackerman Lake and Arctic Village. A few remained scattered through the southern foothills of the Brooks Range east to the international border (Fig. 2). During 24-27 October, 63 radio-collared caribou were found in Canada (56 in the Ogilvie River basin- west of the Dempster Highway, 6 in the Hart River basin and 1 in the Keele Range-Bluefish River). No radio-collared caribou were found in the Richardson Mtns.

By February and March 1984, caribou had moved north and east from Chandalar Lake. Most Porcupine caribou in Alaska were in the East Fork Chandalar River valley in the vicinity of Arctic Village. A few were still in the Brooks Range toward the border. Small bands were also in the low mountains between the Coleen River and Old Crow Flats, south of Bilwaddy Creek (Fig. 3). In Canada a majority of caribou continued to inhabit the Ogilvie Basin area, however, by 10 February 1984 at least 10 radio-collared caribou had moved north to the Eagle Plains area.

A small portion of the Porcupine herd (less than 1,000 animals) did not leave the north slope during winter 1983-84, but wintered in the Schrader Lake/Kikiktat Mountain area. Subsequent surveys and radio-collaring during spring indicated that these Porcupine caribou had little or no contact with Central Arctic herd caribou wintering west of Sunset Pass in the Sadlerochit Mountains and along the Canning River.

Unusually deep snow throughout the southern foothills of the Brooks Range resulted in delayed spring migration. Distribution changed little between March and mid-April. In early May caribou began moving northeast from the Arctic Village area, but many still remained where they had spent most of the winter (Fig. 4). When snow and travel conditions improved in mid- to late May, long lines of hundreds to thousands of caribou began moving along the southern flanks of the Brooks Range across the Sheenjek and Coleen valleys toward the headwaters of the Firth River. There they joined with caribou from Canadian wintering grounds, also moving down the Firth River towards calving grounds on the north slope.

Throughout the winter, calf collars proved much more difficult to track than adult collars. All of 73 functional radio collars on 2+ year old Porcupine caribou were located at least once between 1 October 1983 and 15 May 1984, whereas 6 of 50 calf transmitters were never heard during this period (1 of these was subsequently located, transmitting on mortality mode and at very low output, during June 1984). Retrieval of shed collars and of collars from dead or recaptured calves indicated that most calf collars had broken antennas. This severely reduced transmission range, often to less than 2 km. The problem became progressively worse during the winter, presumably as more antennas broke off. In April and May, only 4 of 68 potentially active adult collars were not located, versus 19 of 37 among calves (note: total numbers reduced by mortality and shedding).

Radio-collared bulls were definitely more prevalent in Canada than Alaska. All of 10 radio-collared 2+ year old males wintered in Canada, whereas about 30% of the 63 radio-collared females wintered in Alaska. No winter composition counts were conducted in either area, but in previous years composition counts have occasionally yielded geographically skewed sex ratios, with more bulls in Canada (Whitten and Cameron, 1980). Thus, it seems

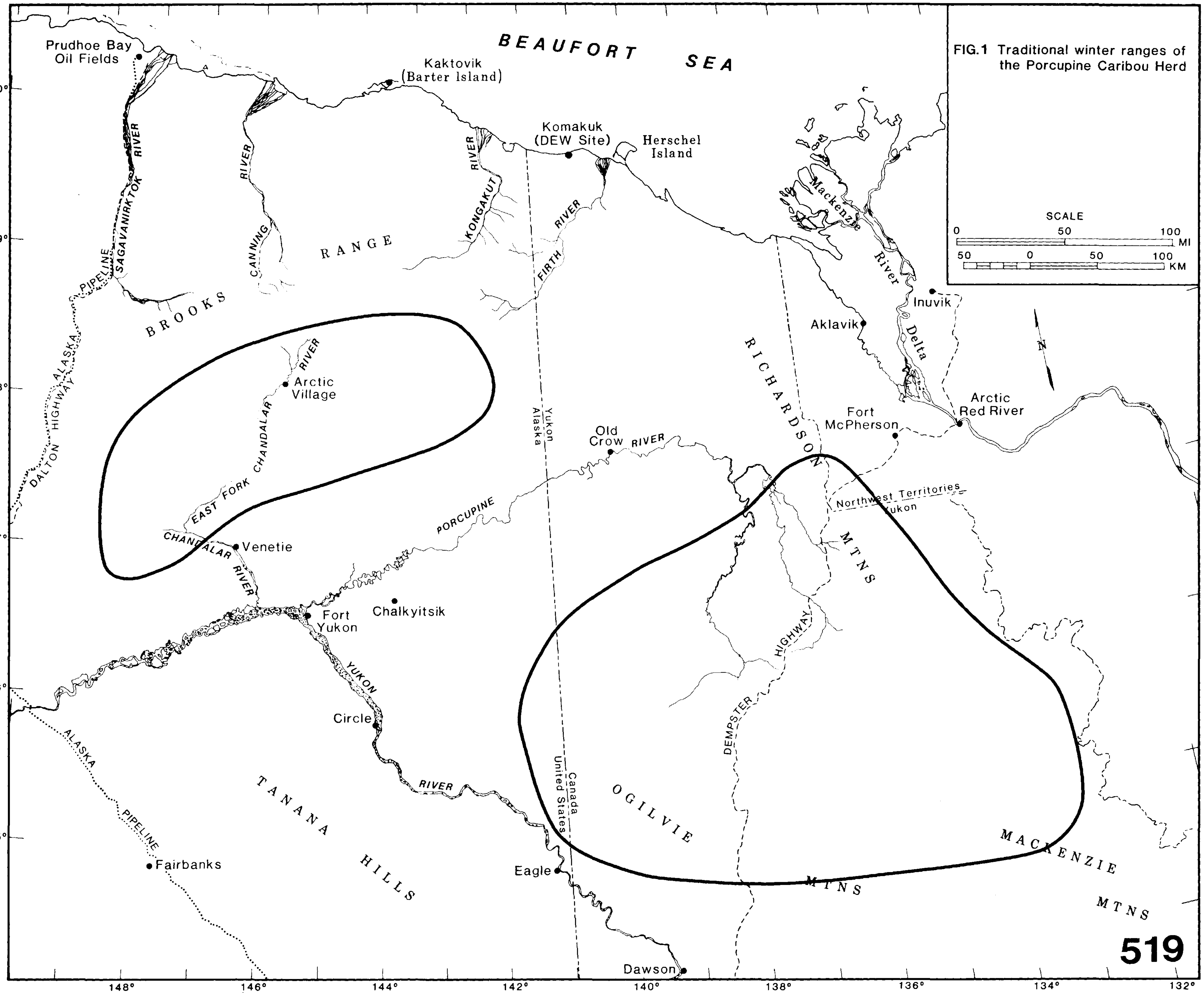

FIG.1 Traditional winter ranges of the Porcupine Caribou Herd

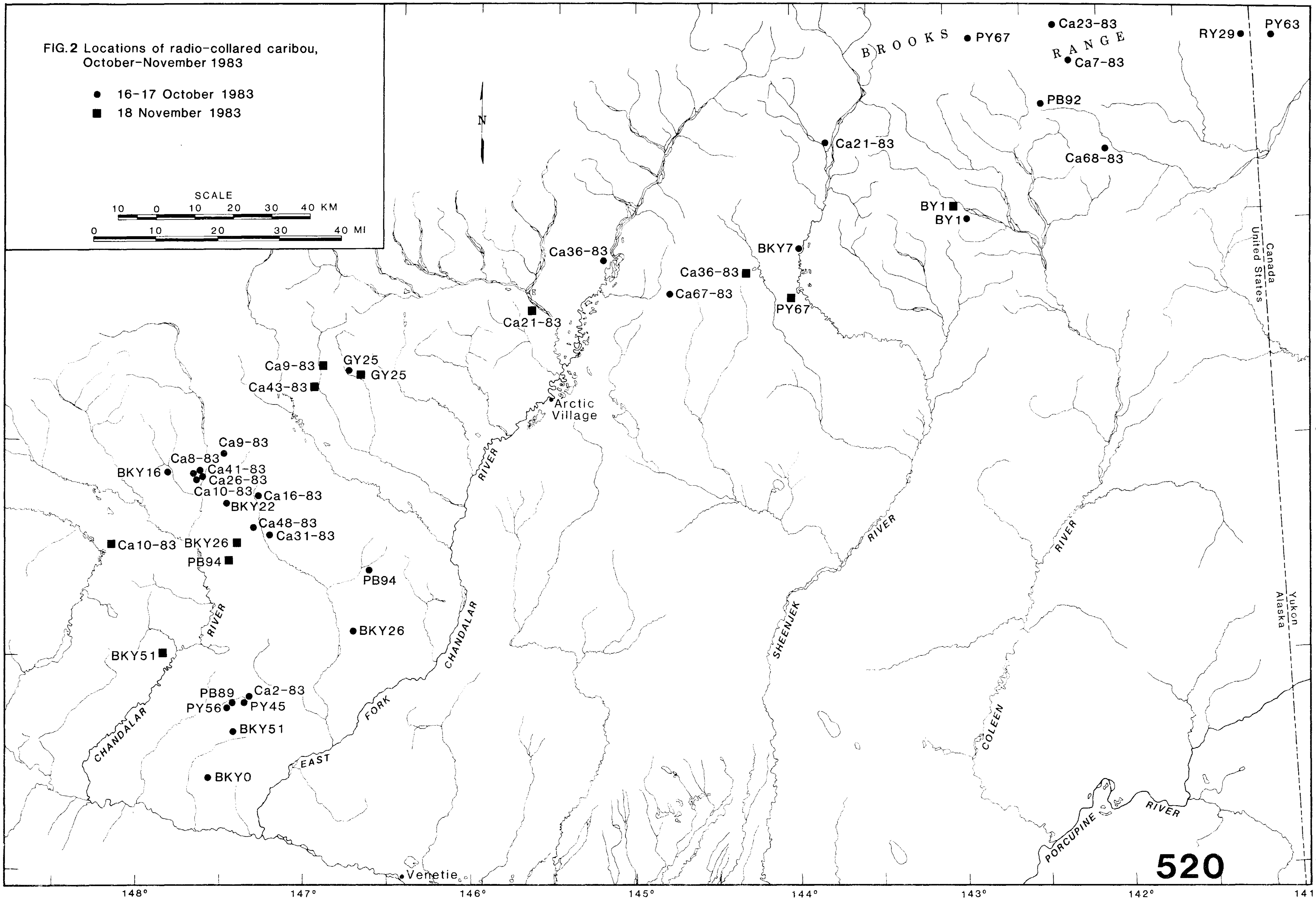

FIG. 2 Locations of radio-collared caribou, October-November 1983

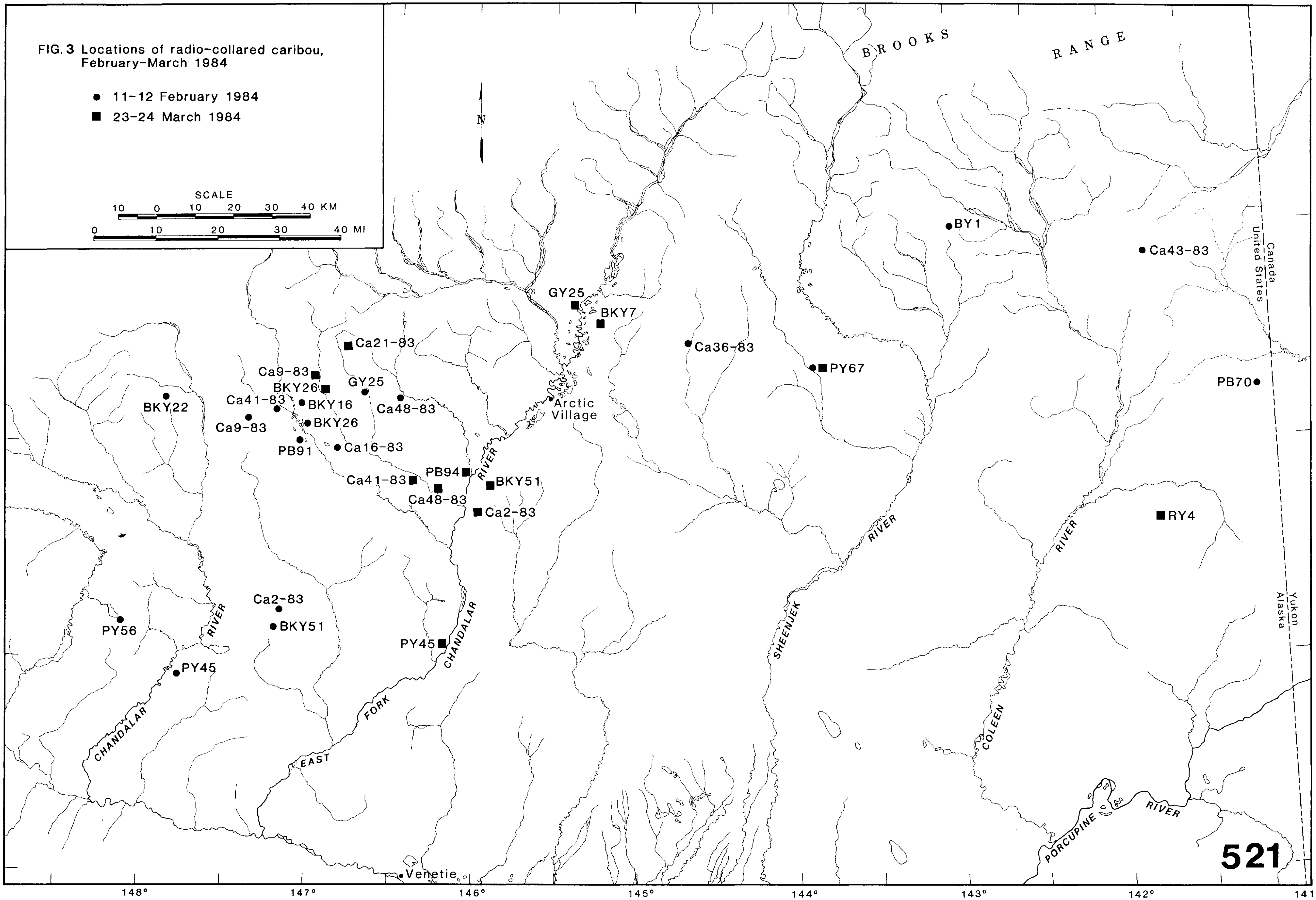
FIG. 3 Locations of radio-collared caribou, February-March 1984
11-12 February 1984
23-24 March 1984
SCALE
10 0 10 20 30 40 KM
0 10 20 30 40 MI
N
BROOKS RANGE
Canada
United States
Yukon
Alaska
BY1
Ca43-83
GY25
BKY7
Ca36-83
PY67
PB70
Ca21-83
Ca9-83
BKY26
GY25
BKY16
Ca41-83
Ca48-83
BKY22
Ca9-83
BKY26
Arctic Village
PB91
Ca16-83
PB94
BKY51
Ca41-83
Ca48-83
Ca2-83
RY4
Ca2-83
BKY51
PY56
PY45
PY45
CHANDALAR RIVER
EAST FORK CHANDALAR RIVER
SHEENJEK RIVER
COLEEN RIVER
PORCUPINE RIVER
RIVER
Venetie
68°
67°
148°
147°
146°
145°
144°
143°
142°
141°

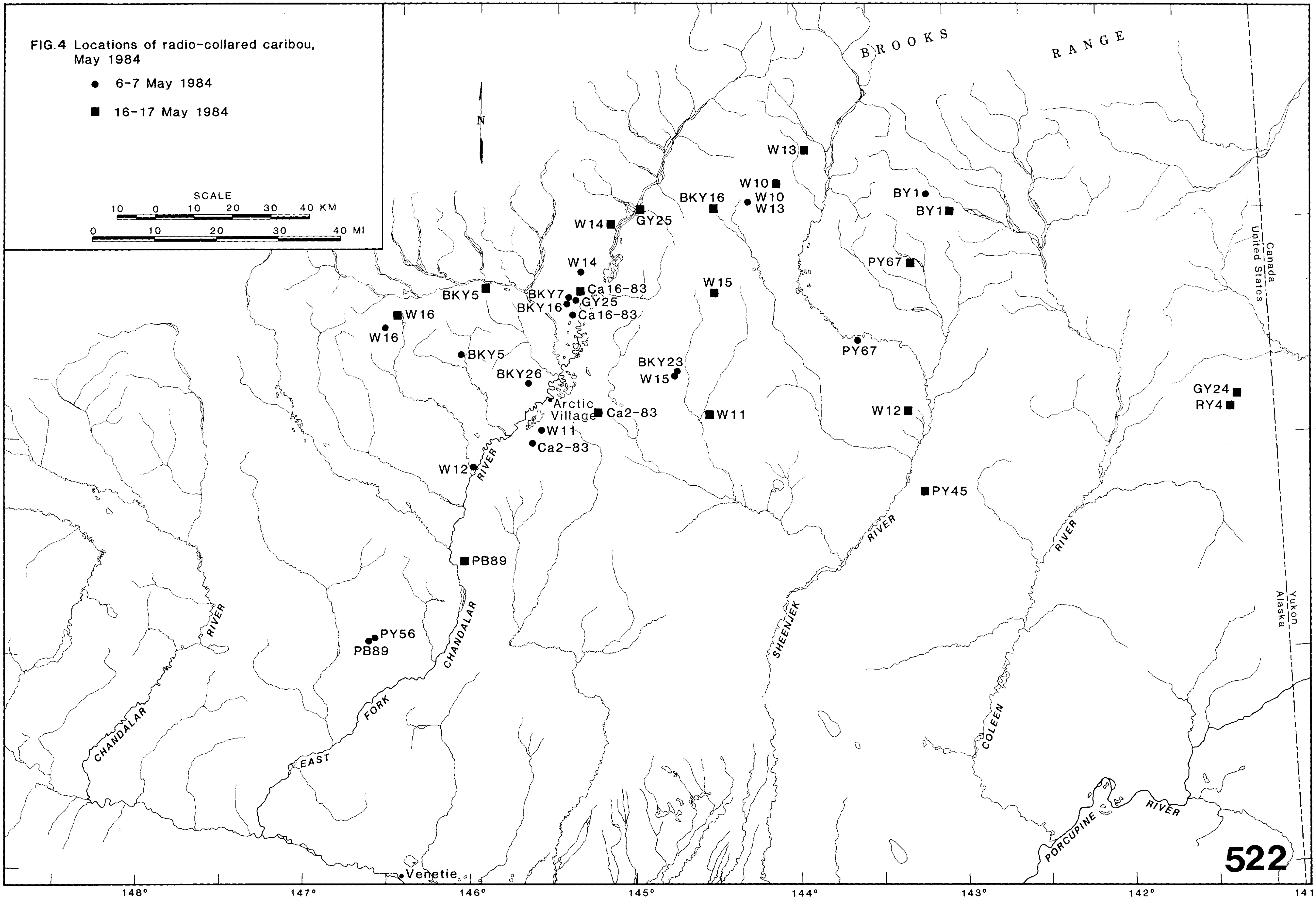

FIG.4 Locations of radio-collared caribou, May 1984

reasonable that more bulls wintered in Canada, and that the caribou wintering in Alaska were predominantly cows and calves.

Among all collared caribou located during the winter (10 Oct - 15 May), a significantly higher proportion of calves than adults was found in Alaska (Table 1). Even after subtracting the 10 adult bulls in Canada, the difference in distribution of calves versus cows was still significant (P 0.05). However, many of the calf relocations in Alaska were from shed collars or mortalities which were detected in October, but probably actually occurred during the July-August migration through the Brooks Range. Caribou in Alaska at that time could have potentially wintered in Canada. Using only relocations after 1 November, when winter distributions were finally established, the proportions of calves versus cows wintering in Alaska and Canada did not differ significantly (P 0.05, X^2 = 1.82). Thus, collared cows and calves were dispersed similarly relative to each other in Alaska and Canada. Overall, the distribution of radio-collared caribou appeared to adequately reflect the distribution of the entire population, except that perhaps the sample size of collared males was too small to reflect the small numbers of bulls which probably did winter in Alaska.

Table 1. Distribution of collared calves and adults in Alaska and Canada during winter 1983-1984.

	1 Oct - 15 May		1 Nov - 15 May	
Category	Alaska	Canada	Alaska	Canada
2+ Adults	18 (0 bulls)	55 (10 bulls)	17 (0 bulls)	55 (10 bulls)
Calves	21	23	15	22

Assuming that the 29% of the radio-collared caribou wintering in Alaska represented 29% of the entire herd, there were roughly 40,000 Porcupine caribou wintering in Alaska. No attempts were made to accurately estimate numbers of caribou on winter range. Casual observations during radio-tracking flights suggested 20-30,000 caribou in Alaska. However, past attempts at gross, nonsystematic estimation of the Porcupine herd on winter range have consistently yielded numbers much lower than the known herd size (LeResche 1975, Whitten and Cameron 1981). Thus, an Alaskan overwintering population of 40,000 caribou is not unreasonable.

Mortality Patterns

At least 20 of the 63 calves radio-collared in 1983 died during their first year of life (i.e., mortality sites were visited and signs of a carcass were found) and at least 23 survived (i.e., were successfully tracked through May 1984). Precise overwinter mortality rates could not be determined, however, due to failure of a number of collars over the winter and also because some mortality signals were not investigated to determine if the signal was emanating from a shed collar or a dead calf. Five collars failed during late summer and were not located after 1 October, eight failed during mid- to late winter, four were shed (i.e., collars with broken elastic bands were retrieved with no sign of a carcass nearby), and three mortality signals were not investigated from the ground (Table 2).

Table 2. Chronology of mortality among radiocollared calves and adults 1983-1984.

Category	Percent of annual mortality (N)			
	Summer (Jun-Aug)	Fall (Sep-Oct)	Winter (Nov-Mar)	Spring (Apr-May)
Calves	52 (12)	26 (6)	22 (5)	0
Adults	0	50 (3)	33 (2)	17 (1)

A minimum first year mortality rate was calculated from the following assumptions: (1) calves whose collars failed during late summer were eliminated from the sample, (2) calves whose collars failed during the winter all survived, (3) calves which shed collars were eliminated from the sample, and (4) the three unverified mortality signals were actually shed collars and were also eliminated from the sample. Thus minimum mortality was 20 dead out of a sample of 51 calves, or 39%. Maximum mortality was calculated similarly, except that all calves whose collars failed during the winter were assumed to have died, and the unverified mortality signals were considered true mortalities. Maximum mortality was thus 31 dead out of a sample of 54, or 57%. Perhaps the most reasonable estimate of mortality, however, would result from assuming that the calves whose collars failed during the winter survived, but that the unverified mortalities were actually dead; 23 of 54 died, or 43%.

Among caribou older than calves, 64 of 73 with active collars in June 1983 lived through May 1984; 6 definitely died and 3 had collars which apparently failed during the winter. Minimum mortality was 8% if the caribou with failed collars survived, and maximum mortality was 12% if those with failed collars died. Omitting those caribou whose collars failed, there were equal numbers of yearlings and adults. Mortality rates did not differ significantly, although the yearling rate was slightly higher (11% versus 6%). All mortalities were among females, which made up most of the sample (60 of 70 collared animals).

Most of the calf mortality occurred during summer (Table 2), especially during the first nine days after birth (Whitten et al. 1984). No adults died during summer 1983. More calves died during fall migration than during the entire mid-winter period and most of the adult mortality also occurred during fall (Table 2). Causes of fall and winter mortality are unknown, as all carcasses had been consumed and/or scattered by predators or scavengers before the mortality sites could be examined. Encounters with assumed higher densities of wolves within and south of the Brooks Range is the most likely explanation for the high mortality during fall. One adult cow was shot by hunters from Ft McPherson, Northwest Territories in April 1984.

Recruitment in spring 1984 can be roughly calculated. To be meaningful, recruitment should be expressed as a proportion of the previous year adult population base. Given 74 calves/100 cows in 1983 (Whitten et al. 1984) and a first year mortality range of 43-57% (probable to maximum), recruitment would be 36-47 yearlings in 1984/100 cows in 1983. This estimate can be converted to a percent recruitment figure if the 1983 bull and yearlings cow ratios are also known. The bull:cow ratio in the Porcupine herd was 60 bulls:100 cows in

1980 (Whitten and Cameron 1981), and has presumably remained the same since then. The yearling:cow ratio in 1983 was not estimated, but early calf survival in 1982 was lower than in 1983, and if overwinter mortality was approximately the same as in the 1983 calf cohort, a conservative 1983 yearling:cow estimate would have been 30 yearlings/100 cows. Potential recruitment in 1984 would then be 36-47 yearlings/100 cows, 60 bulls, and 30 yearlings in 1983, or 19-25%.

The Porcupine herd has been growing at about 6-8% annually in recent years. Assuming no immigration or emigration, adult mortality is the difference between recruitment and actual growth, in this case 11-19%. This estimate is slightly higher than the range of 8-12% observed among collared adults in this study. The Porcupine herd may now be increasing more rapidly in response to lower initial calf mortality in the past two years (Whitten el al. 1984 and this report). If so, the calculated mortality rate would be closer to the range observed among collared animals.

Acknowledgements

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CALVING DISTRIBUTION, INITIAL PRODUCTIVITY, AND NEONATAL MORTALITY OF THE PORCUPINE CARIBOU HERD, 1984

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Key words: Caribou, Porcupine herd, calving distribution, productivity, neonatal mortality, predation, post-calving movements, Arctic-Beaufort, north slope

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25 February 1985

Calving distribution, initial productivity, and neonatal mortality of the Porcupine caribou herd, 1984.

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Abstract: This report presents infomation collected during the second year of a three year study by the Alaska Department of Fish and Game and the U.S. Fish and Wildlife Service of the Porcupine caribou herd's calving distribution, initial productivity and neonatal mortality. Calving distribution and areas of concentrated calving activity were determined by relocation of 31 radio-collared adult (3+ years old) female caribou (Rangifer tarandus), and by aerial reconnaisance surveys during late spring migration and calving seasons. Distributions of calving caribou extended across the Arctic coastal plain and foothills from the Jago River in Alaska to approximately the Babbage River in Canada. Some calving caribou were also distributed along migration routes in the eastern portion of the Brooks Range in Alaska, the British Mountains in Canada, and as far south as the northern margin of the Old Crow Flats. Major concentrations of calving activity occurred on the coastal plain in the vicinity of the Niguanak River, between the Aichilik River, and the Turner River, and on the coastal plain south of Stokes Point in Canada. The peak of calving occurred on 4 June and did not appear to vary significantly from east to west. Twenty-three of 31 (74%) radio-collared females 3 years old or older produced calves, and initial productivity appeared to be similar to that of recent years. During 3-8 June, 77 calves were captured in the Niguanak River and Aichilik-Turner Rivers calving concentration areas, and fitted with mortality sensing radio-transmitters. Radio frequencies were monitored at least daily and visual checks were made every 48h during 4 June-6 July. Monitoring was less intense during the remainder of July and continued on a monthly basis through 1984. Twenty-three productive radio-collared females were monitored as a control group on 1-3 day intervals during 30 May-24 June. During 3 June-12 November, 33 study calves died. Seventeen calves died as a result of study-induced abandonment. The natural mortality rate of remaining calves was 26.7%. Categories of natural mortality included: Undetermined- predation/scavenging (56.25%), wolf (Canis lupus) predation (12.5%), brown bear (Ursus arctos) predation/scavenging (6.25%), golden eagle (Aquila chrysaetos) predation (6.25%), accident/drowning (6.25%), disease-pneumonia (6.25%), and human harvest (6.25%). The geographic distribution of mortality of study calves as well as that of unmarked adults and calves was primarily oriented towards the eastern and southern coastal plain/foothills areas in Alaska, and may be attributed to generally higher densities of predators in that region. Increased incidence of mortality among study calves was measured during fall migration in regions south of the Brooks Range and British Mountains.

Calving distribution, initial productivity, and neonatal mortality of the Porcupine caribou herd, 1984.

Much of the coastal plain portion of the Arctic National Wildlife Refuge (ANWR) was opened to a limited oil and gas exploration program by the Alaska National Interest Lands Conservation Act (ANILCA) of 1980. If significant potential for petroleum resources are indicated, Congress may pass additional legislation to open ANWR to further exploration, leasing and development. Caribou from both the Porcupine and Central Arctic Herds utilize portions of the coastal plain of the ANWR for calving, post-calving aggregations, and insect relief activities during the spring and summer (USFWS 1982). Parturient female caribou and post-parturient females with young calves are sensitive to disturbance associated with human activity (de Vos 1960, Lent 1964, Bergerud 1974, Cameron et al. 1979, Davis and Valkenburg 1979). Studies conducted annually since 1974 have shown that female caribou with young calves avoid the Prudhoe Bay oil field and adjacent Trans-Alaska Pipeline corridor (Cameron and Whitten 1976, 1980). It has been suggested that displacement of parturient female caribou and females with young from traditional areas may cause increased calf mortality which could ultimately contribute to population decline (Bergerud 1976, Calef and Lent 1976, Klein 1980).

Mortality factors and rates associated with potential displacement habitats need to be assessed to make predictions regarding calf survival and herd productivity if traditional calving habitats are further explored and developed for petroleum production. Consequences of displacement from traditional insect relief areas and preferred forage areas, and the overall impacts of human/industrial disturbances also need to be evaluated. ANILCA requires the evaluation of potential adverse effects that oil and gas exploration, production, and development on ANWR might have upon the Porcupine Caribou Herd. In addition, if petroleum development on ANWR is allowed, more information on caribou distribution and habitat use during the calving and post-calving periods is needed to formulate recommendations for leasing schedules, placement of facilities, and other mitigative measures. In particular, causes and patterns of calf mortality need to be examined with emphasis on differences among areas or habitat types, in order to assess the possible effects of displacement from development sites. This study focuses on determining annual calving distribution, initial productivity, and neonatal caribou calf mortality on the calving grounds and post-calving areas of the Porcupine Caribou Herd and was initiated in 1983 as a joint project between the Arctic National Wildlife Refuge, U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game.

Objectives for this study are as follows:

A. Primary

1. Delineate distribution of the Porcupine Caribou Herd calving as part of a continuing effort to collect baseline information on wildlife resources in the portion of ANWR open to petroleum exploration;identify any annual consistencies in calving distribution and/or common characteristics among separate calving areas.

2. Determine initial calf production and extent, causes, and chronology of mortality among neonatal calves (i.e., 4-6 weeks postpartum).

3. Measure variation in calf mortality and calf mortality factors between core and peripheral areas and/or between different habitat types or localities.

B. Secondary

1. Provide productivity data for analysis of herd status.

2. Identify characteristics (i.e., habitat, snow ablation patterns, topography, etc.) of core and peripheral calving areas and/or calving areas in different habitat types or localities.

3. Provide additional collared caribou for concurrent studies of overwinter calf survival and seasonal movements.

4. Provide incidental observations of other species as part of the overall ANWR baseline studies, including casual or incidental locations of radio-collared muskoxen, brown bears, and wolves.

This study is being conducted concurrently with studies of the status (population size, and trend), overwinter calf mortality, and winter distribution of the Porcupine caribou herd. Adult caribou collared in conjunction with those studies aid in the conduct of this investigation. Collectively this study is a part of a comprehensive environmental inventory and assessment of the potential petroleum development area of ANWR. This report presents preliminary findings of the 1984 field season.

Methods and Materials

Study Area

The study area consists of the north slope of ANWR and may extend east to the Blow River in Canada and south to the southern slopes of the Brooks Range, depending on annual variations in caribou distributions. In 1984, the study area extended from the Jago River on the west, to the Babbage River in Canada on the east, and the Beaufort Sea coast on the north to the southern slopes of the Brooks Range.

Most study activities occurred on the coastal plain and foothills portions of the area described above. Descriptions of the physical environment, climate, geology, vegetation, and other wildlife resources of the study area are found in U.S. Fish and Wildlife Service (1982). Logistical operations were based at Kaktovik, Alaska.

Calving Distribution and Initial Productivity

General calving distribution was determined primarily by locating all radio-collared adult female caribou in the Porcupine Herd during late May and early June. All radio-tracking was conducted from aircraft equipped with standard tracking equipment (Telonics, Mesa, AZ). Radio-tracking flights during calving distribution surveys were usually at altitudes greater than 1,000 m AGL. Low altitude (20-100 m AGL) aerial searches were also conducted to identify calving caribou.

A low-level transect extending across the calving grounds from Komakuk Beach to Barter Island was flown using fixed-wing aircraft on 2 June over the areas where collared cows were located. In areas of low caribou density, essentially all caribou within approximately 300 m of the flight line were counted and classified. In high density areas only partial counts of caribou could be obtained, and only newborn calves and adults were classified.

High altitude radio-tracking flights over the northern part of the winter range, and over the mountains and coastal plain east of the calving areas were conducted to determine the distribution of bulls and yearlings during calving.

Neonatal Mortality

Caribou calves were captured from two areas with high densities of calving females. The first capture area was located in the vicinity of Niguanak Ridge between the lower Jago River and the Niguanak River (Fig. 1), and coincided with the historic "core" calving region of the Porcupine herd. The second calf capture location was between the Turner River on the east and the Aichilik River on the west (Fig. 1), and is usually considered a peripheral calving location.

Caribou groups were approached by helicopter (Bell Jet Ranger 206B) with a capture crew of three persons aboard. The helicopter landed approximately 200 m from the caribou and one person took a sitting position on the right skid. The helicopter then proceeded towards the group and a calf was selected for capture. Selection from groups was standardized (calf on extreme left) to minimize sampling bias for slower, younger, and/or weaker calves.

The selected calf was pursued by flying approximately 1 m above the ground. When the helicopter was within 2-3 m of the running calf, the person on the skid stepped off to the side, ran, and grasped the calf. Sterile surgical gloves were worn by personnel handling captured calves and new gloves were used for each handling. When a calf was captured, the helicopter landed and the remaining members of the capture crew assisted in processing the calf.

Captured calves were sexed (Bergerud 1961), weighed, and measured for total body length, right hind foot length, and new hoof length (Haugen and Speake 1958). Characteristics of the umbilicus (moist, dry, absent) and hooves (degree of wear) were noted as described by Miller and Broughton (1974). Each calf was examined for abnormalities and fecal samples were collected from those calves with scours.

An expandable elastic collar supporting a mortality sensing transmitter (Telonics Inc., Mesa, AZ), weighing approximately 114 g was installed around the neck of each calf. Mortality mode for transmitter units was doubling of normal pulse rate following a 1 h motion free period. Estimated battery life was 15 months. Each collar was constructed from a 3.75 cm wide elastic band. The initial collar size (25 cm circumference) was achieved by sewing the left and right ends of the elastic collar band together. Three separate expansion folds per collar were sewn with incremental amounts of cotton thread stitching. Each expansion fold provided an additional 7 cm of collar circumference. Maximum expansion circumference of each collar was 53 cm. Collars were constructed to breakaway after the last expansion fold was used. The color of the collars was changed from the white elastic used in 1983 to a dyed brown color in 1984. This change was made because it was believed that golden eagles might be attracted to the white collars due to their easy sightability (Garner et al. 1985).

Aircraft (PA-18) equipped with standard radio tracking equipment were used to monitor instrumented calves, locate mortalities, determine calf locations, and movements. In those cases in which the capture crew in the helicopter did not observe an immediate reunion of the calf with its dam, aerial relocation and visual checks were made at 1-3 h time intervals following release. All calf radio frequencies were monitored for mortality signals at least once daily and visual locations or locations to caribou group were made for each calf every other day from 3 June through 6 July 1984. Relocation surveys were conducted on a monthly basis from July through November 1984. Visual and group locations were plotted on 1:250,000 and 1:63,360 scale topographic maps.

All mortalities were investigated as soon as possible using a helicopter for access. Each carcass and mortality site was examined for information on the cause of death. Photographs were taken to document mortality sites. Evidence of predators/scavengers at the carcass site were noted and collected. Each carcass was placed in a plastic garbage bag, labeled, and transported to Barter Island. Necropsies were performed on carcasses when sufficient remains were present. In cases where only hair and bones remained, measurements of weight, right hind foot length, and new hoof length were recorded whenever possible. The location of retrieved carcasses was plotted on 1:63,360 scale topographic maps. Criteria for determining the category (Cook et al. 1971) and the cause of each mortality (Table 1) were developed from descriptions of predator kills and feeding characteristics in the literature (Murie 1948, Thompson 1949, Johnson 1951, Borg 1962, Atwell 1964, Mech 1970, Wiley and Bolen 1971, Alford and Bolen 1972, Cole 1972, White 1973, Miller and Broughton 1974, Bolen 1975, Henne 1975, Miller 1975, Mysterud 1975, Buskirk and Gipson 1978).

Carcasses of unmarked calves encountered during this and other field studies were also examined as opportunity allowed. The locations of predators observed on the calving grounds were noted and observations of interactions between caribou and predators were recorded. Concurrent field studies of brown bear, wolf, and golden eagle ecology on the coastal plain on ANWR also provided additional information relative to this study (Garner et al. 1985, Mauer 1985, Weiler et al. 1985).

Initial productivity and subsequent mortality of calves from 31 3+ year old cows and 29 2-year old radio-collared control cows were compared with data from the radio-collared study calves. The control females were radio-tracked in late May and early June 1984 as they arrived on the calving grounds and their locations were plotted on 1:250,000 scale topographic maps. Parturition

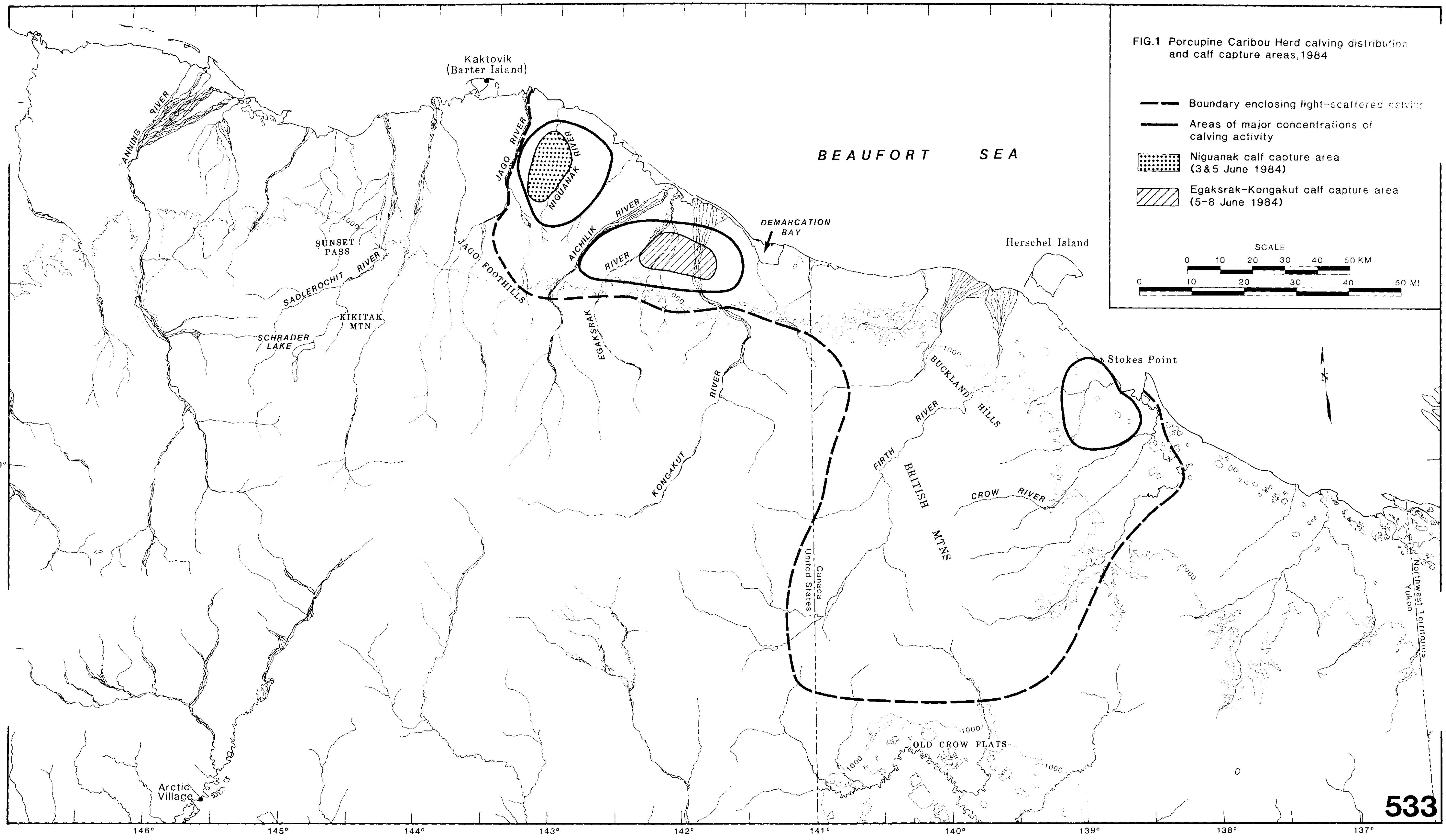

FIG.1 Porcupine Caribou Herd calving distribution and calf capture areas, 1984

Table 1. Criteria used for determining category of observed mortalities of neonatal caribou calves in northeast Alaska.

Criterion	Category
I. Carcass lacks sign of being bitten, chewed or disturbed by predators.	I. Predation-excluded
1. Milk curds absent in abomasum and intestinal tract. Lack of mesentary and subcutaneous fat. Rumen may be packed with vegetation.	1. Starvation
a. No reunion with dam observed following release and subsequently observed unattended by dam prior to death.	a. Probable study-induced abandonment
b. Reunion with dam observed following release, but later observed unattended by dam prior to death.	b. Probable natural abandonment
2. Milk curds present or absent from abomasum or intestinal tract. Mesentary and subcutaneous fat present. Absence of any signs of starvation.	2. Exposure/accident
a. Physical trauma present	
i. Broken bones, bruises, etc.	a. Accident
ii. Gun shot wounds	b. Hunter kill
b. No physical trauma present. Carcass in river or stream. Water in lungs, rumenoreticulum, or abomasum.	c. Drowning
c. No physical trauma or evidence of drowning.	d. Exposure
3. Disease syndrome present, or disease syndrome noted at capture.	3. Disease
4. None of the above.	4. Undetermined
II. Carcass bitten, chewed, and/or partially eaten.	II. Predation/scavenging involved.
A. Lack of blood in wounds, lack of frothy blood in nares and trachea, no bruises surrounding tooth marks, or no subcutaneous hemorrhages present.	1. Scavenging
1. Bones gnawed and chewed, feeding pattern generally not restricted to the upper portion of carcass.	a. Mammalian scavenger (return to I.1 to determine cause of death)
2. Bones not chewed, feeding limited to upper portions of carcass.	b. Avian scavenger (return to I.1 to determine cause of death)
3. Neither of the above, or some characteristics from both.	c. Undetermined
B. Blood in wounds, frothy blood in nares and trachea, bruises surrounding wounds and subcutaneous hemorrhages present.	B. Predation
1. Debilitating physical disorder, or disease syndrome present	1. Predator kill and other factors

Table 1. (Continued).

Criterion	Category
2. No debilitating physical disorder, or disease syndrome present.	2. Predator kill
a. Talon wounds on back and sides of body. Talon wounds on neck. Only upper portion of carcass fed upon. Ribs broken off at backbone. Leg bones usually intact.	a. Golden eagle kill
b. Teeth wounds on neck, sides or legs. Carcass fed upon extensively, bones chewed and carcass parts scattered.	b. Mammalian predator
i. Extensive trauma to carcass. Large portions of carcass missing. Bones broken or crushed. Skull crushed. In older calves, rumen not consumed. Carcass often covered with debris.	i. Brown bear
ii. Extensive trauma to carcass. Bones broken. Carcass not covered with debris. Skin at kill area often not punctured.	ii. Wolf
iii. Extensive trauma to carcass. Evidence not conclusive for any species or conflicting evidence.	iii. Undetermined mammal
c. None of the above.	d. Undetermined predator

status was determined by low-level aerial observations of the presence/absence of young, antler shedding (Lent 1965, Epsmark 1971), and udder distention (Bergerud 1964). Following parturition, productive members of the control group were monitored on a 24-72 hr basis until approximately 26 June.

Results and Discussion

Calving Distribution and Initial Productivity

Spring migration in 1984 followed traditional routes through the Richardson Mountains, across Old Crow Flats, and along the southern flank of the Brooks Range. Many caribou using the latter two routes converged along the international border and followed the Firth River valley through the British Mountains to the arctic coast. Deep snow delayed the onset of migration and most caribou were still on winter range on 1 May (Whitten et al. 1985). By mid-May, caribou were only just approaching the headwaters of the Firth River and the northern edge of Old Crow Flats. At that time it appeared most calving would occur east of the Firth River and in the British Mountains - northern Old Crow Flats region as occurred in 1982, when similar deep snow and late melt-off conditions prevailed on winter range (Whitten and Cameron 1983). However, in marked contrast to the nearly 100% snowcover on the coastal plain west of the Firth river throughout the calving period in 1982, snow conditions on the north slope of the eastern Brooks Range were relatively light during 1984. Once caribou crested the Brooks and British Mountains or reached the headwaters of the Firth River, they were able to proceed rapidly toward traditional calving areas in ANWR. Nevertheless, some cows lagged behind, and a few calves were born in the Brooks and British Mountains or along the northern fringe of Old Crow Flats.

At the onset of calving (i.e., 30 May to 2 June), many caribou were located in the Buckland Hills and on the coastal plain south of Stokes Point (Fig. 2). Numerous bands were also moving westward along the coastal plain and foothills from the Firth River Delta to Demarcation Bay. Highest densities were farther west, however, just north of the Brooks Range foothills from Demarcation Bay to the Aichilik River. Relatively high densities also occurred in the low, hilly country along both sides of the Niguanak River.

Caribou at the vanguard of the calving migration were predominantly pregnant cows, whereas barren cows and yearlings were distributed towards the rear; bulls remained south of the Brooks Range, British, and Barn Mountains (Fig. 2). Throughout the calving period, pregnant cows continued to move northward out of the mountains and westward across the coastal plain until they gave birth (Fig. 3). Ten cows which kept moving in this manner covered a mean distance of 15.5 km/day for 1-8 days immediately prior to calving. Three of these cows moved 20-25 km/day for 1-3 days. Once their calves had been born, parturient cows remained sedentary.

Thus the distribution of caribou changed markedly during the calving period. By the time most calves were actually born, distribution was skewed much farther westward than it had been at the onset of calving (Fig. 4). Ultimately, distribution was more similar to that in 1983 than in 1982. Major differences were that some cows remained in the Buckland Hills/Stokes Point area throughout calving and that very few calved in the Jago River foothills area, which in 1983, and in 8 of the previous 11 years, supported high density calving (Whitten et al. 1984). High density calving did occur immediately east and north of the Jago River foothills, however. Essentially no calving occurred west of the Jago River.

Caribou which had wintered south and east of the Sadlerochit River, near Kikiktat Mountain and Schrader Lake, calved in the Niguanak area. Caribou wintering in the Sadlerochit Mountains from Sunset Pass west and those along the Canning River moved north or northwest, as expected, to Central Arctic Herd calving areas.

Peak of calving among radio-collared cows was between 2 and 6 June (Fig. 5). Very little tracking was done on 3-5 June as the entire study team was involved in calf capture. Many of the calves first detected on 6 June were probably born earlier. Thus it seems likely that the actual peak of calving was on or about 4 June, as it was in 1983 (Whitten et al. 1984). It also appeared during calf capture operations that some cows were still pregnant on 3 June, whereas nearly all had given birth by 5 June, further suggesting that the peak was on 4 June.

Peak of calving did not vary obviously across the calving grounds. A transect was flown over the calving grounds using fixed-wing aircraft on 2 June. Although this was before the peak of calving, some calves were present in all areas surveyed. Calf percentages were lower east of Demarcation Bay (Table 2), but this phenomenon can be explained by the relative abundance of nonpregnant and/or younger cows to the east. Nevertheless, observations of collared cows and of unmarked animals associated with them in 1982 (Whitten and Cameron 1983) indicate that delayed calving in the east or south does occasionally occur. Similar delays were also reported in 1980 (R. Farnell, YTG unpublished report).

Table 2. Calf percentages in various areas of the Porcupine Herd calving grounds, 2 June 1984.

Area	Number of caribou	% Calves
Komakuk Beach to Demarcation Bay	743	10.5
Demarcation Bay to Egaksrak River	255	24.3
Upper Niguanak River to Jago Delta	50	20.0

Surveys to determine initial productivity in the general caribou population were not conducted in 1984. Among collared females, 23 of 31 (74%) aged 3 years or older gave birth to calves. No collared 2-year-olds showed any signs of pregnancy; 28 of 29 with active collars were observed during the calving period, and all lacked hard antlers and/or were growing new, velvet antlers by 1 June. Thus, for the second year, no 2-year-olds were observed to give birth to calves in the Porcupine Herd. The same has been noted for Central Arctic

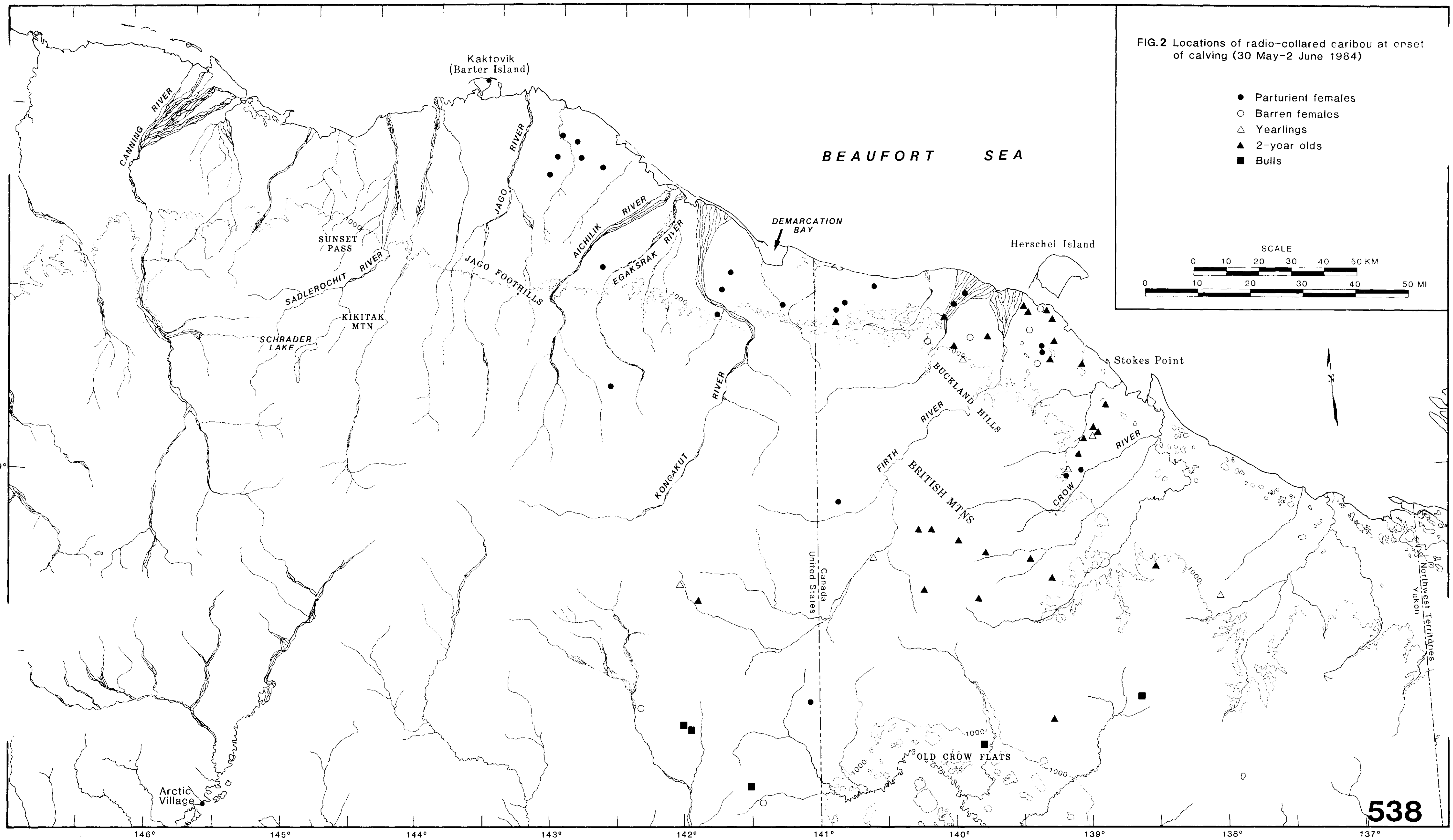

FIG. 2 Locations of radio-collared caribou at onset of calving (30 May-2 June 1984)

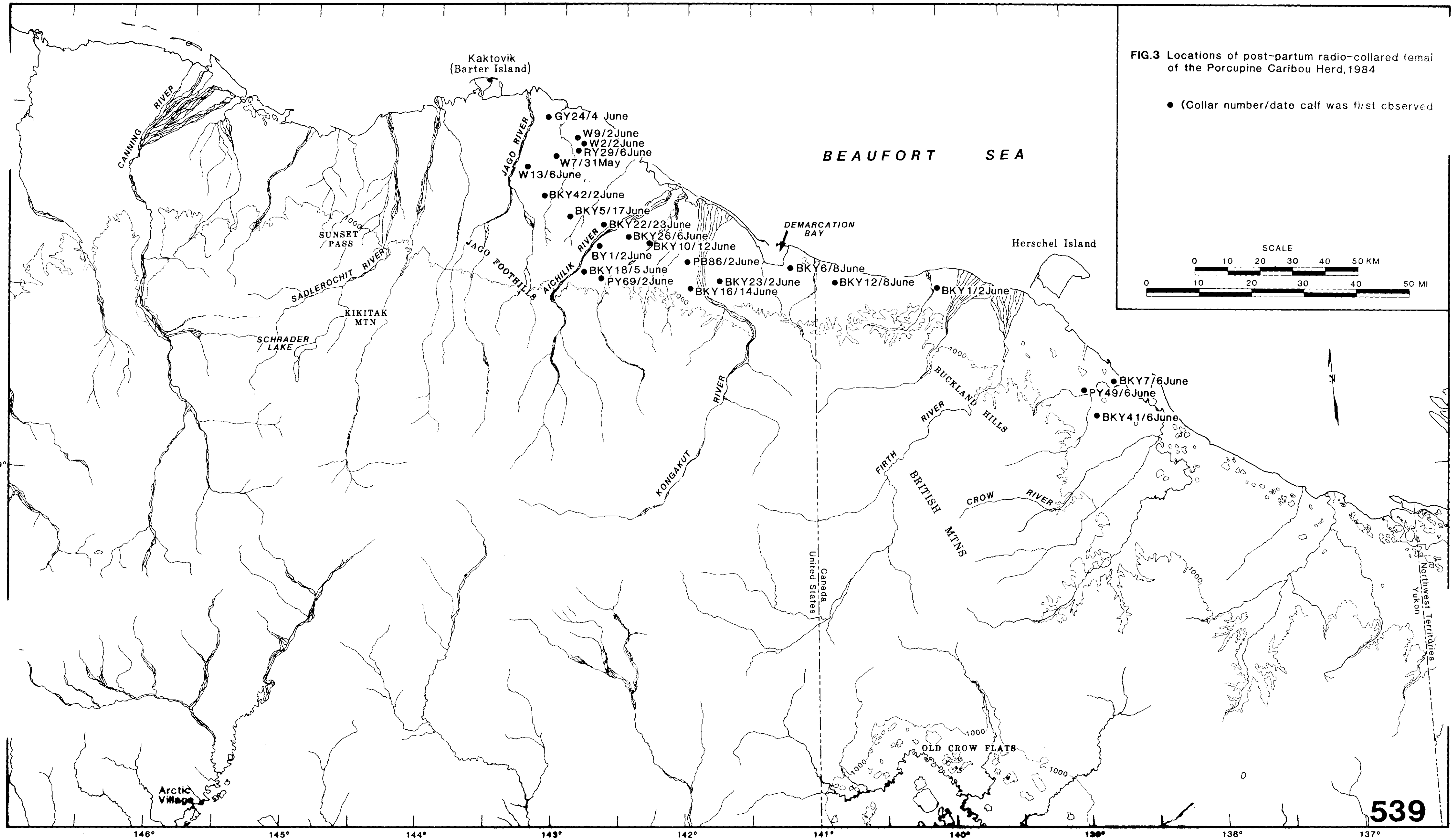
FIG.3 Locations of post-partum radio-collared femal of the Porcupine Caribou Herd, 1984
● (Collar number/date calf was first observed
SCALE
0 10 20 30 40 50 KM
0 10 20 30 40 50 MI
BEAUFORT SEA
Kaktovik
(Barter Island)
GY24/4 June
W9/2June
W2/2June
RY29/6June
W7/31May
W13/6June
BKY42/2June
BKY5/17June
BKY22/23June
BKY26/6June
BKY10/12June
BY1/2June
BKY18/5 June
PY69/2June
PB86/2June
BKY23/2June
BKY16/14June
BKY6/8June
BKY12/8June
BKY1/2June
BKY7/6June
PY49/6June
BKY41/6June
DEMARCATION BAY
Herschel Island
CANNING RIVER
JAGO RIVER
SUNSET PASS
SADLEROCHIT RIVER
KIKITAK MTN
SCHRADER LAKE
JAGO FOOTHILLS
AICHILIK RIVER
KONGAKUT RIVER
BUCKLAND HILLS
FIRTH RIVER
BRITISH MTNS
CROW RIVER
OLD CROW FLATS
Canada
United States
Northwest Territories
Yukon
Arctic Village
1000
69°
146° 145° 144° 143° 142° 141° 140° 139° 138° 137°

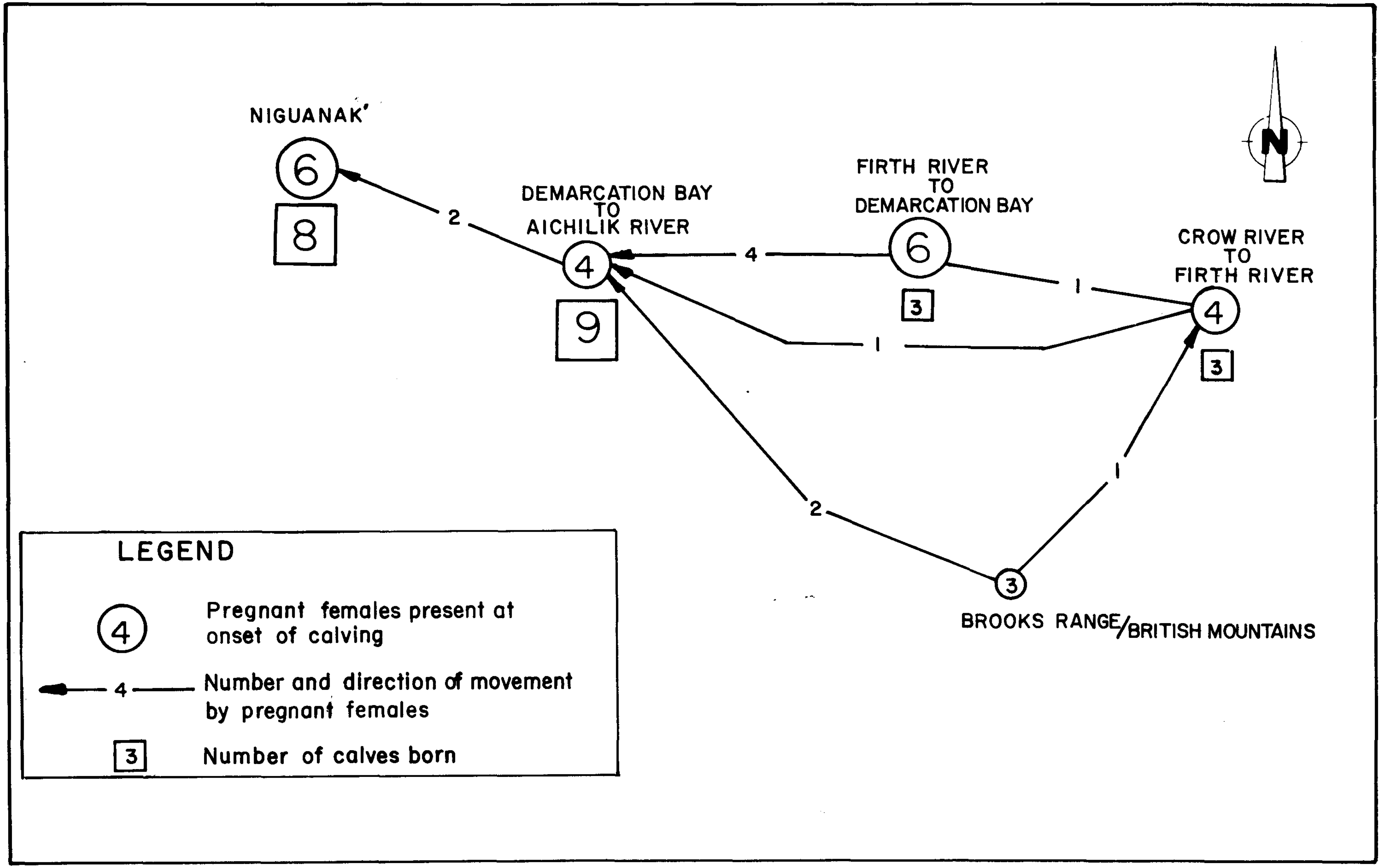

Fig. 4. SCHEMATIC REPRESENTATION OF MOVEMENTS BY PREGNANT RADIO-COLLARED FEMALE CARIBOU DURING THE 1984 CALVING PERIOD.

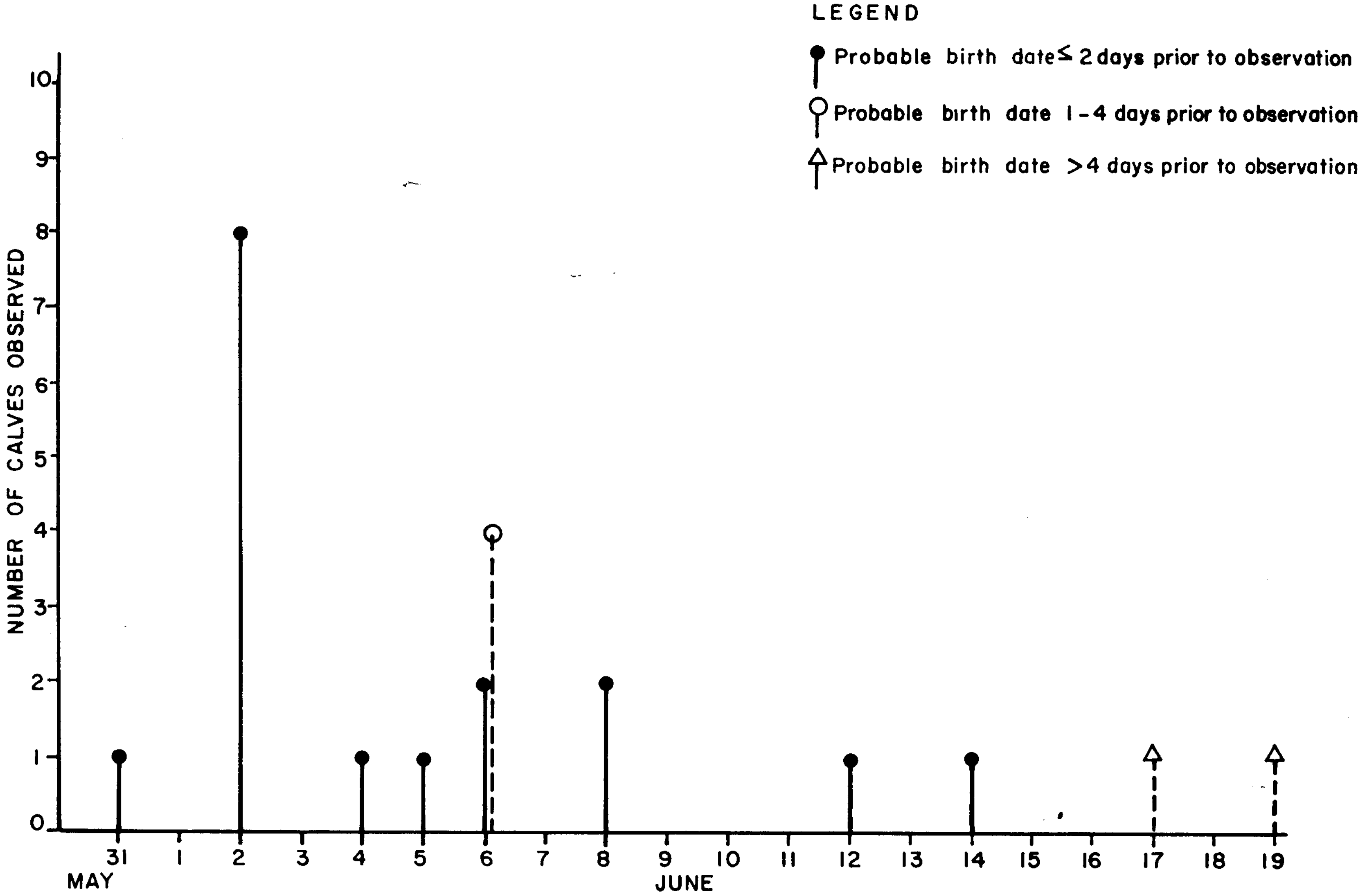

Fig. 5. Dates when newborn calves of 23 radio-collared cows were first observed, Porcupine caribou herd, 1984.

Herd caribou. If this pattern is normal, then population growth potential for the arctic caribou herds in Alaska is lower than for some caribou herds in interior Alaska, where 50% or more of the 2-year-olds may be pregnant (Davis and Valkenburg 1984), but is quite similar to Canadian barren ground caribou (Dauphine 1976).

Initial productivity among collared cows is difficult to compare to overall herd productivity. Collared cows are seldom a representative sample, and the 1984 collared cow cohort is clearly biased toward nonpregnant 2-year-olds. Nevertheless, initial productivity among collared cows aged 3 years or older was quite similar in 1982, 1983, and 1984 (67%, 78%, 74%, respectively) (Whitten et al. 1984, Whitten and Cameron 1983), and overall productivity was presumably similar in all 3 years.

Calf Capture

On 3 June, 30 calves were captured and fitted with radio-collars in the high density calving area along the Niguanak River. Thirty calves were captured in another high density calving area located between the Aichilik and Turner Rivers on 5-6 June (Fig. 1). Eleven additional calves were captured in the high density Niguanak River area on 5 June. One additional calf was collared in this same area on 6 June. Four additional calves were collared on 7 June near the Kongakut River, and one more calf was collared in this same area on 8 June (Table 3). The 17 additional calves were collared due to study induced abandonment in the original 60 calves (see Results and Discussion section of this report).

Cumulative time required for capture operations to search, capture, process and release 77 calves was 7 h 41 min. Average search/capture/processing time was 6.7 min, with processing time averaging 2.9 min and search/capture averaging 3.7 min. Ground observers were not used to determine reunions. Fixed-wing aircraft monitoring techniques were successful in documenting reunions and/or cases of study-induced abandonment.

The average weight for all calves captured (Table 3) was 6.85 kg. Males were slightly heavier on the average, 7.09 kg vs. 6.74 kg for the females. The estimated age of captured calves was 1.92 days old, and was nearly 1 day less than that of calves captured in 1983 (2.8 days old). There were 44 males and 33 females in the captured sample (1.3 males:1 female).

Calf Mortality

During the period 3 June to 12 November, 1984, 33 study calf mortalities were detected and investigated. Mortality signals were recorded for two additional study calves, however, logistical problems have prevented investigation of their status prior to this progress report. Case histories for each mortality are included in the Appendix. Probable study-induced abandonment (17 cases) accounted for 51.5% of all detected mortality (Table 4).

Study-induced mortality (abandonment by the dams or predisposition to predators) is inherent with radio-transmitter techniques. Transfer of foreign scent, either from the capture crew members of from previously captured calves may influence study-induced abandonment. Care was taken to minimize transfer of human scent by wearing disposable, sterile latex gloves, and by holding

Table 3. Physical characteristics and survival related observations of radio-collared caribou calves, Arctic National Wildlife Refuge, 1984.

Calf no.	Capture date	Location	Sex	Weight (kg)	Length (cm)	Hind foot length(cm)	New hoof length(mm)	Umbilicus condition	Hoof condition[a]	Estimated age[b]	Handling time(min)	Status
1	3 June 84	Niguanak R.	F	8.2	85	34.0	9.1	Absent	H/W	3	6.0	Dead (21 Sept)
2	3 June 84	Niguanak R.	M	7.9	81	37.0	9.2	Absent	H	3	5.0	Dead (5 June)
3	3 June 84	Niguanak R.	M	8.0	86	32.0	7.2	Moist	H/W	1	4.0	Dead (4 June)
4	3 June 84	Niguanak R.	F	6.2	76	34.5	8.6	Moist	PH	2	3.0	Alive
5	3 June 84	Niguanak R.	M	6.7	80	32.5	8.4	Moist	PH/SHW	2	3.0	Alive
6	3 June 84	Niguanak R.	M	6.8	79	33.0	8.6	Bloody	PH/S	1	2.0	Alive
7	3 June 84	Niguanak R.	F	6.9	78	32.0	8.9	Moist	PH/W	3	3.0	Alive
8	3 June 84	Niguanak R.	M	7.1	77	32.5	8.6	Dry	H/W	3	3.0	Dead (5 June)
9	3 June 84	Niguanak R.	M	5.5	75	33.0	7.9	Dry	PH/W	2	3.0	Dead (28 August)
10	3 June 84	Niguanak R.	M	7.3	79	34.5	9.4	Moist	PH/W	3	3.0	Dead (5 June)
11	3 June 84	Niguanak R.	M	6.9	75	32.0	8.5	Bloody	PH/W	1	3.0	Alive
12	3 June 84	Niguanak R.	M	6.9	80	33.0	9.2	Moist	H/W	3	5.0	Alive
13	3 June 84	Niguanak R.	F	7.2	81	34.5	8.6	Moist	H/W	3	3.0	Dead (5 June)
14	3 June 84	Niguanak R.	M	7.5	86	33.0	7.8	Dry	PH/W	1	3.0	Alive
15	3 June 84	Niguanak R.	M	6.2	78	33.0	7.0	Moist	PH/W	1	3.0	Dead (5 June)
16	3 June 84	Niguanak R.	F	6.9	87	34.7	8.1	Dry	H/W	2	3.0	Dead (5 June)
17	3 June 84	Niguanak R.	M	7.8	89	34.5	9.8	Dry	PH/W	4	10.0	Alive
18	3 June 84	Niguanak R.	M	7.1	84	36.5	9.2	Moist	PH/W	3	6.0	Alive
19	3 June 84	Niguanak R.	F	6.6	82	31.5	7.8	Dry	H/W	1	3.0	Alive
20	3 June 84	Niguanak R.	F	6.0	78	33.0	7.8	Dry	H/W	1	3.0	Alive
21	3 June 84	Niguanak R.	F	7.8	84	35.5	8.9	Dry	H/W	3	3.0	Dead (5 June)
22	3 June 84	Niguanak R.	F	7.6	85	34.5	10.2	Dry	H/W	5	3.0	Alive
23	3 June 84	Niguanak R.	F	6.1	83	31.8	7.5	Moist	PH/W	1	3.0	Alive
24	3 June 84	Niguanak R.	F	6.1	82	32.0	7.1	Moist	H/W	1	4.0	Dead (4 June)
25	3 June 84	Niguanak R.	M	7.2	89	35.0	10.4	Moist	PH/W	3	3.0	Alive
26	3 June 84	Niguanak R.	F	7.5	91	34.0	8.1	Dry	PH/W	2	2.0	Dead (6 June)
27	3 June 84	Niguanak R.	F	5.4	72	31.0	6.9	Dry	PH/W	1	3.0	Dead (4 June)
28	3 June 84	Niguanak R.	M	8.0	84	33.5	7.7	Dry	H/W	1	3.0	Dead (5 June)
29	3 June 84	Niguanak R.	M	7.5	81	35.0	9.3	Dry	PH/W	3	2.0	Dead (28 August)
30	3 June 84	Niguanak R.	M	6.3	77	31.0	7.1	Dry	H/W	1	3.0	Alive
31	5 June 84	Egak/Kong R.	M	7.3	79	34.5	8.3	Dry	H/W	2	3.0	Alive
32	5 June 84	Egak/Kong R.	F	6.5	83	33.0	8.4	Dry	H/W	2	2.0	Dead (7 June)
33	5 June 84	Egak/Kong R.	M	7.6	86	33.5	9.2	Absent	H/W	3	3.0	Dead (21 Sept)
34	5 June 84	Egak/Kong R.	M	8.3	85	36.0	8.4	Dry	H/W	2	3.0	Alive

Table 3. (Continued).

Calf no.	Capture date	Location	Sex	Weight (kg)	Length (cm)	Hind foot length(cm)	New hoof length(mm)	Umbilicus condition	Hoof condition[a]	Estimated age[b]	Handling time(min)	Status
35	5 June 84	Egak/Kong R.	F	6.8	86	34.5	8.5	Dry	H/W	2	3.0	Alive
36	5 June 84	Egak/Kong R.	F	6.9	78	33.5	7.2	Moist	H/W	1	2.0	Alive
37	5 June 84	Egak/Kong R.	M	7.6	82	33.5	8.2	Dry	H/W	2	3.0	Dead (28 August)
38	5 June 84	Egak/Kong R.	F	-	73	33.5	7.6	Moist	H/W	1	3.0	Alive
39	5 June 84	Egak/Kong R.	M	6.3	81	33.5	8.7	Moist	PH/W	2	2.0	Dead (6 June)
40	5 June 84	Egak/Kong R.	F	6.8	87	34.5	8.7	Absent	H/W	3	3.0	Alive
41	5 June 84	Egak/Kong R.	M	4.1	71	30.0	7.3	Absent	PH/W	1	3.0	Dead (9 June)
42	5 June 84	Egak/Kong R.	F	6.4	82	35.5	8.4	Moist	PH/W	2	3.0	Alive
43	5 June 84	Egak/Kong R.	M	7.1	80	33.5	8.4	Dry	H/W	2	2.0	Dead (10 June)
44	5 June 84	Egak/Kong R.	F	8.2	84	34.5	9.0	Moist	H/W	3	2.0	Alive
45	5 June 84	Egak/Kong R.	M	4.9	76	32.5	7.0	Bloody	PH/W	1	3.0	Alive
46	5 June 84	Kongakut R.	F	6.7	75	33.0	8.3	Dry	H/W	2	2.0	Dead (22 August)
47	5 June 84	Kongakut R.	M	6.6	83	35.5	7.3	Absent	PH/W	1	2.0	Dead (8 June)
48	5 June 84	Kongakut R.	F	6.8	81	36.5	8.1	Bloody	PH/W	1	2.0	Alive
49	5 June 84	Kongakut R.	F	7.4	79	33.5	8.7	Dry	H/W	3	2.0	Alive
50	5 June 84	Kongakut R.	M	6.4	84	35.5	7.8	Bloody	H/W	1	3.0	Alive
51	5 June 84	E Kong. R.	F	5.6	77	32.5	8.2	Moist	PH/W	2	3.0	Dead (24 June)
52	5 June 84	E Kong. R.	M	8.0	89	35.0	8.7	Moist	H/W	3	3.0	Alive
53	5 June 84	E Kong. R.	M	5.1	73	32.5	7.8		S/SW	1	2.0	Dead (6 June)
54	6 June 84	E Kong. R.	M	6.4	84	35.5	9.2	Moist	H/W	3	2.0	Dead (21 Sept)
55	6 June 84	E Kong. R.	F	4.6	77	32.5	8.5	Dry	PH/W	2	2.0	Dead (22 August)
56	6 June 84	E Kong. R.	M	6.3	86	33.0	7.6	Dry		1	3.0	Dead (7 June)
57	5 June 84	E Kong. R.	F	7.5	85	34.5	7.9	Dry	H/W	1	2.0	Alive
58	6 June 84	E Kong. R.	M	7.1	88	35.0	7.6	Absent	H/W	1	3.0	Alive
59	6 June 84	E Kong. R.	M	7.2	84	37.5	7.3	Absent	H/W	1	2.0	Alive
60	6 June 84	E Kong. R.	M	7.7	87	35.0	9.2	Bloody	H/W	1	3.0	Alive
61	5 June 84	Niguanak R.	F	5.6	71	32.0	7.9	Moist	H/W	1	2.0	Dead (26 July)
62	5 June 84	Niguanak R.	M	8.6	86	34.0	8.0	Moist	H/W	2	2.0	Alive
63	5 June 84	Niguanak R.	M	12.0	92	37.0	10.4	Bloody	H/W	1	3.0	Alive
64	5 June 84	Niguanak R.	F	7.3	76	32.5	7.6	Dry	H/W	1	2.0	Alive
65	5 June 84	Niguanak R.	F	8.6	86	35.0	9.1	Dry	H/W	3	2.0	Alive
66	5 June 84	Niguanak R.	M	8.7	88	35.5	8.2			2	2.0	Dead (12 November)
67	5 June 84	Niguanak R.	M	7.2	78	33.0	9.2	Moist	H/W	3	2.0	Alive

Table 3. (Continued).

Calf no.	Capture date	Location	Sex	Weight (kg)	Length (cm)	Hind foot length(cm)	New hoof length(mm)	Umbilicus condition	Hoof condition[a]	Estimated age[b]	Handling time(min)	Status
68	5 June 84	Niguanak R.				No Data Sheet						
69	5 June 84	Niguanak R.	F	6.5	82	33.5	7.8			1	3.0	Alive
70	5 June 84	Niguanak R.	F	6.4	76	33.0	9.0	Dry	H/W	3	3.0	Alive
71	5 June 84	Niguanak R.	M	5.3	75	31.5	8.4	Moist	PH/W	2	3.0	Alive
72	6 June 84	Niguanak R.	M	6.1	81	34.0	6.8	Moist	PH/W	3	3.0	Alive
73	7 June 84	E Kong. R.	F	6.6		33.5	7.6	Moist	PH/W	1	3.0	Dead (13 June)
74	7 June 84	E Kong. R.	M	7.5		35.0	7.7	Dry	H/W	1	3.0	Dead (28 August)
75	7 June 84	E Kong. R.	F	6.0	83	34.5	8.1	Moist	PH/W	2	2.0	Alive
76	7 June 84	E Kong. R.	M	7.3	80	36.5	8.6	Bloody	PH/W	1	3.0	Dead (21 August)
77	8 June 84	Kongakut R.	M	7.6	83	33.5	8.2	Dry	H/W	2	3.0	Alive
		Male Averages		7.09	81.9	34.0	8.40			1.88		
		Female averages		6.74	78.3	33.6	8.25			1.97		
		Overall averages		6.85	81.4	33.8	8.33			1.92	2.93	

[a] AH=all hardened; PH=partially hardened; S=soft; W=hooves worn; SW=slightly worn.
[b] Age rounded to nearest whole day.

calves at arm's length or pressed to the ground. In 1982 and 1983, collars were retrieved from calves that died soon after capture and these collars were used again on newly captured calves. Some collars were reused more than once.

Table 4. Probable causes of mortality for 33 of 77 radio-collared caribou calves between 3 June and 12 November, 1984.

Category	Number of calves	% Total mortality
I. Predation-excluded deaths		
1. Starvation		
a. probable study-induced abandonment	14	42.4
b. probable natural abandonment		
2. Exposure/accident		
a. accident		
b. hunter kill	1	3.0
c. drowning	1	3.0
d. exposure		
3. Disease	1	3.0
4. Undetermined		
II. Predation and/or scavenging involved		
1. Scavenging		
a. mammalian scavenger		
b. avian scavenger/study-induced abandonment	3	9.1
c. undetermined scavenger	1	3.0
2. Predation		
a. Predator kill and other factors		
b. Predator kill		
1. Golden eagle kill	1	3.0
2. mammalian predator		
a. brown bear	1	3.0
b. wolf	2	6.0
c. undetermined mammal	8	27.2
3. Undetermined if predator		
Totals	33	100%

Reused collars were rinsed in cold water, but may have still had scent from a previous calf. Apparent abandonment was 7 out of 60 in the original collaring effort in 1983, but 4 out of 9 among recollars (Whitten et al. 1984). In 1984, 12 of 30 calves were abandoned after the first day of capture, possibly due to use of a large sling (a commercial canvas "log carrier") for weighing calves. It was difficult to keep a struggling calf in the sling and holes were eventually cut for the forelegs. The large surface area may have collected and transferred scent from one calf to another. In 1982, burlap sacks were used to wrap each calf and a scale was hooked through the ends of the sack for weighing. The process was awkward, but sacks were used once and discarded and abandonment was low. In 1983, attempts were made to use large sterile gauze pads to wrap around the calves, but these were too fragile (Whitten et al. 1984). A leather belt with the end run around the calf's chest and back through the buckle to form a tight noose was subsequently used to weight calves in 1983. This method was fast and efficient and probably transferred minimal scent. After the sling proved unsatisfactory on the first day in 1984, the belt system was used thereafter.

In 1984, collars were again reused, but were first rubbed with moss and soil and stored in a large plastic bag with moss and soil in an attempt to mask human and other calf scents. Dickinson et al. (1980) first reported using vegetation to mask human and other neonate scents in a neonatal mortality study of desert native mule deer (Odocoileus hemionus) in southwest Texas. When caribou calf capture was resumed two days later in 1984, the abandonment rate dropped to 5 of 42. Those five collars were also descented and reused. None of the calves receiving descented and reused collars were abandoned. After these experiences, it is recommended that similar descenting be routine for all collars to remove scents from handling preparation as well as from previous calves. This descenting may reduce the approximate 10% abandonment rate that appears to be inherent under the best conditions.

Excluding study-induced mortality, the natural mortality rate for the remaining sample group of 60 calves was 26.8% (n=16) between 3 June and 12 November 1984 (Table 5). In 13 of 16 cases (81.25%) predation was either confirmed or identified as the most probable cause of mortality. Most of the predation-related mortality (9 cases, 76.9%) occurred during August to October when monitoring was conducted on a monthly rather than daily basis, due to logistical considerations (Fig 6). Because of frequently long time lapse between when mortalities occurred and when they were subsequently detected and investigated, in only two cases was there sufficient evidence remaining at the carcass sites to determine the predator species involved. During intensive monitoring (3 June to 6 July) only four mortalities occurred, however, investigation was timely and causes of mortality were established.

Table 5. Proportion of observed natural mortalities occurring radio-collared caribou calves during 3 June to 12 November 1984.

Mortality category	Number of calves	Proportion(%) of sample calves	Proportion(%) of natural mortality
Undetermined - predation/ scavenging involved	9	15.0	56.25
Wolf predation	2	3.3	12.50
Brown bear predation/ scavenging	1	1.7	6.25
Golden eagle predation	1	1.7	6.25
Accidental	1	1.7	6.25
Disease (pneumonia)	1	1.7	6.25
Human harvest	1	1.7	6.25
Totals	16	26.8	100.00

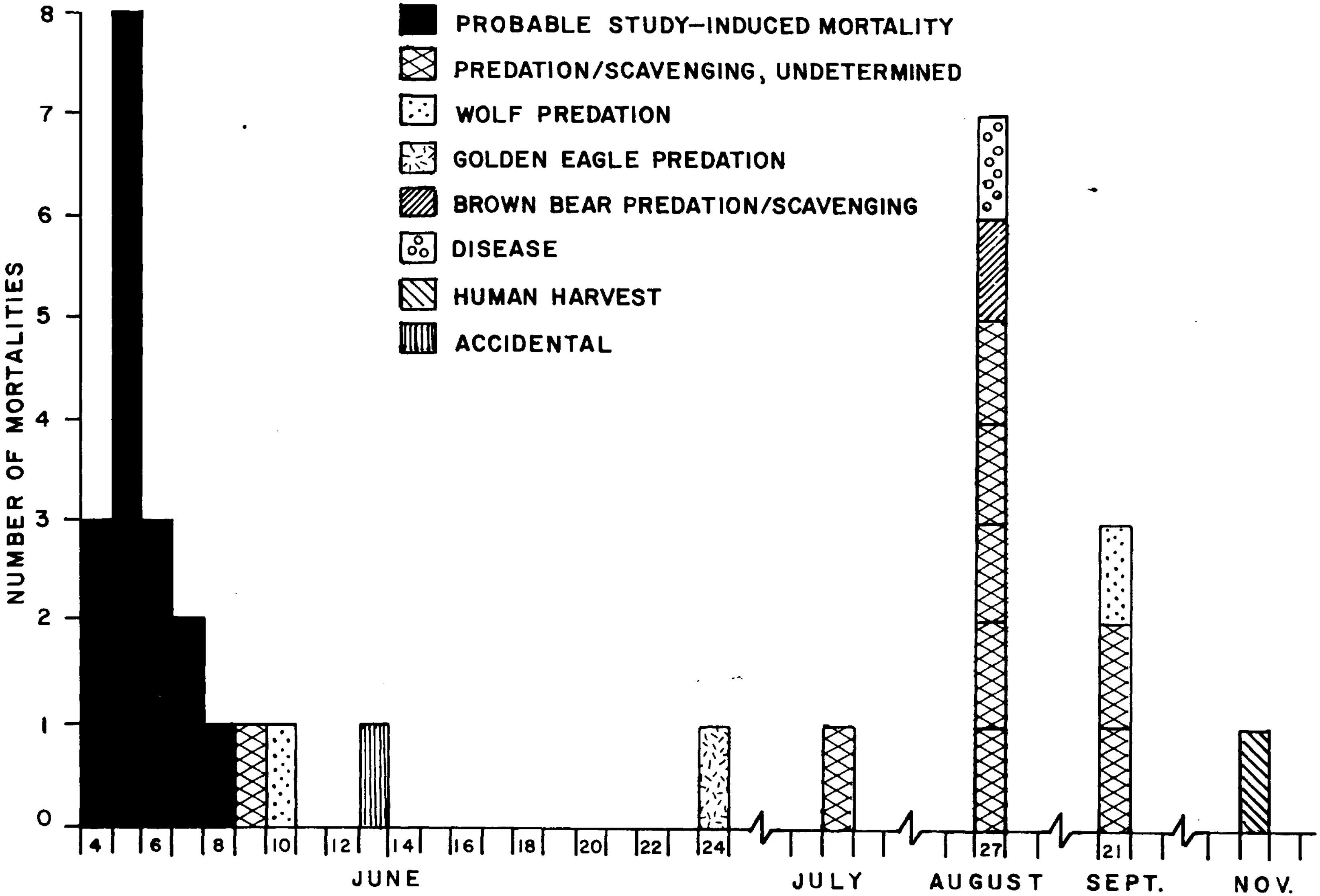

Fig. 6. Chronology of observed mortalities among 33 radio-collared calves, Porcupine caribou herd, 1984.

Predation of study calves by wolves was determined in two instances. The first case was detected on 10 June in the foothills near the Ekaluakat River, when a radio-collared wolf was in the vicinity; the second case was detected 21 September near Pine Creek, Yukon Territory. Wolves were observed on or near the calving grounds more frequently in 1984 than in preceding years. This could be partially related to increased observer effort associated with the initiation of wolf studies in the area at calving time (Weiler et al. 1985). Little information exists regarding wolf abundance on the remainder of the Porcupine Caribou Herd's range, but wolves are presumed to be at higher densities within and south of the Brooks Range. For the seven mortalities occurring during August and September for which predator species could not be determined, wolves were strongly suspected.

One case of predation by a golden eagle was detected among the study calves. This differs somewhat from 1983 results when three golden eagles kills were recorded. The relatively small samples involved, however, preclude complete evaluation of the hypothesis that visual factors such as the color of radio collars may influence rates of predation by golden eagles (See Methods). Golden eagles were frequently observed on the calving grounds and post-calving areas (Mauer 1985). During the calving period (30 May - 15 June), eagles were distributed in a scattered, diffuse manner over the calving grounds. Concentrations of golden eagles were observed in late June and were closely associated with post-calving aggregations of caribou.

Eagles often remained congregated for 3-4 days in areas recently vacated by post-calving caribou, presumably scavenging on carcasses (Mauer 1985). During July, golden eagles were frequently observed in association with caribou herds which had moved into the British Mountains of Canada. Predation of caribou calves by golden eagles were observed as late as 9 and 23 July (D. Russell per comm).

A brown bear was involved as a predator or scavenger in at least one study calf mortality case. The calf involved (No. 37) had been observed on 2 August east of Old John Lake, Alaska, unaccompanied by its dam. Its carcass was subsequently found in a bear's kill cache on 29 August, 4.8 km from the previous observation site. Due to its potentially orphaned status, this calf may have been predisposed to predation.

One study calf (No. 73) was found on 13 June lying in shallow water near the west side of the Kongakut River. Although no water was found in the calf's lungs to indicate drowning, death was apparently due to an accident while crossing the river.

One study calf found on 28 August apparently died as a result of severe fibral pneumonia infection of the lungs and pericardium. On 12 November a study calf was shot by a hunter approximately 51 km north of Aklavik, NWT (Kent Jingfors pers. comm.). A study calf captured in 1983 was also killed by a hunter from Aklavik during November. These cases are the only instances of study calf mortality due to hunting detected thus far, although several collared adults have been shot in the past.

Eleven of the 16 natural mortalities were males and only 5 were females, (2.2 males/female). The sex ratio of all captured calves was 1.3 males/female. Although this higher mortality rate for males was not statistically different from the mortality rate of females, it is consistent with reports for other caribou populations (Kelsall 1968).

Four of 16 (25%) natural mortalities occurred during the calving and immediate post-calving period on the coastal plain in Alaska. The estimated ages of study calves that died on the calving/post-calving areas was 7 days(3 calves) and 21 days (1 calf)(Fig. 7). During the July post-calving movements only one mortality occurred. Mortalities increased sharply in August (n=7) and September (n=3), when the Porcupine herd was widely dispersed south of the continental divide in Alaska and Canada (Fig. 5). This pattern is similar to 1983 when initial mortality was also relatively high after birth, decreased in July and increased again during late summer and fall as caribou moved into areas with presumably higher predator densities (Whitten et al. 1984 and 1985). Evidence remaining at the carcass sites of August - September mortalities indicated that all but one case were probably predation-related. During August and September caribou were observed most often in shrub habitats and were perhaps more vulnerable to ambush by predators. Group sizes were smaller during this time and the herd was dispersed over a wide area, tending to make individual calves more vulnerable to attack by predators.

Nineteen carcasses of unmarked calves were collected from areas utilized by calving and post-calving caribou during 3 June to 6 July. Several additional carcasses were observed from fixed-wing aircraft, but could not be retrieved due to a lack of ground access. Necropsy examinations revealed that four of these calves (21.0%) were killed by golden eagles; two (10.5%) were killed by wolves; two (10.5%) were killed by brown bears; four (21.0%) were scavenged by birds/cause of death unknown; two (10.5%) died of starvation/pneumonia complications; one (5.25%) was stillborn, and one (5.25%) was subject to predation and/or scavenging by unknown species (Fig 8). Collection dates for the golden eagle kills ranged from 10 June to 6 July. The latter case involved a calf weighing 18 kg. The wolf kills were found associated with radio-collared wolves and documented by puncture wounds on the skull case matching wolf canine tooth dimensions. Interestingly there were no corresponding puncture wounds through the skin covering the skull, indicating a controlled squeeze of the calf's head rather than a bite or tear.

Two radio-collared adult females died on the calving/post-calving areas, however, it was not possible to determine causes of mortality. Four unmarked adult cow carcasses were also investigated. One appeared to have died or was predisposed to predation as a result of complications during birth. Another cow possibly died from parturition complications, however it was not possible to identify the exact cause of mortality. A brown bear apparently killed one cow and the fourth cow died of unknown causes.

Excluding study-related mortalities, calf survival on the calving and post-calving areas was generally good among radio-collared calves (93%) for 3 June to 6 July 1984. Calves born to radio-collared females (control calves) also survived well (95.6% during about the same period)(Appendix A-2). Slightly lower calf survival rates were reported in 1983 for study calves (82.5%) and control cows (72.2%)(Whitten et al. 1984).

The geographic distribution of caribou mortality sites (adults and calves) investigated on the calving and post-calving areas in Alaska was skewed towards the eastern coastal plain and foothills region (Aichilik River -

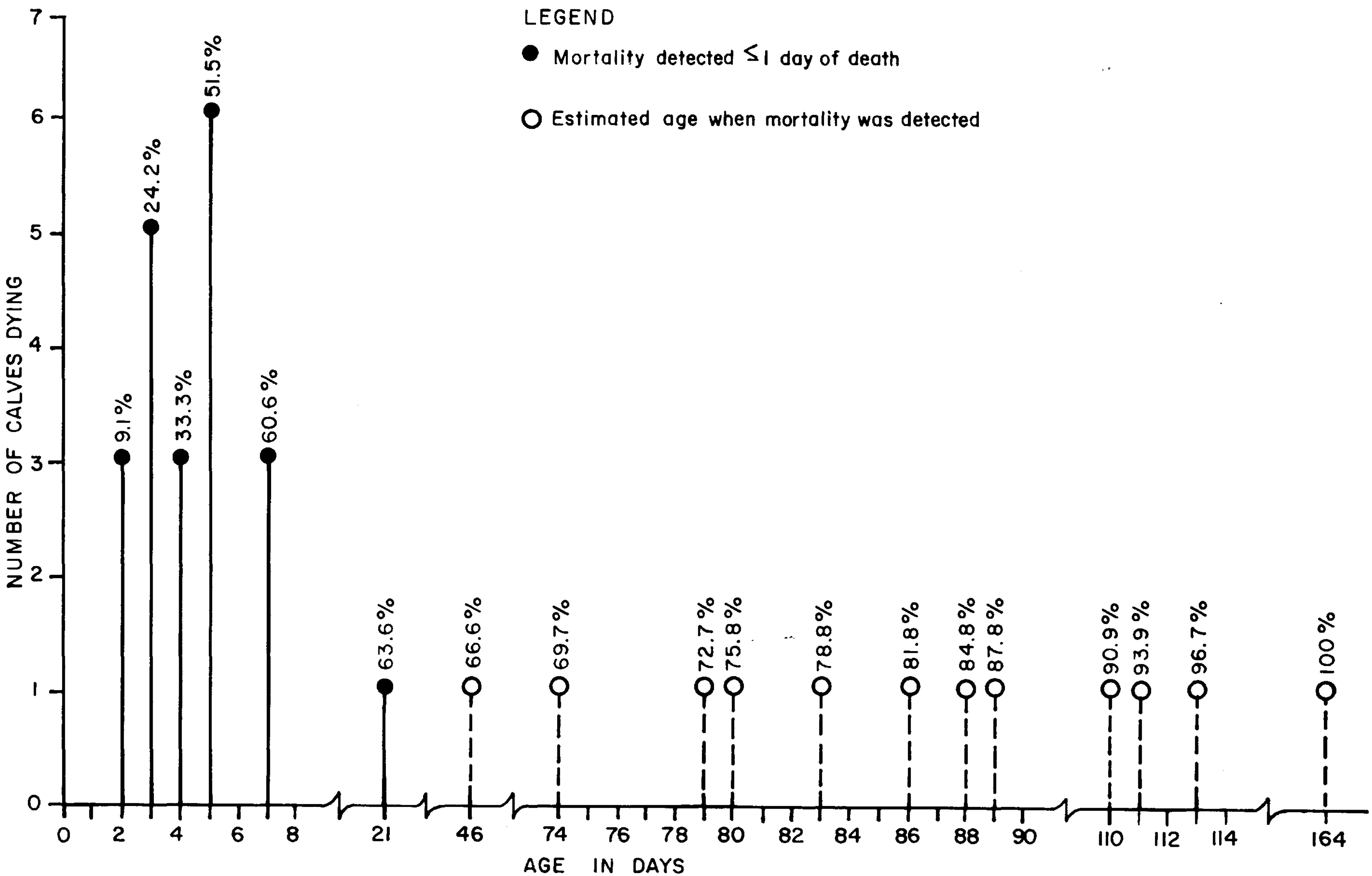

Fig. 7. Number of radio-collared caribou calves dying and cumulative proportions of mortality occurring within estimated age classes, Porcupine caribou herd, 1984.

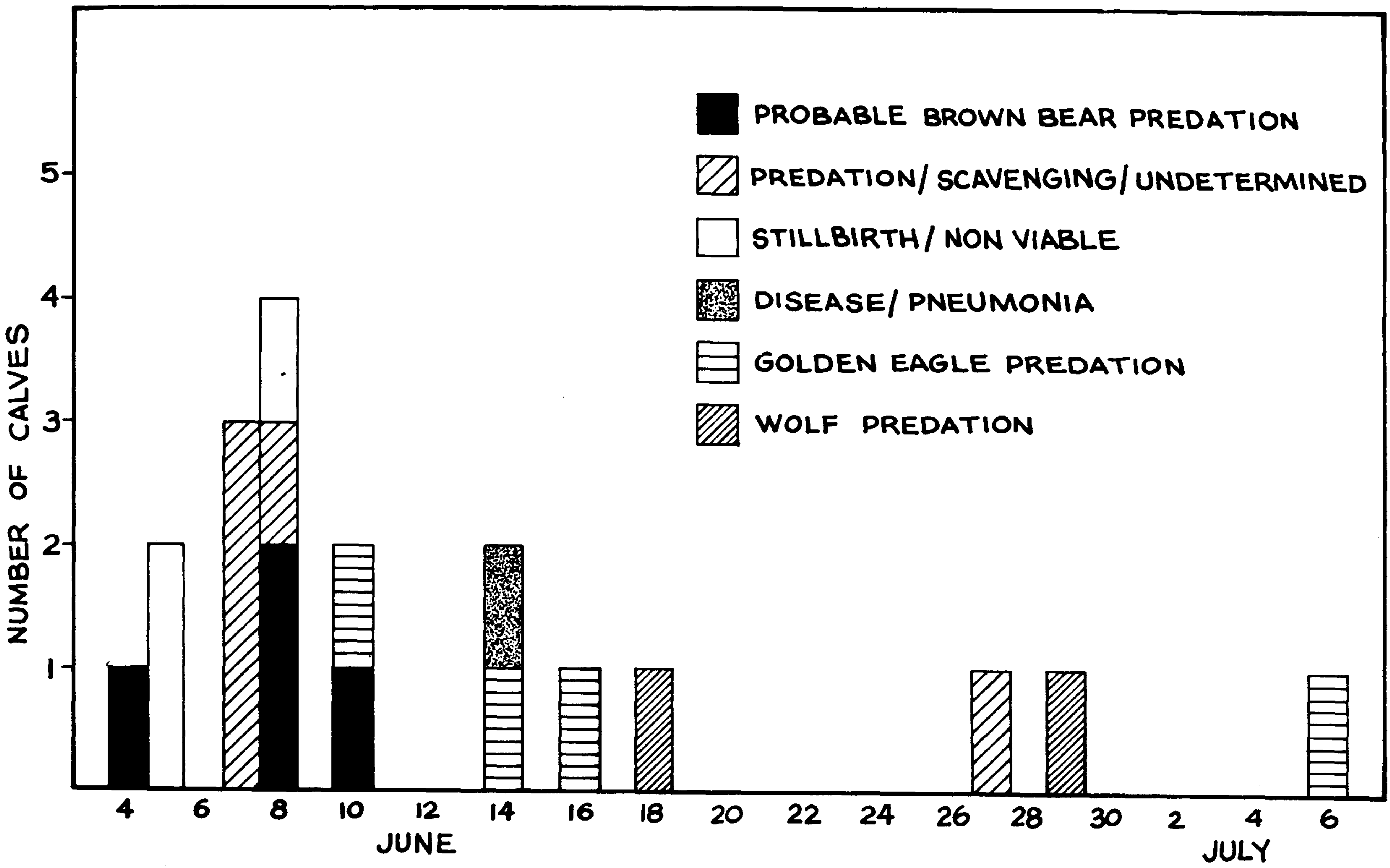

Fig. 8. Chronology of mortality detection by category for 19 unmarked calf carcasses, Porcupine caribou herd, 1984.

Canada border)(Fig 9). There was no natural mortality detected among study calves in the Niguanak River calving concentration area and only 2 of 17 mortality sites for unmarked calves were found there. All natural mortality of study calves detected during 3 June-6 July occurred in the Egaksrak-Kongakut calving area and involved only those calves that were originally captured there (Fig. 9). Thirteen of 17 unmarked calf carcasses for which the location of mortality was documented, were also found in the eastern area (Fig 9). Four unmarked adult females and one radio-collared adult female also died east of the Aichilik river. An additional radio-collared adult female died in the foothills approximately 13 km east of the international border. A majority (60%) of study calf mortality sites detected in 1983 also occurred in foothills terrain located to the south and east of coastal plain calving concentration areas (Whitten et al. 1984). These data suggest that mortality rates may be greater in eastern/southern "peripheral" calving areas adjacent to foothills and mountainous terrain than in the northern/western "core" calving areas of the coastal plain. Data regarding densities of reported observations of golden eagles (Mauer 1985), distribution and relative abundance of marked and unmarked brown bears (Garner et al. 1983, 1984, 1985) and the location of wolf dens and pack activity area (Weiler et al. 1985) tend to support this supposition. One note of caution in this hypothesis. Observer effort was higher in the eastern portion of the study area than the west, however, the disproportionate distribution of detected caribou mortalities in the eastern coastal plain would suggest that the hypothesis has some merit.

Movements

Calves captured and marked in the Niguanak River ("core") concentration area remained in the general area during the first two weeks post-capture. Their movement rates were low and non-directional (Fig 10). The movement rate for calves captured in the Egaksrak-Kongakut ("peripheral") calving area was also low during the same period, however, their movements were more directional on a west/northwest bearing (Fig 11). During this period, group size gradually increased in each area. By 18 June, the Niguanak study calves were in large groups and had established an east/southeastern direction of movement (Fig 10). The two groups merged on about 19-20 June on the coastal plains between the Niguanak and Aichikik Rivers (Fig 11). At this time, the west/northwest moving Egaksrak-Kongakut groups reversed it's direction in concert with the east/southeast movement of the Niguanak groups (Fig 10). During the first two weeks following calving the net movement rate/24h of the Egaksrak-Kongakut study calves increased from 2-3 km/day to 5 to 6 km/day (Fig 12). The direction of movement remained generally east-southeast and most caribou were now located in the foothills and northern flanks of the Brooks Range from the Kongakut River to the Aichilik River. During the period of 24-26 June the rate of movement continued to increase, reaching 18.5 km/day by 26 June.

A major separation occurred during this time in which about 2/3 of the radio-collared caribou moved along the coastal plain and foothills on an easterly course into Canada (Fig 10). The other portion moved along a southern course into the mountains between the Kongakut and Aichilik Rivers (Fig 10). Unfavorable weather conditions as well as logistical problems posed by the widely separated groups prohibited continuation of daily monitoring of these movements. Periodic surveys after 27 June found that the eastern distribution had reached the Firth River-Spring Creek area by 3 July and the

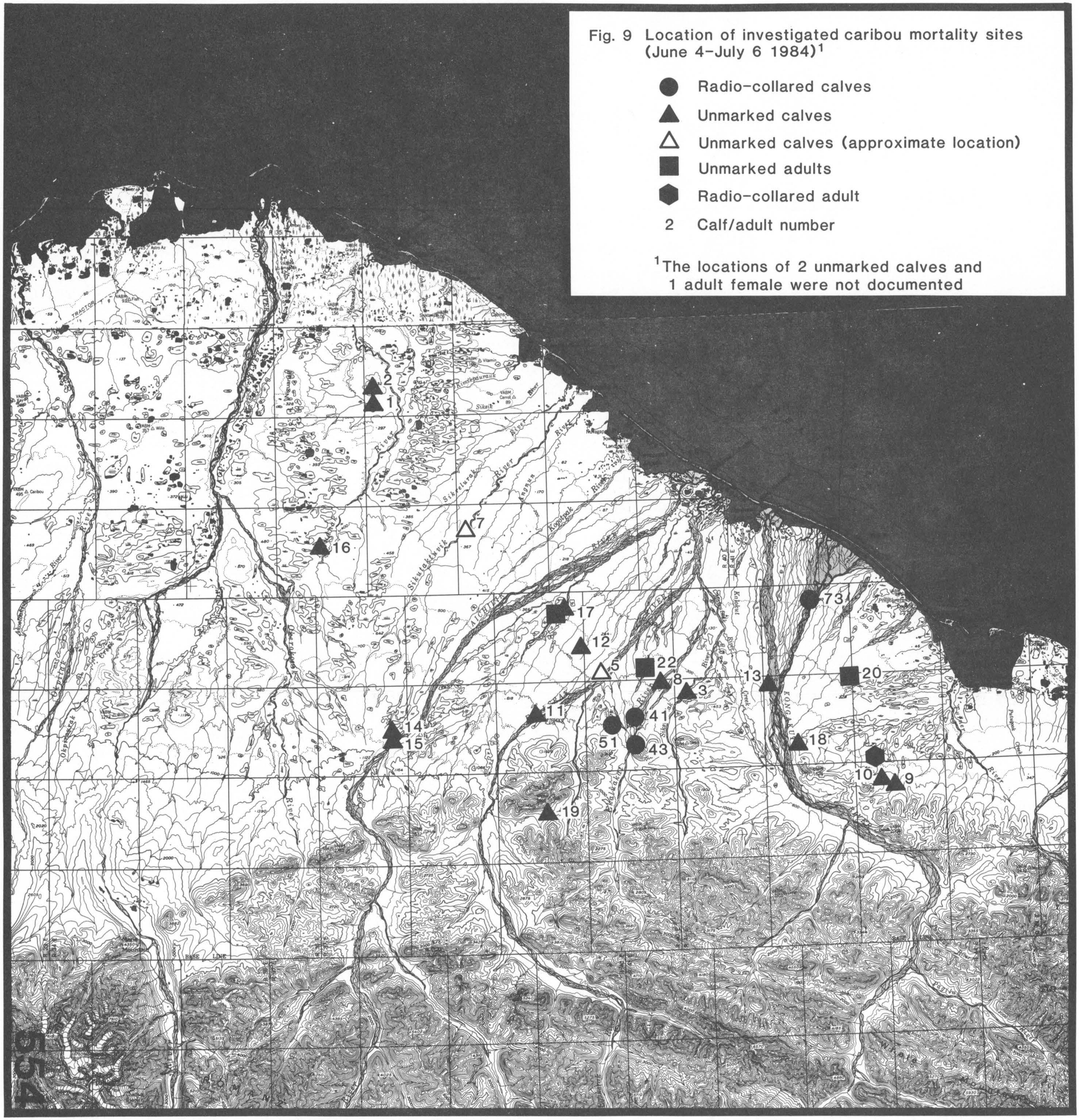

Fig. 9 Location of investigated caribou mortality sites (June 4-July 6 1984)[1]

Fig 10: Summary of movements and general distributions of calves radio-collared near the Niguanak River

(3-30 June, 1984)

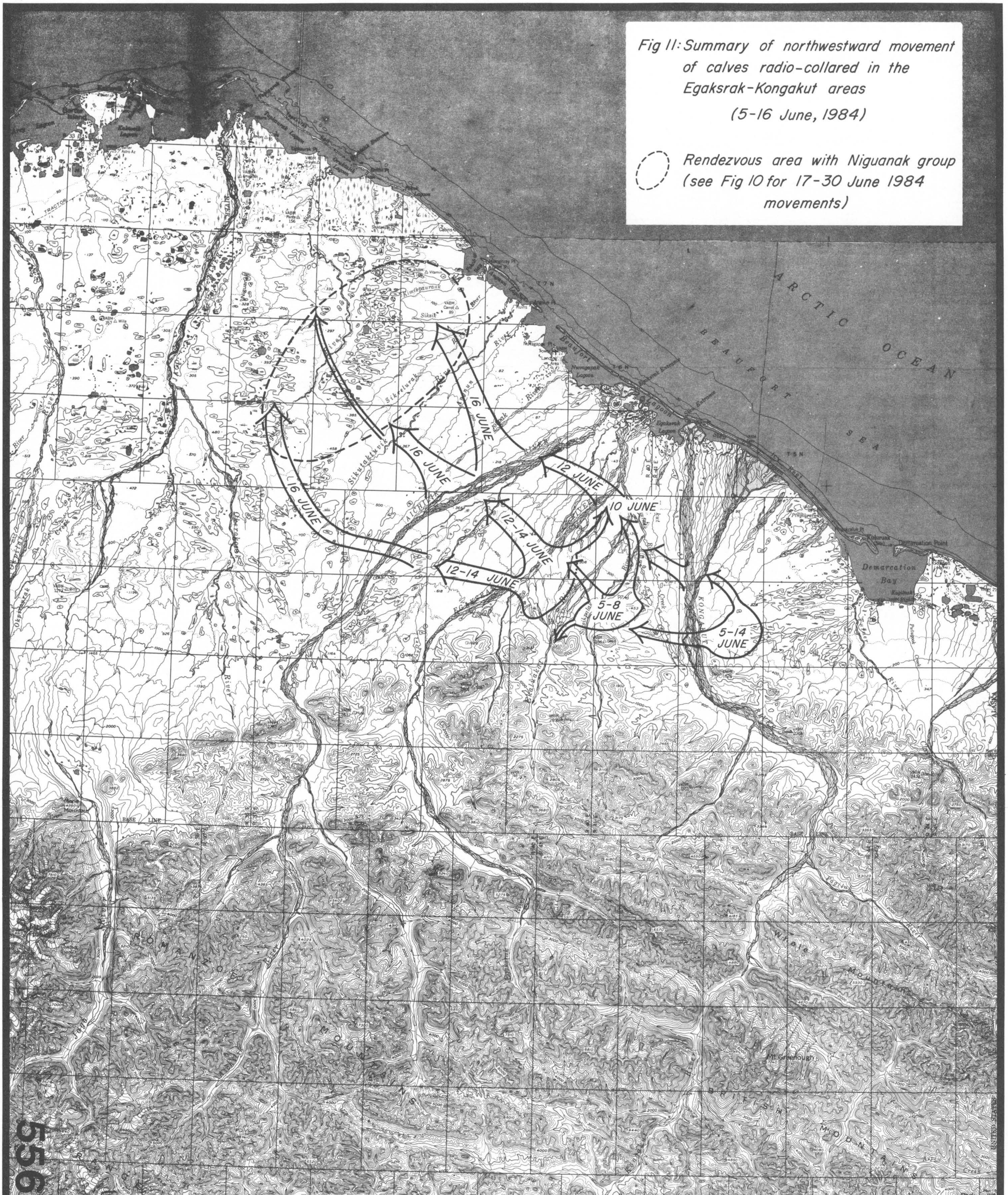

Fig 11: Summary of northwestward movement of calves radio-collared in the Egaksrak-Kongakut areas (5-16 June, 1984)

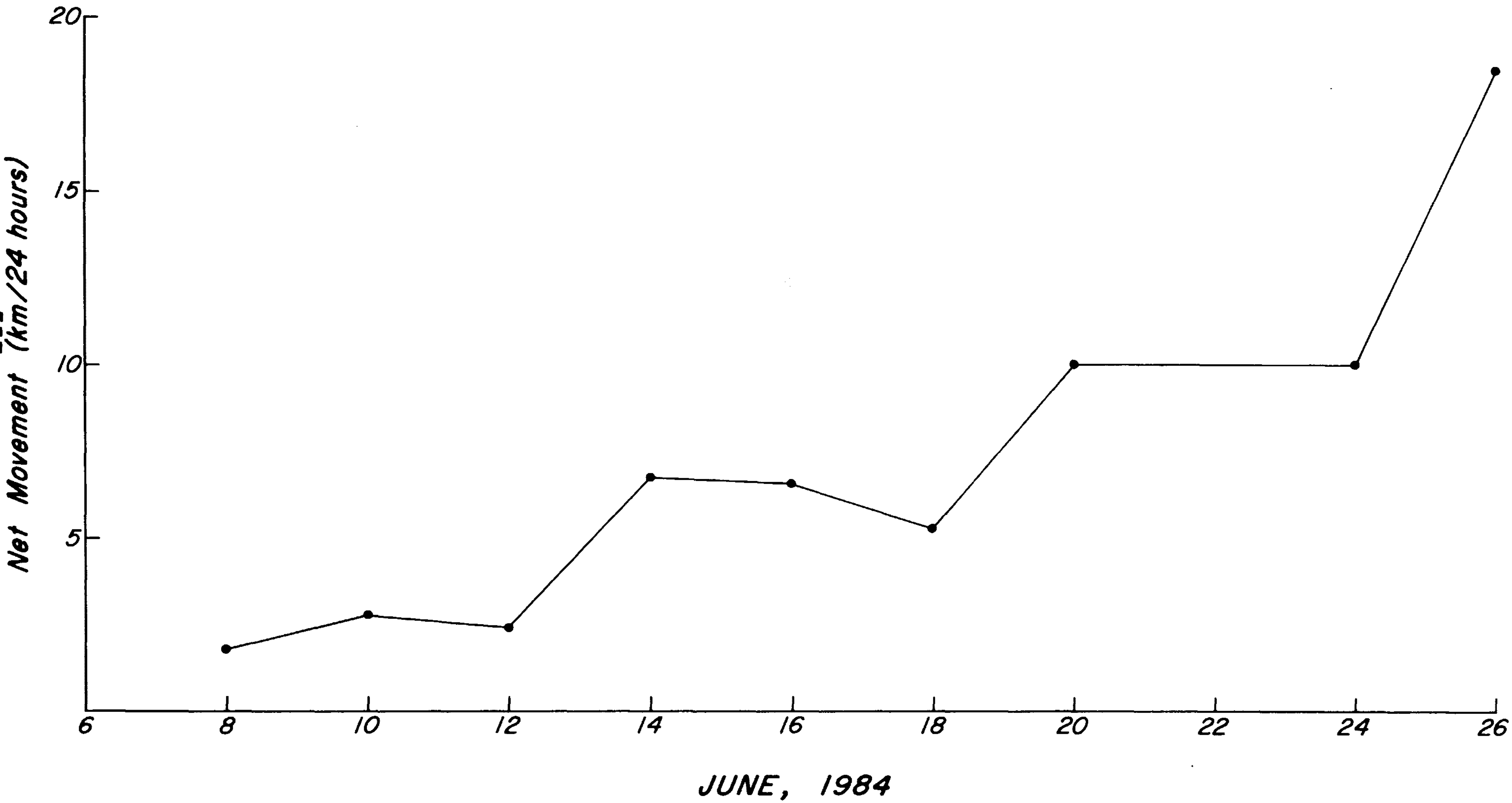

Fig. 12. Net movement rates for radio-collared caribou calves (8-26 June 1984).

southern distribution had crossed the continental divide between the Kongakut river drainage to the Sheenjek River and Coleen River drainages by 1 July. Movement by this group was especially rapid in the mountainous region and probably exceeded 25-30 km/day. During the same period (27 June-5 July), the eastern (coastal plains/foothills) group moved slower, spending 2-3 days in the Fish Creek basin before moving into mountainous terrain between the Malcolm and Firth Rivers.

Acknowledgements

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APPENDIX

ANWR Progress Report Number FY85-18

Mortality Case History

Calf No: 1
Sex: Female
Captured: 3 June 1984
Location: coastal plain between Jago and Niguanak Rivers.

Weight: 8.4 kg
Total Length: 85 cm
Umbilicus condition: absent
Right hind foot length: 34 cm
Hoof condition: hard/worn
New hoof length: 9.1 mm
Health Status: appeared healthy at capture
Processing time: 6 min.
Estimated age at capture: 3 days old
Cow-calf reunion: Capture crew did not observe reunion. Observed with dam the following day.

Signal Monitored: 29 times/ 110 day period
Number of visual relocations: 3
Mortality detected: 21 September 1984
Location: Thomas Creek, Yukon Territory
Carcass collected: 22 September 1984
Distance from capture site: 185 km
Carcass weight:
Response time: 24 hours
Total length:
Right hind foot length:
New hoof length:

Carcass condition and disposition: Partially covered by snow. Bones, hair and rumen present. Bones chewed/crushed, rumen contents scattered. Collar broken and stained with blood. No scats found.

Necropsy findings:

Mortality category: Predation/scavenging involved. Predator/scavenger undetermined (wolf probable).

Mortality Case History

Calf No: 2
Sex: Male
Captured: 3 June 1984
Location: coastal plain between Jago and Niguanak Rivers.

Weight: 8.1 kg
Total Length: 81 cm
Umbilicus condition: absent
Right hind foot length: 37 cm
Hoof condition: hard
New hoof length: 9.2 mm
Health Status: appeared healthy at capture
Processing time: 5 min.
Estimated age at capture: 3 days old
Cow-calf reunion: Capture crew observed reunion 1 min after release. Observed unattended by dam following day.

Signal Monitored: 3 times/ 2 day period
Number of visual relocations: 3
Mortality detected: 1109 5 June 1984
Location: Niguanak Ridge
Carcass collected: 1415 5 June 1984
Distance from capture site:
Carcass weight: 7.3 kg
Response time: 3 hours
Total length: 90 cm
Right hind foot length: 36 cm
New hoof length: 8.3 mm

Carcass condition and disposition: No indication of trauma. No caribou in immediate area.

Necropsy findings: Vegetation in abomasum and rumen, milk absent. All other internal organs normal. No indication of wounds or trauma associated with carcass.

Mortality category: Predation excluded, starvation, probable study-induced abandonment.

Mortality Case History

Calf No: 3
Captured: 3 June 1984

Sex: Male
Location: coastal plain between Jago and Niguanak Rivers.

Weight: 8.2 kg
Umbilicus condition: moist
Hoof condition: hard/worn
Health Status: appeared healthy at capture
Processing time: 4 min.

Total Length: 86 cm
Right hind foot length: 32 cm
New hoof length: 7.2 mm
Estimated age at capture: 1 day old

Cow-calf reunion: Capture crew did not observe reunion. Observed unattended by dam 1.5 hours after release.

Signal Monitored: 2 times/ 2 day period
Mortality detected: 4 June 1984
Carcass collected: 1956 4 June 1984
Carcass weight: 7.0 kg
Total length: 91 cm
Right hind foot length: 35 cm
New hoof length: 8.5 mm

Number of visual relocations: 2
Location:
Distance from capture site:
Response time:

Carcass condition and disposition: Lying on right side. No indication of trauma. No caribou in immediate area. No sign of predators.

Necropsy findings: Vegetation in abomasum, milk absent. All other internal organs normal.

Mortality category: Predation excluded, starvation, probable study-induced abandonment.

Mortality Case History

Calf No: 8
Sex: Male
Captured: 3 June 1984
Location: coastal plain between Jago and Niguanak Rivers.

Weight: 7.3 kg
Total Length: 77 cm
Umbilicus condition: dry
Right hind foot length: 32.5 cm
Hoof condition: hard/partially worn
New hoof length: 8.6 mm
Health Status: appeared healthy at capture
Processing time: 3 min.
Estimated age at capture: 3 days old
Cow-calf reunion: Capture crew did not observe reunion. Observed with dam 1.5 hours after release.

Signal Monitored: 3 times/ 2 day period
Number of visual relocations: 3
Mortality detected: 1114 5 June 1984
Location:
Carcass collected: 1406 5 June 1984
Distance from capture site:
Carcass weight: 6.4 kg
Response time: 3 hours
Total length: 81 cm
Right hind foot length: 34 cm
New hoof length: 7.1 mm

Carcass condition and disposition: No indication of trauma. No caribou in immediate area. No sign of predators.

Necropsy findings: Vegetation fragments in abomasum, milk absent. All other internal organs normal. No indication of wounds or trauma associated with carcass.

Mortality category: Predation excluded, starvation, probable study-induced abandonment.

Mortality Case History

Calf No: 9
Sex: Male

Captured: 3 June 1984
Location: coastal plain between Jago and Niguanak Rivers.

Weight: 5.7 kg
Total Length: 75 cm

Umbilicus condition: dry
Right hind foot length: 33 cm

Hoof condition: partially hard/worn
New hoof length: 7.9 mm

Health Status: appeared healthy at capture

Processing time: 3 min.
Estimated age at capture: 2 days old

Cow-calf reunion: Capture crew did not observe reunion. Observed without dam 1.5 hrs after release. Observed with dam following day.

Signal Monitored: 28 times/ 27 day period
Number of visual relocations: 4

Mortality detected: 28 August 1984
Location: Marten Creek, Alaska

Carcass collected: 29 August 1984
Distance from capture site: 225 km

Carcass weight:
Response time: 24 hours

Total length:

Right hind foot length:

New hoof length:

Carcass condition and disposition: No carcass found. Collar under snow. Collar torn and blood stained (blood test positive).

Necropsy findings:

Mortality category: Predation/scavenging involved. Predator/scavenger undetermined.

Mortality Case History

Calf No: 10
Sex: Male
Captured: 3 June 1984
Location:

Weight: 7.5 kg
Total Length: 79 cm
Umbilicus condition: moist
Right hind foot length: 34.5 cm
Hoof condition: partially hard/worn
New hoof length: 9.4 mm
Health Status: appeared healthy at capture
Processing time: 3 min.
Estimated age at capture: 3 days old
Cow-calf reunion: Capture crew did not observe reunion. Calf followed crew to helicopter. Unattended by dam 1.5 hours and 24 hours after release.

Signal Monitored: 2 times/ 2 day period
Number of visual relocations:
Mortality detected: 1234 5 June 1984
Location:
Carcass collected: 1234 5 June 1984
Distance from capture site:
Carcass weight: 5.9 kg
Response time:
Total length: 86 cm
Right hind foot length: 35.5 cm
New hoof length: 6.9 mm

Carcass condition and disposition: Dispatched by project investigators when abandonment was apparent and starvation imminent. No caribou or predators observed in immediate area.

Necropsy findings: Vegetation in abomasum, milk absent. Lungs appeared slightly bloody. All other internal organs normal.

Mortality category: Predation excluded, euthenized, starvation imminent. Probable study-induced abandonment.

Mortality Case History

Calf No: 13
Captured: 3 June 1984

Sex: Female
Location: coastal plain between Jago and Niguanak Rivers.

Weight: 7.4 kg
Umbilicus condition: moist
Hoof condition: hard/worn
Health Status: appeared healthy at capture
Processing time: 3 min.

Total Length: 81 cm
Right hind foot length: 34.5 cm
New hoof length: 8.6 mm

Estimated age at capture: 3 days old

Cow-calf reunion: Capture crew did not observe reunion. Unattended by dam 1.5 hours and 24 hours after release.

Signal Monitored: 3 times/ 2 day period
Mortality detected: 1143 5 June 1984
Carcass collected: 1236 5 June 1984
Carcass weight: 6.1 kg
Total length: 81 cm
Right hind foot length: 32.4 cm
New hoof length: 6.7 mm

Number of visual relocations:
Location:
Distance from capture site:
Response time: 1 hour

Carcass condition and disposition: Hole (42.6 mm diameter) on right rump, hemorrhage at wound (appears to be made by an avian scavenger). No other indication of trauma. No caribou in the immediate area. No other sign of predators.

Necropsy findings: Vegetation in abomasum, milk absent. All other internal organs normal. No other indication of trauma.

Mortality category: Predation/scavenging involved (avain sp.) - predisposed due to probable starvation/study-induced abandonment.

Mortality Case History

Calf No: 15
Captured: 3 June 1984
Sex: Male
Location: coastal plain between Jago and Niguanak Rivers.

Weight: 6.4 kg
Umbilicus condition: moist
Hoof condition: partially hard/worn
Health Status: appeared healthy at capture
Processing time: 3 min.
Total Length: 78 cm
Right hind foot length: 33 cm
New hoof length: 7.0 mm
Estimated age at capture: 1 day old
Cow-calf reunion: Capture crew did not observe reunion. Unattended 24 hours after release.

Signal Monitored: 3 times/ 2 day period
Mortality detected: 1116 5 June 1984
Carcass collected: 1245 5 June 1984
Carcass weight: 5.2 kg
Total length: 80 cm
Right hind foot length: 33 cm
New hoof length: 6.0 mm
Number of visual relocations: 2
Location:
Distance from capture site:
Response time: 1.5 hours

Carcass condition and disposition: No indication of trauma. No caribou in immediate area. No sign of predators at carcass site.

Necropsy findings: Trace of vegetation in abomasum, milk absent. All other internal organs normal.

Mortality category: Predation excluded, starvation, probable study-induced abandonment.

Mortality Case History

Calf No: 16
Captured: 3 June 1984

Sex: Female
Location: coastal plain, east side of Niguanak River.

Weight: 7.1 kg
Umbilicus condition: dry
Hoof condition: hard/worn

Total Length: 87 cm
Right hind foot length: 34.7 cm
New hoof length: 8.1 mm

Health Status: slight mucous on muzzle - moved slow

Processing time: 3 min.
Estimated age at capture: 2 days old

Cow-calf reunion: Capture crew did not observe reunion. Unattended day after release.

Signal Monitored: 3 times/ 2 day period
Mortality detected: 1344 5 June 1984
Carcass collected: 1349 5 June 1984
Carcass weight: 5.4 kg
Total length: 78 cm
Right hind foot length: 33 cm
New hoof length: 6.9 mm

Number of visual relocations: 2
Location:
Distance from capture site:
Response time: 5 min.

Carcass condition and disposition: Dispatched by project investigators when abandonment was apparent and starvation imminent. No caribou or predators in immediate area.

Necropsy findings: Vegetation in abomasum, milk absent. All other internal organs normal.

Mortality category: Predation excluded, euthenized, starvation imminent, probable study-induced abandonment.

Mortality Case History

Calf No: 21
Sex: Female
Captured: 3 June 1984
Location: coastal plain between Jago and Niguanak Rivers.

Weight: 8.0 cm
Total Length: 84 cm
Umbilicus condition: dry
Right hind foot length: 35.5 cm
Hoof condition: hard/worn
New hoof length: 8.9 mm
Health Status: appeared healthy at capture
Processing time: 3 min.
Estimated age at capture: 3 days old
Cow-calf reunion: Capture crew did not observe reunion. Attended by dam following day.

Signal Monitored: 2 times/ 2 day period
Number of visual relocations: 2
Mortality detected: 1116 5 June 1984
Location:
Carcass collected: 1309 5 June 1984
Distance from capture site:
Carcass weight: 6.4 kg
Response time:
Total length: 88.9 cm
Right hind foot length: 35 cm
New hoof length: 11.0 mm

Carcass condition and disposition: No indication of trauma. No caribou in immediate area. No sign of predators at carcass site.

Necropsy findings: Vegetation in abomasum, milk absent. All other internal organs normal.

Mortality category: Predation excluded, starvation, probable study-induced abandonment.

Mortality Case History

Calf No: 24
Sex: Female
Captured: 3 June 1984
Location: coastal plain between Jago and Niguanak Rivers.

Weight: 6.3 kg
Total Length: 82 cm
Umbilicus condition: moist
Right hind foot length: 32 cm
Hoof condition: hard/worn
New hoof length: 7.1 mm
Health Status: appeared healthy at capture
Processing time: 4 min.
Estimated age at capture: 1 day old
Cow-calf reunion: Capture crew did not observe reunion. Unattended by dam following day.

Signal Monitored: 2 times/ 2 day period
Number of visual relocations: 2
Mortality detected: 1818 4 June 1984
Location:
Carcass collected: 1253 5 June 1984
Distance from capture site:
Carcass weight: 5.3 kg
Response time: 19 hours
Total length: 75 cm
Right hind foot length: 30 cm
New hoof length: 7.1 mm

Carcass condition and disposition: No indication of trauma. Slight scouring at anus. No caribou in immediate area. No sign of predators at carcass sight.

Necropsy findings: Vegetation in abomasum, milk absent. All other internal organs normal.

Mortality category: Predation excluded, starvation, probable study-induced abandonment.

Mortality Case History

Calf No: 26
Sex: Female
Captured: 3 June 1984
Location: coastal plain between Jago and Niguanak Rivers.

Weight: 7.7 kg
Total Length: 91 cm
Umbilicus condition: dry
Right hind foot length: 34 cm
Hoof condition: partially hard/worn
New hoof length: 8.1 mm
Health Status:
Processing time: 2 min.
Estimated age at capture: 2 days old
Cow-calf reunion: Capture crew did not observe reunion. Unattended by dam following day.

Signal Monitored: 3 times/ 2 day period
Number of visual relocations: 2
Mortality detected: 6 June 1984
Location:
Carcass collected: 1553 6 June 1984
Distance from capture site:
Carcass weight: 5.9 kg
Response time:
Total length: 69 cm
Right hind foot length: 34 cm
New hoof length: 7.1 mm

Carcass condition and disposition: Intact, no indication of trauma. No caribou in immediate area. No sign of predators at carcass site.

Necropsy findings: Dried blood in throat; puncture wound (4.1 mm diameter). Hemorrhage on left side of larynx. Vegetation in abomasum, milk absent. All other internal organs normal.

Mortality category: Predation/scavenging involved, avian scavengers. Starvation, probable study-induced abandonment.

Mortality Case History

Calf No: 27
Captured: 3 June 1984

Sex: Female
Location: coastal plain between Jago and Niguanak Rivers.

Weight: 5.6 kg
Umbilicus condition: dry
Hoof condition: partially hard/worn
Health Status: appeared healthy at capture
Processing time: 3 min.

Total Length: 72 cm
Right hind foot length: 31 cm
New hoof length: 6.9 mm
Estimated age at capture: 1 day old

Cow-calf reunion: Capture crew did not observe reunion. Unattended by dam following day.

Signal Monitored: 2 times/ 1 day period
Mortality detected: 4 June 1984
Carcass collected: 2020 4 June 1984
Carcass weight: 4.6 kg
Total length: 72 cm
Right hind foot length: 31.5 cm
New hoof length: 6.9 mm

Number of visual relocations: 2
Location:
Distance from capture site:
Response time:

Carcass condition and disposition: Lying on left side. Intact, no indication of trauma. No caribou in immediate area. No sign of predators.

Necropsy findings: Scouring at anus. Abomasum empty, milk absent. All other internal organs normal.

Mortality category: Predation excluded, starvation, probable study-induced abandonment.

Mortality Case History

Calf No: 28
Sex: Male
Captured: 3 June 1984
Location: coastal plain between Jago and Niguanak Rivers.

Weight: 8.2 kg
Total Length: 84 cm
Umbilicus condition: dry
Right hind foot length: 33.5 cm
Hoof condition: hard/worn
New hoof length: 7.7 mm
Health Status: appeared healthy at capture
Processing time: 3 min.
Estimated age at capture: 1 day old
Cow-calf reunion: Capture crew did not observe reunion. Unattended by dam following day.

Signal Monitored: 2 times/ 2 day period
Number of visual relocations: 2
Mortality detected: 5 June 1984
Location:
Carcass collected: 1315 5 June 1984
Distance from capture site:
Carcass weight: 6.6 kg
Response time:
Total length: 82 cm
Right hind foot length: 35 cm
New hoof length: 8.5 mm

Carcass condition and disposition: Intact, no indication of trauma. No caribou in immediate area. No sign of predators at carcass site.

Necropsy findings: Vegetation in abomasum, milk absent. All other internal organs normal.

Mortality category: Predation excluded, starvation, probable study-induced abandonment.

Mortality Case History

Calf No: 29
Captured: 3 June 1984

Sex: Male
Location: coastal plain between Jago and Niguanak Rivers.

Weight: 7.7 kg
Umbilicus condition: dry
Hoof condition: partially hard/worn
Health Status: appeared healthy at capture
Processing time: 2 min.

Total Length: 81 cm
Right hind foot length: 35 cm
New hoof length: 9.3 mm

Estimated age at capture: 3 days old

Cow-calf reunion: Capture crew did not observe reunion. Observed with dam the following day.

Signal Monitored: 25 times/ 33 day period
Mortality detected: 28 August 1984
Carcass collected: 29 August 1984
Carcass weight:
Total length:
Right hind foot length:
New hoof length:

Number of visual relocations: 2
Location: Upper Christian River
Distance from capture site: 270 km
Response time: 24 hours

Carcass condition and disposition: Bones and hair present. Long bones and ribs broken. Collar torn, blood stained, transmitter cannister chewed.

Necropsy findings:

Mortality category: Predation/scavenging involved, predator/scavenger undetermined.

Mortality Case History

Calf No: 32
Captured: 5 June 1984

Sex: Female
Location: coastal plain between Egaksrak and Kongakut Rivers.

Weight: 6.8 kg
Umbilicus condition: dry
Hoof condition: hard/worn
Health Status: appeared healthy at capture
Processing time: 2 min.

Total Length: 83 cm
Right hind foot length: 33 cm
New hoof length: 8.4 mm
Estimated age at capture: 2 days old

Cow-calf reunion: Capture crew did not observe reunion. Attended by dam 3 hrs after release. Observed unattended by dam 24 hours after release.

Signal Monitored: 3 times/ 2 day period
Mortality detected: 1653 7 June 1984
Carcass collected: 1711 7 June 1984
Carcass weight: 5.5 kg
Total length: 76 cm
Right hind foot length: 33.5 cm
New hoof length: 7.6 mm

Number of visual relocations: 3
Location:
Distance from capture site:
Response time: 2 hours

Carcass condition and disposition: Lying on right side, intact. No indication of trauma. No caribou in immediate area. No sign of predators at carcass site.

Necropsy findings: Vegetation in abomasum, milk absent. Lungs cloudy, heart enlarged. All other internal organs normal.

Mortality category: Predation excluded, starvation, probable study-induced abandonment.

Mortality Case History

Calf No: 33
Captured: 5 June 1984

Sex: Male
Location: coastal plain between Aichilik and Kongakut Rivers.

Weight: 7.9 kg
Umbilicus condition: absent
Hoof condition: hard/worn
Health Status: appeared healthy at capture
Processing time: 3 min.

Total Length: 85.5 cm
Right hind foot length: 33.5 cm
New hoof length: 9.2 mm
Estimated age at capture: 3 days old

Cow-calf reunion: Capture crew did not observe reunion. Observed with dam 3 hours after release.

Signal Monitored: 28 times/ 108 day period
Mortality detected: 21 September 1984
Carcass collected: 22 September 1984
Carcass weight:
Total length:
Right hind foot length:
New hoof length:

Number of visual relocations: 4
Location: Caribou Bar Creek, Yukon Territory
Distance from capture site: 250 km
Response time: 24 hours

Carcass condition and disposition: Bones crushed, rumen contents scattered/uneaten, appears death was recent to date of collection. Collar intact, tested positive for presence of blood.

Necropsy findings:

Mortality category: Predation/scavenging involved. Predator/scavenger undetermined.

Mortality Case History

Calf No: 37
Sex: Male
Captured: 5 June 1984
Location: coastal plain between Aichilik and Kongakut Rivers.

Weight: 7.9 kg
Total Length: 82 cm
Umbilicus condition: dry
Right hind foot length: 33.5 cm
Hoof condition: hard/worn
New hoof length: 8.2 mm
Health Status: appeared healthy at capture
Processing time: 3 min.
Estimated age at capture: 2 days old
Cow-calf reunion: Capture crew did not observe reunion. Observed with dam the following day. Observed unattended by dam 2 August 1984 - probable orphan.

Signal Monitored: 28 times/ 84 day period
Number of visual relocations: 2
Mortality detected: 28 August 1984
Location: north side of Old John Lake
Carcass collected: 29 August 1984
Distance from capture site: 220 km
Carcass weight:
Response time:
Total length:
Right hind foot length:
New hoof length:

Carcass condition and disposition: Bones and hair partially covered by soil and moss by brown bear. Bear scats containing coribou hair were present. Collar stained with blood, cannister attachment bent.

Necropsy findings:

Mortality category: Predation/scavenging involved. Predator/scavenger probable brown bear.

Mortality Case History

Calf No: 39
Sex: Male
Captured: 5 June 1984
Location: coastal plain between Egaksrak and Kongakut Rivers.

Weight: 6.6 kg
Total Length: 80.5 cm
Umbilicus condition: moist
Right hind foot length: 33.5 cm
Hoof condition: partially hard/worn
New hoof length: 8.7 mm
Health Status: appeared to be healthy at capture
Processing time: 2 min.
Estimated age at capture: 2 days old
Cow-calf reunion: Capture crew did not observe reunion. Unattended by dam 2.5 hours after release.

Signal Monitored: 2 times/ 1 day period
Number of visual relocations: 2
Mortality detected: 2049 6 June 1984
Location:
Carcass collected: 1718 7 June 1984
Distance from capture site:
Carcass weight: 5.7 kg
Response time: 21 hours
Total length: 81 cm
Right hind foot length: 34.5 cm
New hoof length: 8.4 mm

Carcass condition and disposition: Tongue partially removed, right eye removed, hair removed from right rump. Remainder of carcass intact. No caribou in immediate area.

Necropsy findings: Stomach empty, milk absent. Lungs cloudy/bloody, heart appears to be enlarged. All other internal organs normal.

Mortality category: Predation/scavenging involved (avian), starvation, probable study-induced abandonment.

Mortality Case History

Calf No: 41
Captured: 5 June 1984

Sex: Male
Location: coastal plain between Egaksrak and Kongakut Rivers.

Weight: 4.4 kg
Umbilicus condition: absent
Hoof condition: partially hard/worn
Health Status: appeared healthy at capture
Processing time: 3 min.

Total Length: 70.5 cm
Right hind foot length: 30 cm
New hoof length: 7.3 mm
Estimated age at capture: 3 days old

Cow-calf reunion: Capture crew did not observe reunion. Observed with dam the following day.

Signal Monitored: 5 times/ 3 day period
Mortality detected: 1847 9 June 1984
Carcass collected: 2240 9 June 1984
Carcass weight: 1.8 kg
Total length:
Right hind foot length: 33.7 cm
New hoof length: 7.95 mm

Number of visual relocations: 4
Location: coastal plain west of Ekaluakat River.
Distance from capture site: 10.4 km
Response time: 4 hours

Carcass condition and disposition: Approximately 60% consumed, all internal organs and flesh removed, remainder of carcass held together by remnants of torn skin and connective tissue. Fragment of jaw bone chewed, remainder of skeletal bones not chewed. Skull cap intact, palate removed, puncture wound above right eye (4 mm diameter). Golden eagle perched approx. 0.1 km from carcass. Feathers and scats of Golden eagle at carcass site.

Necropsy findings: Wounds on anterior scalp (9.4, 9.4 mm diameter parallel; 3.6, 3.6 mm diameter parallel; 17.2 mm separates pairs of parallel wounds).

Mortality category: Predation/scavenging involved, mammalian predator undetermined, avian scavenger/Golden eagle.

Mortality Case History

Calf No: 43
Captured: 5 June 1984

Sex: Male
Location: coastal plain between Egaksrak and Kongakut Rivers.

Weight: 7.4 kg
Umbilicus condition: dry
Hoof condition: hard/worn
Health Status: appeared healthy at capture
Processing time: 2 min.

Total Length: 79.5 cm
Right hind foot length: 33.5 cm
New hoof length: 8.4 mm
Estimated age at capture: 2 days old

Cow-calf reunion: Capture crew did not observe reunion. Observed with dam 2.25 hrs. after release.

Signal Monitored: 6 times/ 5 day period
Mortality detected: 10 June 1984
Carcass collected: 1250 10 June 1984
Carcass weight: 6.1 kg
Total length: NA
Right hind foot length: 34.5 cm
New hoof length: 7.95 mm

Number of visual relocations: 2
Location: Mountain slope east side of Ekaluakat River.
Distance from capture site: 9.6 km
Response time: 3 hrs.

Carcass condition and disposition: Lying on left side, approximately 35% consumed, internal organs consumed, legs intact, mid-section of vertebrae missing, hemorrhage around mouth. Puncture wounds on left thigh (33 mm apart, 1.5 and .7 cm deep). Skin peeled away from back. No predator sign noted at carcass site.

Necropsy findings: Skull punctured anterior to orbital arches approx. 13 mm diameter, 38.2 mm apart, skin covering skull trauma not punctured, hemorrhage only on internal surface of skin. Partially digested vegetation found in remnant of intestine.

Mortality category: Predation included, probable wolf kill.

Mortality Case History

Calf No: 46
Sex: Female
Captured: 5 June 1984
Location: coastal plain between the Aichilik and Kongakut Rivers.

Weight: 7.0 kg
Total Length: 74.5 cm
Umbilicus condition: dry
Right hind foot length: 33 cm
Hoof condition: hard/worn
New hoof length: 8.3 mm
Health Status: appeared healthy at capture
Processing time: 2 min.
Estimated age at capture: 2 days old
Cow-calf reunion: Capture crew did not observe reunion. Observed with dam the following day.

Signal Monitored: 25 times/ 78 day period
Number of visual relocations: 4
Mortality detected: 22 August 1984
Location: Muskeg Creek, Yukon Territory
Carcass collected: 22 September 1984
Distance from capture site: 140 km
Carcass weight:
Response time: 30 days
Total length:
Right hind foot length:
New hoof length:

Carcass condition and disposition: No carcass found. Collar was intact (unlikely that it was shed from a live animal).

Necropsy findings:

Mortality category: Predation/scavenging probable. Predator/scavenger undetermined.

Mortality Case History

Calf No: 47
Captured: 5 June 1984
Sex: Male
Location: coastal plain between Egaksrak and Kongakut Rivers.

Weight: 6.9 kg
Umbilicus condition: absent
Hoof condition: partially hard/worn
Health Status: appeared healthy at capture
Processing time: 2 min.
Total Length: 82.5 cm
Right hind foot length: 35.5 cm
New hoof length: 7.3 mm
Estimated age at capture: 1 day old
Cow-calf reunion: Capture crew did not observe reunion. Attended by cow 2.75 hours after release. Unattended by dam following day.

Signal Monitored: 4 times/ 3 day period
Number of visual relocations: 4
Mortality detected: 1628 8 June 1984
Carcass collected: 8 June 1984
Carcass weight: 5.8 kg
Total length: 82.5 cm
Right hind foot length: 35.5 cm
New hoof length: 8.6 mm
Location:
Distance from capture site:
Response time:

Carcass condition and disposition: Intact, no indication of trauma. No caribou in immediate area. No sign of predators at carcass site.

Necropsy findings: Vegetation in abomasum, milk absent. Lungs cloudy/dark, heart enlarged. All other internal organs normal.

Mortality category: Predation excluded, starvation. Probable study-induced abandonment.

Mortality Case History

Calf No: 51
Captured: 5 June 1984

Sex: Female
Location: coastal plain between Egaksrak and Kongakut Rivers.

Weight: 5.9 kg
Umbilicus condition: moist
Hoof condition: partially hardened/worn
Health Status: appeared healthy at capture
Processing time: 3 min.

Total Length: 76.5 cm
Right hind foot length: 32.5 cm
New hoof length: 8.2 mm
Estimated age at capture: 2 days old

Cow-calf reunion: Capture crew did not see reunion. Observed with dam 1.75 hours after release.

Signal Monitored: 20 times/ 19 day period
Mortality detected: 1219 24 June 1984

Number of visual relocations: 3
Location: Foothills west side of Ekaluakat River aufeis field.

Carcass collected: 1524 24 June 1984
Carcass weight: 8.6 kg
Total length: 98 cm
Right hind foot length: 32 cm
New hoof length: 11.2 mm

Distance from capture site: 21.7 km
Response time: 3 hours

Carcass condition and disposition: Lying on right side, carcass intact and no external indication of trauma. Cow observed standing near carcass when helicopter approached. Golden eagle perched approximately 1.1 km to the west of carcass.

Necropsy findings: Six round puncture wounds on upper thorax and shoulder (3.3-14.3 mm diameter) with internal hemorrhage at each wound site. Hemorrhage of lung cavity, lungs bloody and clouded. All other organs and body structures normal.

Mortality category: Predation/scavenging involved, Golden eagle kill.

Mortality Case History

Calf No: 53
Sex: Male
Captured: 5 June 1984
Location: coastal plain east of the Kongakut River.

Weight: 5.4 kg
Total Length: 72.5 cm
Umbilicus condition: NA
Right hind foot length: 32.5 cm
Hoof condition: soft/slight wear
New hoof length: 7.8 mm
Health Status: appeared healthy at capture
Processing time: 2 min.
Estimated age at capture: 1 day old
Cow-calf reunion: Capture crew observed reunion. Unattended by dam 1.75 hours after release.

Signal Monitored: 2 times/ 1 day period
Number of visual relocations: 2
Mortality detected: 1525 6 June 1984
Location:
Carcass collected: 1912 7 June 1984
Distance from capture site:
Carcass weight: 4.9 kg
Response time: 28 hours
Total length: 80.5 cm
Right hind foot length: 34.5 cm
New hoof length: 7.6 mm

Carcass condition and disposition: Intact, no indication of trauma. No caribou in the immediate area. No sign or predators at carcass site.

Necropsy findings: Stomach empty, milk absent. Lungs cloudy/bloody, all other internal organs normal.

Mortality category: Predation excluded, starvation, probable study-induced abandonment.

Mortality Case History

Calf No: 54
Sex: Male
Captured: 6 June 1984
Location: coastal plain east of Kongakut River.

Weight: 6.7 kg
Total Length: 84 cm
Umbilicus condition: moist
Right hind foot length: 35.5 cm
Hoof condition: hard/worn
New hoof length: 9.2 mm
Health Status: appeared healthy at capture
Processing time: 2 min.
Estimated age at capture: 3 days old
Cow-calf reunion: Capture crew did not observe reunion. Observed with dam 12 hours after release.

Signal Monitored: 23 times/ 107 day period
Number of visual relocations: 2
Mortality detected: 21 September 1984
Location: Pine Creek, Yukon Territory
Carcass collected: 22 September 1984
Distance from capture site: approx. 325 km
Carcass weight:
Response time: 24 hours
Total length:
Right hind foot length:
New hoof length:

Carcass condition and disposition: Scattered bones, bones broken, rumen contents present, wolf scats present. Collar intact, blood stained, retrieved from spruce tree.

Necropsy findings:

Mortality category: Predation/scavenging involved. Probable wolf kill.

Mortality Case History

Calf No: 55
Captured: 6 June 1984
Sex: Female
Location: Coastal plain east of the Kongakut River.

Weight: 4.9 kg
Umbilicus condition: dry
Hoof condition: partially hardened/worn
Total Length: 76.5 cm
Right hind foot length: 32.5 cm
New hoof length: 8.5 mm
Health Status: scouring - otherwise appeared normal
Processing time: 2 min.
Estimated age at capture: 2 days old
Cow-calf reunion: Capture crew did not observe reunion. Observed with dam approximately 12 hours after release.

Signal Monitored: 25 times/ 77 day period
Number of visual relocations: 2
Mortality detected: 22 August 1984
Location: Old Crow Range, Yukon Territory
Carcass collected: 22 September 1984
Distance from capture site: 245 km
Carcass weight:
Response time: 30 days
Total length:
Right hind foot length:
New hoof length:

Carcass condition and disposition: No carcass found. Collar broken and tested positive for presence of blood.

Necropsy findings:

Mortality category: Predation/scavenging involved. Predator/scavenger undetermined.

Mortality Case History

Calf No: 56
Captured: 6 June 1984
Sex: Male
Location: coastal plain east of Kongakut River.

Weight: 6.6 kg
Umbilicus condition: dry
Hoof condition: NA
Health Status: diarrhea present at capture
Processing time: 3 min.
Total Length: 85.5 cm
Right hind foot length: 33 cm
New hoof length: 7.6 mm
Estimated age at capture: 1 day old
Cow-calf reunion: Capture crew observed reunion 1 min. after release. Unattended by dam following day.

Signal Monitored: 2 times/ 2 day period
Number of visual relocations: 2
Mortality detected: 1525 7 June 1984
Carcass collected: 1718 7 June 1984
Carcass weight: 5.7 kg
Total length: 85 cm
Right hind foot length: 34 cm
New hoof length: 7.8 mm
Location:
Distance from capture site:
Response time: 2 hours

Carcass condition and disposition: Intact, no indication of trauma. No caribou in immediate area, no sign of predators at carcass site.

Necropsy findings: Vegetation in rumen, milk absent. Lungs cloudy, all other internal organs normal.

Mortality category: Predation excluded, starvation, probable study-induced abandonment.

Calf No: 61
Captured: 5 June 1984

Sex: Female
Location: coastal plain between the Jago and Okerokovik Rivers.

Weight: 5.9 kg
Umbilicus condition: moist
Hoof condition: hard/worn
Health Status: appeared healthy at capture
Processing time: 2 min.

Total Length: 71 cm
Right hind foot length: 32 cm
New hoof length: 7.9 mm
Estimated age at capture: 1 day old

Cow-calf reunion: Capture crew did not observe reunion. Observed with dam 9.75 hours after release.

Signal Monitored: 24 times/ 25 day period
Mortality detected: 20 July 1984

Number of visual relocations: 4
Location: British Mountains west of Firth River, Yukon Territory

Carcass collected: 20 July 1984
Carcass weight:
Total length:
Right hind foot length:
New hoof length:

Distance from capture site: 142km
Response time:

Carcass condition and disposition: Approximately 85% consumed. Flesh removed from skeleton, bones partially attached by remnants of skin and connective tissue, interval organs removed. Bones not broken or gnawed. No sign of predators found at carcass site.

Necropsy findings:

Mortality category: Predation/scavenging involved, avian scavengers, cause of mortality undetermined.

Mortality Case History

Calf No: 66
Captured: 5 June 1984

Sex: Male
Location: coastal plain between the Jago and Niguanak Rivers.

Weight: 9.0 kg
Umbilicus condition: NA
Hoof condition: NA
Health Status: appeared healthy at capture
Processing time: 2 min.

Total Length: 88 cm
Right hind foot length: 35.5 cm
New hoof length: 8.2 mm
Estimated age at capture: 2 days old

Cow-calf reunion: Capture crew observed reunion after release.

Signal Monitored: 29 times/ 66 day period
Number of visual relocations: 1
Mortality detected: 12 November 1984
Location: W. channel MacKenzie River, 52 km north of Aklavik, NorthWest Territories.

Carcass collected:
Carcass weight:
Total length:
Right hind foot length:
New hoof length:

Distance from capture site: 330 km
Response time: NA

Carcass condition and disposition: Shot by hunter.

Necropsy findings:

Mortality category: Predation excluded, hunter kill.

Mortality Case History

Calf No: 73
Sex: Female
Captured: 7 June 1984
Location:

Weight: 6.9 kg
Total Length: NA
Umbilicus condition: moist
Right hind foot length: 33.5 cm
Hoof condition: partially hard/worn
New hoof length: 7.6 mm
Health Status: appeared healthy at capture
Processing time: 3 min.
Estimated age at capture: 1 day old
Cow-calf reunion: Capture crew observed reunion 1 min. after release.

Signal Monitored:________ times/_____day period
Number of visual relocations:
Mortality detected:
Location: West channel of lower Kongakut River.
Carcass collected: 1815 13 June 1984
Distance from capture site: 10 km
Carcass weight: 7.2 kg
Response time:
Total length: 83 cm
Right hind foot length: 35.5 cm
New hoof length:

Carcass condition and disposition: Intact, lying in approximately 10 cm of water (west channel of Kongakut River). No indication of trauma. No caribou or predators observed in the immediate area.

Necropsy findings: Slight bruise and hemorrhage on brisket and at base of neck and shoulders. No puncture holes in the skin. No water in trachea, esophagus, stomach or intestines. Trachea clear of obstructions. Lungs appeared normal (aerated). Vegetation and milk present in stomach. All other organs were normal.

Mortality category: Predation excluded, probable accidental injury and/or drowning.

Mortality Case History

Calf No: 76
Sex: Male
Captured: 7 June 1984
Location: coastal plain east of Kongakut River.

Weight: 7.6 kg
Total Length: 79.5 cm
Umbilicus condition: bloody
Right hind foot length: 36.5 cm
Hoof condition: partially hard/worn
New hoof length: 8.6 mm
Health Status: appeared healthy at capture
Processing time: 3 min
Estimated age at capture: 1 day old
Cow-calf reunion: Capture crew observed reunion 2 minutes after release.

Signal Monitored: 24 times/ 75 day period
Number of visual relocations: 0
Mortality detected: 21 August 1984
Location: Upper Bell River, Yukon Territory
Carcass collected: 22 September 1984
Distance from capture site: 275 km
Carcass weight:
Response time: 30 days
Total length:
Right hind foot length:
New hoof length:

Carcass condition and disposition: No carcass found. Collar intact (unlikely that it was shed while animal was alive). Tested negative for presence of blood.

Necropsy findings:

Mortality category: Predation/scavenging involved. Predator/scavenger undetermined.

Mortality Case History

Calf No: Unmarked 01
Sex: Male
Captured:
Location:

Weight:
Total Length:
Umbilicus condition:
Right hind foot length:
Hoof condition:
New hoof length:
Health Status:
Processing time:
Estimated age at capture:
Cow-calf reunion:

Signal Monitored:________ times/_____day period
Number of visual relocations:
Mortality detected:
Location: coastal plain between Jago and Niguanak River
Carcass collected: 4 June 1984
Distance from capture site:
Carcass weight: 2.9 kg
Response time:
Total length:
Right hind foot length: 35 cm
New hoof length: 9.1 mm

Carcass condition and disposition: Carcass remains spread out on snow bank in creek draw. 75% consumed, flesh and vicera removed, skin and bones attached. Skull crushed, bones broken and chewed. Brown bear tracks and hair present. Glaucous gull tracks present.

Necropsy findings:

Mortality category: Predation/scavenging involved. Brown bear, Glaucous gull.

Mortality Case History

Calf No: Unmarked 02
Sex: Male
Captured:
Location:

Weight:
Total Length:
Umbilicus condition:
Right hind foot length:
Hoof condition:
New hoof length:
Health Status:
Processing time:
Estimated age at capture:
Cow-calf reunion:

Signal Monitored:________ times/_____day period
Number of visual relocations:
Mortality detected:
Location: coastal plain between Jago and Niguanak Rivers
Carcass collected: 5 June 1984
Distance from capture site:
Carcass weight: 3.5 kg
Response time:
Total length: 67.5 cm
Right hind foot length: 28.5 cm
New hoof length: 6.6 mm

Carcass condition and disposition: Found lying in tussock meadow. Intact - no external indication of trauma. Appears to be very young (less than 1 day old). No cow observed in the area.

Necropsy findings: No indication of wounds or trauma. Stomach and rumen empty. No internal fat deposits, organs fetal in appearance. Lungs dark/clouded.

Mortality category: Predation excluded, still birth or not viable birth.

Mortality Case History

Calf No: Unmarked 03
Captured:

Sex: Male
Location:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Total Length:
Right hind foot length:
New hoof length:
Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 5 June 1984
Carcass weight: 6.5 kg
Total length: 84 cm
Right hind foot length: 33.5 cm
New hoof length: 8.2 mm

Number of visual relocations:
Location:
Distance from capture site:
Response time:

Carcass condition and disposition: Found on dryas terrace with cow standing near carcass. Intact, no external indication of trauma. Hooves soft/unworn, umbilicus moist, pelage dry. Cow with 2 hard antlers, placenta protruding from vagina.

Necropsy findings: Stomach empty, lungs clouded, fat present on kidneys, all other internal organs normal.

Mortality category: Predation excluded, probable stillbirth.

Mortality Case History

Calf No: Unmarked 04
Sex: Female
Captured:
Location:

Weight:
Total Length:
Umbilicus condition:
Right hind foot length:
Hoof condition:
New hoof length:
Health Status:
Processing time:
Estimated age at capture:
Cow-calf reunion:

Signal Monitored:________ times/_____day period
Number of visual relocations:
Mortality detected:
Location: foothills Ekaluakat River
Carcass collected: 7 June 1984
Distance from capture site:
Carcass weight: 3.6 kg
Response time:
Total length: 78.5 cm
Right hind foot length: 33.0 cm
New hoof length: 8.7 mm

Carcass condition and disposition: Found lying on right side in wet sedge area. No cow present. About 30% consumed. Tongue partially consumed. Fed on from left side through rib cage, heart and lungs gone, left hip/upper thigh removed, flesh removed from anus and pubic area. Jaegers observed at carcass.

Necropsy findings: No puncture wounds or indicaton of trauma found. All internal organs except a portion of liver consumed.

Mortality category: Predation/scavenging involved, scavenging, avian scavenger, cause of death undetermined.

Mortality Case History

Calf No: Unmarked 05 | Sex: Female
Captured: | Location:

Weight: | Total Length:
Umbilicus condition: | Right hind foot length:
Hoof condition: | New hoof length:
Health Status:
Processing time: | Estimated age at capture:
Cow-calf reunion:

Signal Monitored:________ times/_____day period | Number of visual relocations:
Mortality detected: | Location: coastal plain west side of Egaksrak River
Carcass collected: 7 June 1984 | Distance from capture site:
Carcass weight: 4.8 kg | Response time:
Total length: 82 cm
Right hind foot length: 34.5 cm
New hoof length: 7.2 mm

Carcass condition and disposition: 95% intact, lying on left side. Right eye and tongue removed. Skin opened on right shoulder and right rear thigh. Lungs and intestines partially fed on. Hooves partially hard and worn. Umbilicus dried. No cow present. Jaegers present at the carcass when collected.

Necropsy findings: Right lung gone, left lung dark and clouded, heart partially eaten, stomach with green colored mucous, yellow material in intestines. All other internal organs normal. No indication of wounds or trauma except for areas of avian feeding.

Mortality category: Predation/scavenging involved, scavenging, avian scavenger, cause of death undetermined.

Mortality Case History

Calf No: Unmarked 06
Captured:

Sex: Male
Location:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Total Length:
Right hind foot length:
New hoof length:
Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 7 June 1984
Carcass weight: 6.8 kg
Total length: 86 cm
Right hind foot length: 36 cm
New hoof length: 8.6 mm

Number of visual relocations:
Location:
Distance from capture site:
Response time:

Carcass condition and disposition: Mostly intact, right eye removed, bruise on right rear rib area - no other indication of trauma. Hooves hard/worn, umbilicus dry. Antlered cow standing at the carcass.

Necropsy findings: Lungs cloudy, vegetation and milk curds present in stomach, all other internal organs appear normal.

Mortality category: Predation/scavenging involved, scavenging, avian scavenger, cause of death undetermined.

Mortality Case History

Calf No: Unmarked 07
Captured:

Sex: Female
Location:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Total Length:
Right hind foot length:
New hoof length:

Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 8 June 1984
Carcass weight: 5.1 kg
Total length: 79.5 cm
Right hind foot length: 32.5 cm
New hoof length: 7.6 mm

Number of visual relocations:
Location: coastal plain near Angun River
Distance from capture site:
Response time:

Carcass condition and disposition: Lying on right side on gravel bar. Left eye removed, right eye and nose chewed, skin around tail opened. No cow present at carcass.

Necropsy findings: Lungs aerated/dark, milk curds present in stomach, all other internal organs appear normal.

Mortality category: Predation/scavenging involved, scavenging, avian scavenger, cause of death undetermined.

Mortality Case History

Calf No: Unmarked 08
Captured:

Sex: Female
Location:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Total Length:
Right hind foot length:
New hoof length:

Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 8 June 1984
Carcass weight: 4.1 kg
Total length: 70.5 cm
Right hind foot length: 31 cm
New hoof length: 8.1 mm

Number of visual relocations:
Location: coastal plain near Ekaluakat River
Distance from capture site:
Response time:

Carcass condition and disposition: Found lying in tussock tundra area, antlered cow standing at carcass site. No external indication of trauma - carcass intact. Hooves hardened/worn. Umbilicus dry.

Necropsy findings: Lungs dark. Stomach and rumen empty, milk curds absent. All other internal organs normal. Lacks internal fat deposits.

Mortality category: Predation excluded, starvation - not related to abandonment.

Mortality Case History

Calf No: Unmarked 09
Captured:

Sex: Undetermined
Location:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Total Length:
Right hind foot length:
New hoof length:

Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 8 June 1984
Carcass weight: 2.2 kg
Total length:
Right hind foot length: 34 cm
New hoof length: 7.2 mm

Number of visual relocations:
Location:
Distance from capture site:
Response time:

Carcass condition and disposition: 65% consumed. Carcass chewed up, partially scattered, leg disarticulated, bones intact/attached by skin. Skull crushed, brain removed, neck and abdomen gone.

Necropsy findings: Ears and right eye removed. No internal organs present. Bird feces and black feathers present.

Mortality category: Predation/scavenging involved, mammalian and avian scavengers, probable brown bear kill.

Mortality Case History

Calf No: Unmarked 10
Sex: Female
Captured:
Location:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:
Total Length:
Right hind foot length:
New hoof length:
Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 8 June 1984
Carcass weight: 3.8 kg
Total length: 72 cm
Right hind foot length: 31 cm
New hoof length: 8.0 mm
Number of visual relocations:
Location: coastal plain east of Kongakut River
Distance from capture site:
Response time:

Carcass condition and disposition: Lying on right side on snow bank. Chest cavity opened, heart and lungs gone. Puncture wounds: (1) left jugular 6.3 mm diameter, (1) below right ear 3.8 mm diameter Subcutaneous hemorrhage at wounds and on skull. Skull broken. Hooves partially hard/worn. Umbilicus dry. No cow present. Collared brown bear #1234 0.4 km to west.

Necropsy findings: Bruises on left and right shoulder and right loin area. Lower ramus broken. No internal organs present.

Mortality category: Predation/scavenging involved, predation, brown bear kill.

Mortality Case History

Calf No: Unmarked 11
Captured:

Sex: Undetermined
Location:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Total Length:
Right hind foot length:
New hoof length:
Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 10 June 1984
Carcass weight: 3.6 kg
Total length:
Right hind foot length: 34.7 cm
New hoof length: 7.6 mm

Number of visual relocations:
Location:
Distance from capture site:
Response time:

Carcass condition and disposition: 70% consumed, flesh removed from carcass, internal organs gone. Bones not chewed, connected by skin. Hemorrhage in mouth cavity. Compound fracture of left hind foot. Head unharmed externally. Two golden eagles feeding on carcass when collected.

Necropsy findings: Head skinned - skull fractured posterior to right eye above right ear, and above left eye. Hemorrhage associated with skull fractures. Puncture wound in skin (2.4 mm diameter) above right eye. Dried blood, tissue and soil on wound of broken leg indicates injury occurred prior to death.

Mortality category: Predation/scavenging involved, predation, Golden Eagle kill, probable predisposed to predation (broken leg).

Mortality Case History

Calf No: Unmarked 12
Captured:

Sex: Undetermined
Location:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Total Length:
Right hind foot length:
New hoof length:

Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 10 June 1984
Carcass weight: 3.6 kg
Total length:
Right hind foot length: 35 cm
New hoof length: 7.3 mm

Number of visual relocations:
Location:
Distance from capture site:
Response time:

Carcass condition and disposition: 65% consumed, majority of flesh removed from skeleton, internal organs gone, limbs attached by skin, disarticulated from vertebrae. Skull partially crushed. Collected from brown bear. 2 Golden eagles near carcass.

Necropsy findings: Hemorrhage above right eye and inside braincase.

Mortality category: Predation/scavenging involved, predation, brown bear kill.

Mortality Case History

Calf No: Unmarked 13
Captured:

Sex: Male
Location:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Total Length:
Right hind foot length:
New hoof length:

Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 14 June 1984
Carcass weight: 5.0 kg
Total length: 84 cm
Right hind foot length: 31.6 cm
New hoof length: 6.7 mm

Number of visual relocations:
Location: coastal plain west of Kongakut River
Distance from capture site:
Response time:

Carcass condition and disposition: Intact lying on left side on a dryas terrace area. No external indication of trauma. Antlerless cow standing by carcass.

Necropsy findings: No internal indication of wounds or trauma, lungs mottled dark red, stomach contained vegetation, milk curds absent. Internal fat lacking, liver dark.

Mortality category: Predation excluded, starvation/pneumonia, not related to abandonment.

Mortality Case History

Calf No: Unmarked 14
Captured:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Sex: Undetermined
Location:

Total Length:
Right hind foot length:
New hoof length:

Estimated age at capture:

Signal Monitored:_______ times/____day period
Mortality detected:
Carcass collected: 14 June 1984
Carcass weight: 8.9 kg
Total length:
Right hind foot length: 35.9 cm
New hoof length: 10.45 mm

Number of visual relocations:
Location: foothills west of Aichilik River
Distance from capture site:
Response time:

Carcass condition and disposition: Lying on left side in tussock/shrub tundra. Skin removed from right rib cage - flesh removed. Internal organs partially removed. 2 Golden eagles feeding on carcass when collected. Cow caribou nearby.

Necropsy findings: Extensive hemorrhage associated with round puncture wounds - dorsal surface of left shoulder (4.8 mm diameter); left flank (4.2 mm diameter); left neck (4.8 mm and 2.8 mm diameter). Oval punctures of left shoulder (33 mm and 35 mm across). Vegetation in stomach, fat on kidneys and mesentery.

Mortality category: Predation/scavenging included; predation, Golden eagle kill.

Mortality Case History

Calf No: Unmarked 15
Sex: Female
Captured:
Location:

Weight:
Total Length:
Umbilicus condition:
Right hind foot length:
Hoof condition:
New hoof length:
Health Status:
Processing time:
Estimated age at capture:
Cow-calf reunion:

Signal Monitored:________ times/_____day period
Number of visual relocations:
Mortality detected:
Location: foothills west of Aichilik River
Carcass collected: 16 June 1984
Distance from capture site:
Carcass weight: 5.5 kg
Response time:
Total length:
Right hind foot length: 35.6 cm
New hoof length: 9.25 mm

Carcass condition and disposition: Lying on left side near willow and wet sedge hummocks. 40% consumed. Tongue, right ear and eyes removed. Chest cavity opened, heart and lungs and intestines gone. Flesh removed from right flank and thigh. Right ribs broken and removed. 3 Glaucous gulls feeding on carcass when collected.

Necropsy findings: Carcass skinned: hemorrhage associated with round puncture wounds on lower left dorsal surface (4.1 mm and 3.0 mm in diameter). Right mandible disarticulated from skull, right maxillae gone, left maxillae disarticulated, palate removed, remainder of braincase intact.

Mortality category: Predation/scavenging involved, predation, Golden eagle kill.

Mortality Case History

Calf No: Unmarked 16
Captured:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Sex: Female
Location:

Total Length:
Right hind foot length:
New hoof length:

Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 18 June 1984
Carcass weight: 7.0 kg
Total length: 80 cm
Right hind foot length: 36 cm
New hoof length: 10.1 mm

Number of visual relocations:
Location: coastal plain west of Niguanak River
Distance from capture site:
Response time:

Carcass condition and disposition: Lying on right side in tussock/hummock tundra. Adult cow standing at carcass site. Flesh removed from left shoulder and rib area.

Necropsy findings: Bruise and slight hemorrhage above right eye. No wounds in skin, no broken bones or skull. Heart and right lung removed. Massive hemorrhage in abdominal cavity and around small intestines. Stomach contained vegetation and milk curds.

Mortality category: Predation/scavenging involved, predator/scavenger undetermined.

Mortality Case History

Calf No: Unmarked 17
Captured:

Sex: Male
Location:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Total Length:
Right hind foot length:
New hoof length:

Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 27 June 1984
Carcass weight: 10.7 kg
Total length: 91 cm
Right hind foot length: 32.5 cm
New hoof length: 11.9 mm

Number of visual relocations:
Location: coastal plain east of Aichilik River
Distance from capture site:
Response time:

Carcass condition and disposition: Intact with blood stain lower left neck. Wolf observed near carcass site.

Necropsy findings: Carcass skinned - multiple tear wounds (4.6-14.5 mm diameter) on lower rib cage and neck. Extensive hemorrhage associated with wounds. Vegetation and milk curds present in stomach. Internal organs appear normal

Mortality category: Predation/scavenging involved, predation, wolf kill.

Mortality Case History

Calf No: Unmarked 18
Captured:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Sex: Male
Location:

Total Length:
Right hind foot length:
New hoof length:

Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 29 June 1984
Carcass weight: 10.0 kg
Total length: 86 cm
Right hind foot length: 31.6 cm
New hoof length:

Number of visual relocations:
Location: coastal plain of north VABM Dar
Distance from capture site:
Response time:

Carcass condition and disposition: Intact near to location of radio-collared wolf. Tear wounds (2) on back (20 mm diameter). Blood stains around wounds.

Necropsy findings: Massive hemorrhage associated with tear wounds on back. Flesh wounds on underside of chest but no holes in skin. Elongate puncture of skull case behind left ear (4 x 12 mm). No corresponding puncture of skin over wound. Extensive hemorrhage in abdominal cavity. Milk curds in stomach, internal organs appear normal.

Mortality category: Predation/scavenging involved, predation, wolf kill.

Calf No: Unmarked 19
Sex: Male
Captured:
Location:

Weight:
Total Length:
Umbilicus condition:
Right hind foot length:
Hoof condition:
New hoof length:
Health Status:
Processing time:
Estimated age at capture:
Cow-calf reunion:

Signal Monitored:________ times/_____day period
Number of visual relocations:
Mortality detected:
Location: foothills east of Egaksrak River
Carcass collected: 6 July 1984
Distance from capture site:
Carcass weight: 18.1 kg
Response time:
Total length: 104 cm
Right hind foot length: 40 cm
New hoof length: 13.1 mm

Carcass condition and disposition: Intact except for small holes torn on right rump (16.9 mm and 18.1 mm diameter). Carcass still warm, bleeding from wounds in skin. Golden eagle feeding on carcass when found.

Necropsy findings: Multiple round puncture wounds on right neck, rib cage and top of back (2.5-18.4 mm diameter). Massive hemorrhage associated with puncture wounds. Vegetation and milk curds in stomach, internal organs normal.

Mortality category: Predation/scavenging involved, predation, Golden eagle kill.

Mortality Case History

Animal No: Unmarked 20
Captured:

Sex: Adult cow and fetus
Location:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Total Length:
Right hind foot length:
New hoof length:

Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 13 June 1984
Carcass weight:
Total length:
Right hind foot length:
New hoof length:

Number of visual relocations:
Location: coastal plain near Kongakut River
Distance from capture site:
Response time:

Carcass condition and disposition: Fetus partially extending (legs first) from vagina of dead cow, remainder of fetus in birth canal. Brown bear #1188 feeding on carcass. Cow observed alive previous day - did not stand up when aircraft passed overhead.

Necropsy findings: Not conducted

Mortality category: Predation/scavenging involved, brown bear predator/scavenger. Cause of death - complication during birth process - probable predisposition to brown bear predation.

Mortality Case History

Animal No: Unmarked 21
Captured:

Sex: Adult cow (antlerless)
Location:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Total Length:
Right hind foot length:
New hoof length:

Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 8 June 1984
Carcass weight:
Total length:
Right hind foot length:
New hoof length:

Number of visual relocations:
Location:
Distance from capture site:
Response time:

Carcass condition and disposition: Lying on right side, 10% consumed. Brown bear feeding on right leg. Throat and left mandible chewed. Intestines extending out of hole in rear of carcass. No calf or fetus present.

Necropsy findings: NA

Mortality category: Predation/scavenging involved, brown bear kill, no indication of predisposition to predation.

Mortality Case History

Animal No: Unmarked 22

Sex: Adult female

Captured:

Location:

Weight:

Total Length:

Umbilicus condition:

Right hind foot length:

Hoof condition:

New hoof length:

Health Status:

Processing time:

Estimated age at capture:

Cow-calf reunion:

Signal Monitored:________ times/_____day period

Number of visual relocations:

Mortality detected:

Location: coastal plain west of Ekaluakat River

Carcass collected: 14 June 1984

Distance from capture site:

Carcass weight:

Response time:

Total length:

Right hind foot length:

New hoof length:

Carcass condition and disposition: Found lying on left side, antlers present, udder not distended, hemorrhage from mouth and vagina. Right abdominal wall torn, avian feeding - right eye gone. One immature Golden eagle feeding on carcass when found. No calf or fetus present.

Necropsy findings:

Mortality category: Predation/scavenging involved, avian scavenger (Golden eagle), cause of death undetermined.

Mortality Case History

Animal No: Unmarked 23
Captured:

Sex: Adult cow
Location:

Weight:
Umbilicus condition:
Hoof condition:
Health Status:
Processing time:
Cow-calf reunion:

Total Length:
Right hind foot length:
New hoof length:

Estimated age at capture:

Signal Monitored:________ times/_____day period
Mortality detected:
Carcass collected: 15 June 1984
Carcass weight:
Total length:
Right hind foot length:
New hoof length:

Number of visual relocations:
Location: coastal plain east of Aichilik River
Distance from capture site:
Response time:

Carcass condition and disposition: Lying on left side, 2 antlers, udder not distended, tongue and left eye gone. Hole in left rib cage, part of lungs and intestines consumed. Five Glaucous gulls feeding on carcass when found. No other indication of trauma. No calf or fetus present.
Necropsy findings:

Mortality category: Predation/scavenging involved, avian scavenging (Glaucous gulls), cause of death undetermined.

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Appendix Table 1. Chronology of calving, calf mortality, udder distention, and antler retention of 31 radio-collared control cows in the Porcupine caribou herd, 1984[a]

Cow # and Status	May 30	May 31	June 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
BKY-0:																																
calf			N					N																								
udder			U					N																								
antlers (#)			0					0																								
BKY-1:																																
calf		N	N	Y				Y		Y		Y		Y		Y	Y								Y							
udder		U	Y	U				U		U		U		U		U	U								U							
antlers (#)		2	2	2				2		1		0		0		0	0								0							
BKY-5:																																
calf		N	N	N				N											Y													
udder		N	N	N				N											U													
antlers (#)		0	0	0				0											0													
BKY-6:																																
calf			N	N			N	N		Y		Y		Y		Y	Y							Y								
udder			U	U			Y	Y		U		U		U		U	U							U								
antlers (#)			2	2			2	2		2		1		0		0	0							0								
BKY-7:																																
calf		N	N					Y		Y																						
udder		U	U					U		U																						
antlers (#)		2	2					2		1																						
BKY-10:																																
calf		N	N	N		N		N		N		N		Y		Y	Y						Y		Y							
udder		U	U	U		U		U		U		U		U		U	U						U		U							
antlers (#)		2	2	2		1		1		1		0		0		0	0						0		0							
BKY-12:																																
calf		N		N				N		Y		Y		Y		Y	Y							Y		Y						
udder		U		Y				Y		U		U		U		U	U							U		U						
antlers (#)		2		2				2		0		0		0		0	0							0		0						
BKY-16:																																
calf		N						N		N		N		N		Y	Y															
udder		U						Y		Y		U		U		U	U															
antlers (#)		2						2		2		2		1		0	0															
BKY-18:																																
calf		N	N	N			Y		Y								Y	Y	Y				Y									
udder		U	U	Y			U		U								U	U	U				U									
antlers (#)		1	1	1			1		1								0	0	0				0									

Appendix Table 1. (Continued).

Cow # and	May		June																													
Status	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
BKY-19:																																
calf	N																		Died													
udder	U																															
antlers (#)	0																															
BKY-22:																																
calf																					Y											
udder																					U											
antlers (#)																					0											
BKY-23:																																
calf		N		Y	Y		Y	Y		Y		Y		Y		Y	Y							Y								
udder		U		U	U		U	U		U		U		U		U	U							U								
antlers (#)		2		2	2		2	0		0		0		0		0	0							0								
BKY-26:																																
calf			N	N				Y	Y			Y		Y		Y	N				Y	Y										
udder			U	U				U	U			U		U		U	U				U	U										
antlers (#)			2	2				2	0			0		0		0	0				0	0										
BKY-41:																																
calf	N							Y		Y											Y											
udder	Y							U		U											U											
antlers (#)	2							2		0											0											
BKY-42:																																
calf	N			Y		Y			Y		Y		Y		Y		Y		Y				Y	Y								
udder	U			U		U			U		U		U		U		U		U				U	U								
antlers (#)	2			2		2			0		0		0		0		0		0				0	0								
BY-1:																																
calf	N	N		Y	Y		Y			Y		Y		Y		Y	Y															
udder	U	U		U	U		U			U		U		U		U	U															
antlers (#)	2	2		2	2		2			0		0		0		0	0															
RY-4:																																
calf		N		N			N	N											N													
udder		Y		Y			U	U											U													
antlers (#)		0		0			0	0											0													
RY-29:																																
calf				N		N		Y				Y	Y		Y		Y		Y												Died	
udder				U		U		U				U	U		U		U		U													
antlers (#)				2		2		2				1	0		0		0		0													

Appendix Table 1. (Continued).

Cow # and Status	May 30	May 31	June 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
GY-24:																																
calf		N	N	N		Y			Y		Y		N		N		N		N													
udder		U	U	U		U			U		U		U		U		U		U													
antlers (#)		2	2	2		2			0		0		0		0		0		0													
GY-25:																																
calf	N																				N											
udder	U																				U											
antlers (#)	0																				0											
GY-27:																																
calf			N					N													N											
udder			U					U													U											
antlers (#)			0					0													0											
PY-49:																																
calf		N	N					Y		Y									Y		Y				Y							
udder		U	U					U		U									U		U				U							
antlers (#)		2	1					1		1									0		0				0							
PY-67:																																
calf			N	N													N	N														
udder			N	U													U	U														
antlers (#)			0	0													0	0														
PY-69:																																
calf				Y			Y		Y			Y		Y		Y	Y							Y								
udder				U			U		U			U		U		U	U							U								
antlers (#)				2			2		1			1		0		0	0							0								
PB-86:																																
calf	N	N		Y	Y		Y	Y		Y		Y		Y		Y							Y									
udder	U	U		U	U		U	U		U		U		U		U							U									
antlers (#)	2	2		2	2		2	2		0		0		0		0							0									
PB-87:																																
calf		N		N				N										N														
udder		U		U				U										U														
antlers (#)		0		0				0										0														
W2:																																
calf		N		Y			Y		Y				Y		Y		Y		Y				Y		Y							
udder		U		U			U		U				U		U		U		U				U		U							
antlers (#)		2		0			0		0				0		0		0		0				0		0							

Appendix Table 1. (Continued).

Cow # and	May		June																													
Status	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
W7:																																
calf		Y		Y			Y		Y				Y		Y		Y		Y					Y		Y						
udder		U		U			U		U				U		U		U		U					U		U						
antlers (#)		2		0			0		0				0		0		0		0					0		0						
W9																																
calf		N		Y			Y						Y		Y		Y		Y				Y			Y						
udder		U		U			U						U		U		U		U				U			U						
antlers (#)		0		0			0						0		0		0		0				0			0						
W13:																																
calf			N	N			N	Y	Y				Y		Y		Y		Y					Y								
udder			U	U			Y	U	U				U		U		U		U					U								
antlers (#)			2	2			2	2	2				0		0		0		0					0								
W15:																																
calf			N	N			N	N		N		N		N		N		N						N								
udder			U	U			N	U		Y		Y		N		N		U						U								
antlers (#)			2	2			2	2		2		2		0		0		0						0								

[a]N=no; Y=yes; U=undetermined.

ANWR Progress Report Number FY 85-1-Impacts

EFFECTS OF WINTER SEISMIC EXPLORATION ON THE COASTAL PLAIN OF THE ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, 1984

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Key Words: Surface disturbance, winter seismic exploration, tundra, vegetation change, terrain sensitivity, recovery, thaw depths, track depression, thaw settlement, traffic patterns, snow depth, Alaska, Arctic National Wildlife Refuge, Arctic-Beaufort

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14 December 1984

Effects of winter seismic exploration on the coastal plain, Arctic National Wildlife Refuge, Alaska, 1984

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Abstract: The impacts of the 1984 winter seismic exploration program upon the vegetation, thermal regime, and visual resources of the Arctic Coastal Plain were measured. Short-term impacts of vehicle traffic were evaluated, and this data will be used as a basis for a long-term recovery studies. Changes in vegetation and soils associated with various levels of disturbance were assessed on 16 intensive study plots (30m x 4m) and 52 photo trend plots (10m x 4m). Vegetation disturbance in wet lowland areas ranged from compression of standing dead and slight surface scuffing to compaction of the moss mat below the water surface. Disturbance in tussock tundra ranged from scuffing of tussocks and less than 25% decrease in vegetative cover to mound top destruction with ruts starting to form, over 50% decrease in vegetative cover,and over 15% peat exposed. Disturbance in Dryas river terrace commonly included over 50% vegetation damage and over 15% soil exposed. Generally, soil exposure was limited to the surface of the organic layer. Thaw depth increases (P 0.05), ranging from 2.7 - 7.8cm, occurred in 35% of the disturbed plots within all vegetation types. Track depression, due to a combination of compaction and thaw settlement, was evident at 1 plot in moist sedge, prostrate shrub tundra where the average track depression was 8.9cm. The relationship between disturbance levels, vegetation types, traffic patterns, and snow cover was examined using interpretation of color infrared aerial photographs (1:6000 scale). Higher level disturbances occurred more often in vegetation types with high micro-relief and those dominated by birch (*Betula nana*), dryas (*Dryas integrifolia* subsp. *integrifolia*), and ericaceous shrubs (*Vaccinium vitis-idaea*, *Ledum palustre* subsp. *decumbens*) than in wet lowland habitats. Camp move vehicles (cat-trains) caused higher disturbance levels than seismic vehicles. Narrow, concentrated trails (both camp move and seismic) caused higher levels of disturbance than diffuse trails. Nodwell turns created more disturbance than straight Nodwell trails. A reliable understanding of the relationship between snow cover and disturbance caused by future winter seismic exploration include avoiding narrow, concentrated vehicle trails; routing vehicle traffic and locating campsites in less sensitive vegetation types and areas of high snow cover; and strict monitoring to prevent leaks and spills of oil, diesel, and gasoline.

Effects of winter seismic exploration on the coastal plain of the Arctic National Wildlife Refuge, Alaska, 1984.

The Alaska National Interest Lands Conservation Act (ANILCA), Section 1002, authorizes oil and gas exploration activities on the coastal plain of the Arctic National Wildlife Refuge (ANWR), and requires that such exploration occur in a manner which avoids significant adverse effects to fish and wildlife, their habitat, and the environment. During January - May 1984, Geophysical Services Incorporated (GSI) conducted a winter seismic exploration program, utilizing the drilled shothole technique. Two crews completed a total of 607 mi (977 km) of seismic line arranged in a 6 x 12 mi (9.7 x 19.3 km) grid over the coastal plain, an area of 1.5 million acres ($6x10^5$ha)(Fig. 1). The vehicles used by each crew included the following:

8 Nodwell mounted Drills (2.81 psi)
1 Chieftain tracked recording vehicle (3.52 psi)
4 Nodwells geophone trucks (2.81 psi)
1 Nodwell preload vehicle (2.81 psi)
8 Bombardiers (1.3 psi)
1 Gravity snow cat (1.3 psi)
1 Camp utility vehicle with crane (2.81 psi)
6 Caterpillar D-7 tractors (10.5 psi)
1 Ski-mounted camp (13-14 trailers, 6.0 psi each)
3-Ski-mounted fuel sleighs for 18,000 gallons (6.0 psi each)
1 Dynamite magazine (8.0 psi)
1 Magazine for detonators (less than 1.0 psi)

Data collection on each seismic line required multiple passes of bombardiers, Nodwell drills, preload vehicle, geophone trucks, and the Chieftain recorder truck. The ski-mounted camps pulled by Caterpillar D-7 tractors (cat-trains) usually moved daily to stay ahead of the crews. These camp moves occasionally followed the seismic line, but often followed separate routes to minimize surface disturbance. Resupply of fuel and explosives was by ski-mounted tanks and magazines pulled overland by a Caterpillar D-7 tractor from the coast. Other supplies and personnel were flown in by a turbine beaver or twin otter, which landed on a frozen lake or snow - covered tundra near the camps.

U.S. Fish and Wildlife Service (FWS) monitors accompanied the seismic crews throughout the 1984 season to ensure that regulations and permit stipulations were followed. FWS monitors worked with the party managers and survey crews to route vehicle traffic in areas where surface disturbance would hopefully be minimized.

This study was designed to assess the overall impacts of the 1984 exploration program and to provide base line data for future monitoring efforts. The following objectives of this study address management needs identified during the 1984 monitoring season:

1) Determine the snow cover needed to provide adequate protective cover and minimize surface disturbance.
2) Determine the relative sensitivity of vegetation types on the arctic coastal plain.

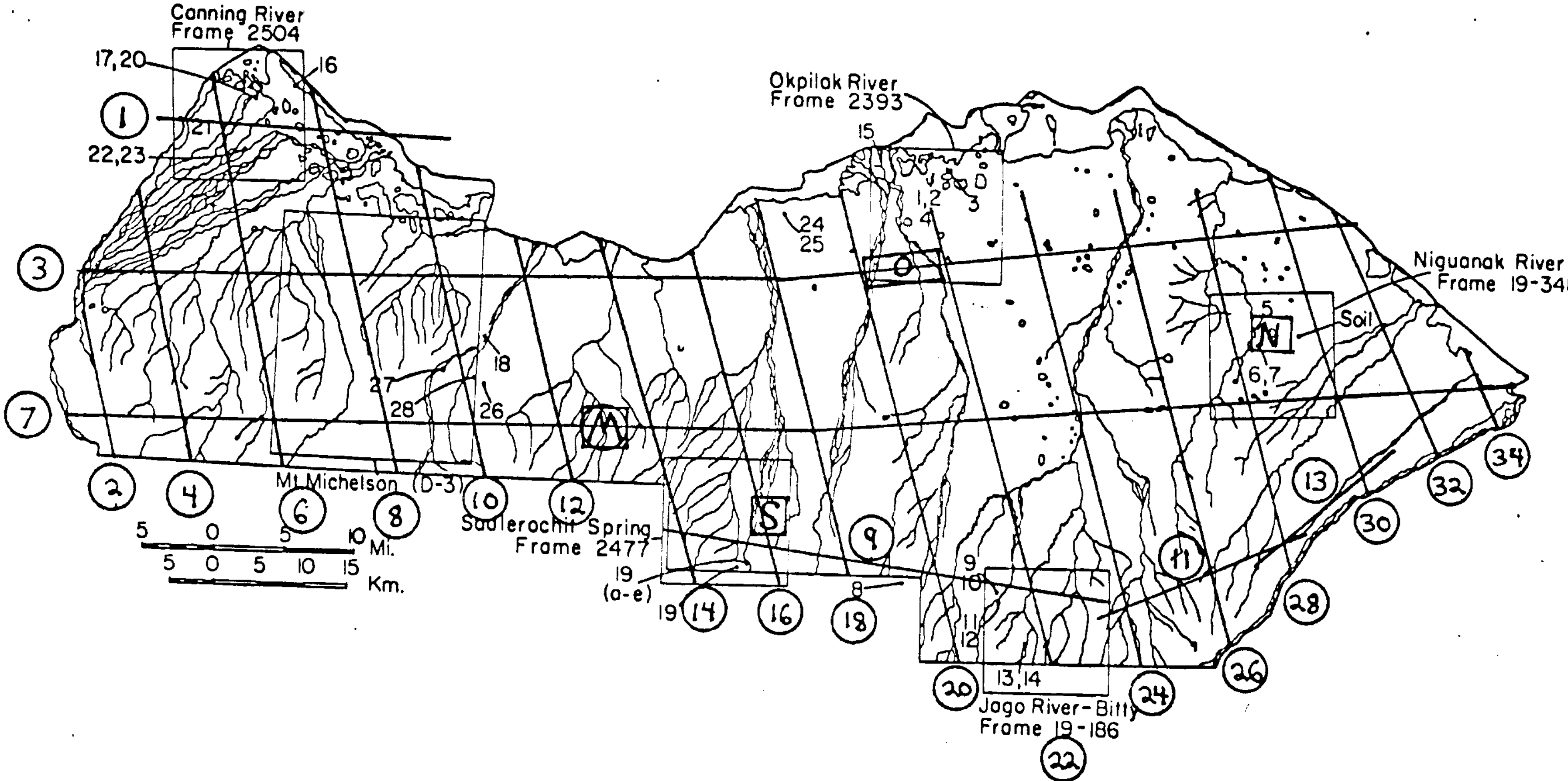

Figure 1. Map of the location of the 1984 seismic lines and intensive study plots on the coastal plain, Arctic NWR, Alaska.

○ Seismic lines 1-34.

□ Intensive study plots: M-Marsh Creek, S-Sadlerochit River, O-Okpilak River, N-Niguanak.

Base map from Walker et. al. (1983).

3) Determine which traffic patterns minimize surface disturbance.
4) Determine recovery times needed for different levels of disturbance.

The preliminary results presented in this paper are based on:

- intensive study plots
- photo trend plots
- aerial photo interpretation
- summer observations

Intensive study plots were established to gather detailed information on the effects of vehicle traffic on the tundra. Factors which influence the level of disturbance caused by winter vehicle use are summarized in Fig. 2. At each intensive study plot, descriptive data on vegetation type, surface form, slope, soil texture, and soil moisture were recorded. These plots were established during the winter, and data were gathered on snow cover and traffic pattern. During the summer field season, the effects of vehicle passage on vegetative cover, shrub height, thaw depth, and track depression were sampled.

Photo trend plots were established to provide a data base for long-term recovery observations. The amount of disturbance was rated and documented with photographs at each plot. These plots were located throughout the coastal plain to cover all levels of disturbance, but especially areas with high levels of disturbance, where recovery will be slower and of more concern.

Low-level aerial photography was obtained for a portion of the seismic lines and camp move routes. Basic disturbance levels and vegetation types were identified on these photos. This portion of the study was designed to assess overall impacts and relate disturbance levels to snow data, vegetation types, and traffic patterns.

During the summer field season, low-level aerial reconnaissance was conducted on the majority of trails created by the 1984 seismic exploration program. This reconnaissance was conducted using helicopter and frequent stops were made to assess disturbance on the ground. These observations of trail disturbance contributed to the assessment of the overall impacts by broadening the basis for comparing the nature and magnitude of disturbances.

STUDY PLOTS

Methods

Intensive Study Plots

Intensive study plots were established in 4 areas on the coastal plain (Fig. 1):

- Marsh Creek and Line 7 intersection
- Sadlerochit River and Line 16 intersection
- Okpilak River and Line 3 intersection
- East of the Niguanak River at the large lake on Line 28

these areas were inspected immediately after seismic work was completed in the winter. Plots were selected to represent different disturbance levels,

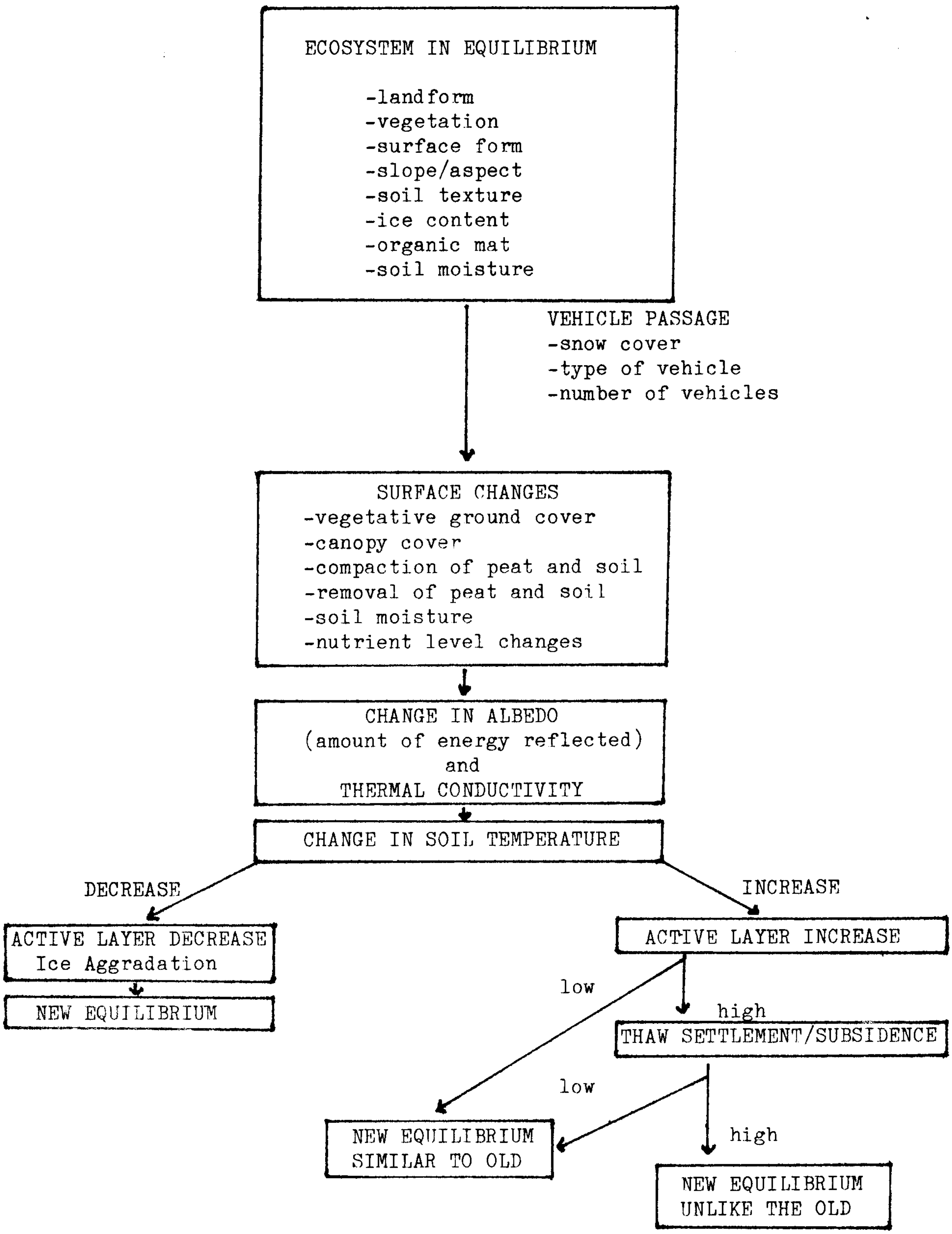

Figure 2. Effects of vehicle passage on an arctic ecosystem (adapted from Webber and Ives, 1978).

depending on the amount of vegetation damage and soil exposed, in each of the major vegetation types, as defined by Walker et al. (1982).

Plots were marked in the winter by 2 stakes wired to rebar located 30 m apart. Snow depth was measured at 20 random points (using a random number table) located along a 30 m tape. At 5 of these points, randomly allocated, snow profiles were dug and the heights of the following layers were measured:

- depth hoar - ground layer with large crystals and much air space
- windpacked snow
- crust layers
- new snow

These stakes were relocated in the summer, and plots, 4 m x 30 m, were established on the trails. Control plots, also 4 m x 30 m, were established nearby in an undisturbed area with similar habitat characteristics. Sometimes, plots were varied according to the disturbance found at a given location. At plot S5 where the trail was narrower, a 3m x 30 m plot was established. In some areas, such as camp move routes, disturbance occurred in separate tracks (S8, N12). Measurements would then be taken in the tracks and in adjacent undisturbed strips between the tracks (for a control). Each track where measurements were taken was marked by stakes 30 m apart. Each plot was described by landcover class, (Walker et al. 1982), vegetation, landform, and surface form (Walker et al. 1983). Percent slope was measured with an abney level, and aspect recorded.

Disturbance at each plot was classified in the summer using a system adapted from the Muskeg Research Institute (1970)(Table 1). A comparison between visual and sampling estimates was made. A series of photographs were taken at each plot to provide a visual record of disturbance. Stereo triplets were taken from each end of the disturbed and control plots using a 35 mm wide-angle lens and 100 ASA color print film. Two vertical ground photos of 1 m^2 quadrats were taken by standing on a platform above the plots, using a 35 mm wide-angle lens and 100 ASA color print film. Opposite corners of the 1 m^2 quadrat were marked with rebar, so that photographs can be taken at the exact location in subsequent years. Aerial stereo triplets of disturbed and control plots were taken from the helicopter at an altitude of 60 m. These photos were taken with a 50 mm lens and 400 ASA color print film.

Vegetative cover was sampled on the disturbed and control plots using a point frame. Point sampling is the most objective method for measuring vegetative cover and eliminating variation between observers (Goodall 1953). The point frame was constructed from plastic pipes with guideholes at 20cm intervals through which wire pins were lowered vertically to sample vegetation. A total of 200 points were sampled on 10 separate transects in each plot. Estimates of percent cover of plant species, litter, organic soil, organic-mineral soil, and mineral soil were obtained by recording the first interception of the pin with each species and the ground cover. On riparian willow plots, the height of each shrub hit by a point was recorded.

The physical characteristics of soils of undisturbed tundra were sampled. Five soil texture profiles were described adjacent to each control plot. Soil texture (Table 2) was qualitatively determined based on the soil descriptions of Bates et al. (1982). Samples for soil moisture and bulk density determinations were extracted with a constant volume sampler (3cm deep, 5.4cm diameter) from the surface horizon at 3-6cm. Samples of lower horizons were

Table 1. Disturbance Ratings (adapted from Muskeg Research Institute, 1970).

Vegetation:	
1.	Undamaged
2.	Standing dead vegetation compressed - no surface disturbance
3.	Shrubs broken - no surface disturbance
4.	Tearing and scattering of vegetation - 10% Dead
5.	Tearing and scattering of vegetation - 25% Dead
6.	Tearing and scattering of vegetation - 50% Dead
7.	Tearing and scattering of vegetation - 75% Dead
8.	Tearing and scattering of vegetation - 90% Dead
9.	Tearing and scattering of vegetation - 100% Dead
Soil[a]	
1.	None Exposed
2.	1-5% Exposed
3.	10% Exposed
4.	25% Exposed
5.	50% Exposed
6.	75% Exposed
7.	90% Exposed
8.	100% Exposed
Structure:	
1.	Undamaged
2.	Slight damage
3.	Mound top scuffing
4.	Mound top destruction
5.	Ruts starting to form
6.	Ruts slightly deeper
7.	Ruts continuous
8.	Ruts with standing water

[a]Note: organic, organic-mineral, or mineral soil

Table 2. Soil Texture Classification

Soil Type	Description
Organic	Plant material that can range from light, yellow brown, undecomposed material to black, completely decomposed material. This class includes fibrous peat with undecomposed to weakly decomposed plant structures that are still recognizable. The class also includes strongly to completely decomposed peat in which plant structures are unrecognizable and all peat escapes through fingers when squeezed.
Organic-Mineral Soil	Highly organic mineral material. The organic material is usually black and strongly decomposed, but can also be fibrous. Mineral material may be of any texture.
Mineral Soil	
Sand	Individual grains readily seen. Feels grainy with little floury material. Does not form cast when squeezed.
Sandy Loam	Very grainy mixture of sand, silt, and clay. Forms a weak cast.
Loam	Mixture of sand, silt, and clay. Soft and smooth with evident graininess. Slightly sticky and forms a moderate cast.
Silt Loam	Floury with slight graininess, slightly sticky, and forms a weak cast.
Silt	Fine-grained material that is very floury, non-sticky, flakes when rolled, and forms a weak cast.
Clayey Loam	Some graininess, sticky. Forms a strong cast, and rolls into a fairly thin ribbon that barely supports its own weight.
Clay	Smooth, very sticky material that rolls into long, thin ribbons and forms a strong cast when squeezed.
Gravel	Up to 3 inches diameter. Gravelly soils contain 15-90% gravel.

extracted in zones of uniform texture. Field weight and oven-dry weight (105°C for mineral samples, 65°C for organic samples) were determined for percent moisture and bulk density calculations.

Ten surface soil samples (3cm deep, 5.4cm diameter) from areas of bare organic and mineral soil were obtained to assess seed stores available to recolonize disturbed areas. The soil samples were placed in a greenhouse for 7 weeks where; temperatures fluctuated from 15° to 25°C, humidity was high, and samples were watered 3 times per week. Seedlings were then harvested, and identified by lifeform or species, whenever possible.

Active layer depth (thaw depth) was determined by 40 probes along a diagonal transect across the disturbed and control plots. All thaw depths were measured in August during the time of maximum thaw.

The surface heights of the trails and surrounding areas were measured using a surveyor's level. These track depression measurements give an estimate of the amount of subsidence, compression, or removal of material. Permanent reference elevation markers were established from which the trail level can be measured in future years.

Photo Trend Plots

Photo trend plots were established to provide a semi-quantitative approach to assess the response of a larger variety of sites. These plots were located throughout the coastal plain, and included the major vegetation types and levels of disturbance which had been observed. These plots were permanently marked with 2 stakes and rebar located 10 m apart.

Landcover class and vegetation type was described at each plot, according to Walker et al. (1982) and Walker et al. (1983). Disturbance at each plot was visually rated (according to Table 1) and traffic pattern and slope were recorded. The major species at each plot were listed and their apparent sensitivity to disturbance was rated according to ocular estimates based upon the following scale:

1. Cover severely decreased.
2. Cover moderately decreased.
3. No change evident.

Resprouting of plants, by species, was noted.

Photographs were taken as described in the previous section. Stereo pairs were taken from each end of the plot, and from the helicopter at an altitude of 60 m. Vertical photos were taken of two 1 m^2 quadrats. These quadrats were subjectively located in representative disturbance types on each plot, and were permanently marked with rebar.

Active layer depth was measured by 30 probes in the disturbed area and 30 probes in an adjacent undisturbed control.

Results And Discussion

Plot Descriptions

Sixteen intensive study plots were estabished (Table 3). Vegetation types

Table 3. Intensive study plots, coastal plain, Arctic NWR, Alaska, 1984.

Plot	Vegetation Type	Snow Depth (cm)	Traffic Pattern	Disturbance Rating: Vegetation (%)	Disturbance Rating: Soil (%)	Disturbance Rating: Structure[1]	Vegetative Cover: C (%)	Vegetative Cover: D (%)	Vegetative Cover: (%) Decrease	Soil Exposed: C (%)	Soil Exposed: D (%)
Marsh Creek											
M-1	Moist Sedge, Prostrate Shrub	21.1 ± 3.8	All-narrow	10	1-5	2	34.8	32.8	6	0.8	2.2
M-2	Moist Tussock, Dwarf Shrub	19.3 ± 5.6	All-narrow	25 75R	10 50R	5	82.5	41.4	50	0.3	3.8
M-3	Moist Dwarf Shrub, Tussock	20.1 ± 8.6	All-narrow	50	25	5	84.7	32.3	62	0.7	4.0
M-4	Open Riparian Shrubland	24.6 ± 7.9	All-narrow	25	tr	2	121.0	66.7	45	0.3	0.0
Okpilak											
O-3	Moist Tussock Dwarf Shrub	11.4 ± 2.8	Camp-narrow	50	25	4	124.5	74.0	41	3.0	15.0
O-6	*Dryas* River Terrace	4.1 ± 1.5	Seismic-narrow	75	50	4	98.0	12.5	87	1.0	26.5
O-7	Moist Sedge/ Barren	11.7 ± 4.6	Seismic-diffuse	25	10	3	114.5	57.0	50	0.0	11.0
O-11	Moist/Wet Sedge	No Data	Camp-narrow	10	10	3	99.0	53.0	46	1.0	20.5
O-12	Moist/Wet Sedge polygon rim	No Data	Camp-narrow	75R	75R	5	129.5	67.5	48	0.5	20.5

Table 3. (Continued).

Plot	Vegetation Type	Snow Depth (cm)	Traffic Pattern	Disturbance Rating			Vegetative Cover			Soil Exposed	
				Vegetation (%)	Soil (%)	Structure[1]	C (%)	D (%)	(%) Decrease	C (%)	D (%)
Sadlerochit											
S-1	Moist Sedge Tussock, Dwarf shrub	17.8 ± 3.8	Seismic-diffuse	10	1-5	3	109.0	85.5	22	0	2.0
S-4	Moist Dwarf Shrub, Tussock	10.2 ± 6.1	Seismic-diffuse	25	1-5	3	149.5	114.0	24	0	1.0
S-5	Closed Riparian Shrubland	23.6 ± 4.1	Seismic-narrow	25	0	1	169.7	130.9	23	0	1.2
S-6	Moist Dwarf Shrub, Tussock	7.9 ± 4.1	Camp-narrow	50R	25R	4	149.0	103.0	31	0	8.5
S-8	Moist Sedge Tussock, Dwarf Shrub	13.2 ± 8.4	Camp-diffuse	50R	10R	4	132.5	78.5	41	0	10.5
Niguanak											
N-11	Moist Sedge/ Barren	9.7 ± 2.8	Seismic-diffuse	25	10	3	120.5	73.5	39	0.5	4.5
N-12	Moist Sedge/ Barren	8.1 ± 3.6	Camp-diffuse	25	10	3	107.0	62.5	42	3.0	7.0

C - control plot, D- disturbed plot, tr - trace amount
R % disturbance estimated in vehicle ruts.
[1]Structure. 1. Undamaged; 2. Slight Damage; 3. Mound top scuffing; 4. Mound top destruction; 5. Ruts starting to form; 6. Ruts slightly deeper; 7. Ruts continuous; 8. Ruts with standing water

listed are based on the Landsat land cover classes developed for the coastal plain of ANWR (Walker et al. 1982). Snow depth and traffic patterns are listed for each plot. Disturbance levels according to the rating scheme (Table 1) are listed. Total vegetative cover and exposed soil determined by the point sampling method are shown in the final columns of Table 3.

These study plots are a sample of the disturbance levels observed within each vegetation type on the coastal plain in the 1984 field season. The main disturbance types not represented are the higher level disturbances found in Moist/Wet Sedge and Moist Sedge, Prostrate Shrub Tundra, where compression of the moss layer has occurred.

The subjective disturbance rating for vegetation, in most cases, approximates the decrease in vegetative cover estimated by the point sampling method. However, a few inconsistencies are apparent. First it is important to define the area for which a disturbance estimate is being made. Often two levels of disturbance existed on a trail, one in the concentrated tracks or ruts and another in the overall area. In this case, often two disturbance ratings were given. The area was usually defined as a plot 4 m X 30 m for sampling purposes. The amount of disturbance in a concentrated track or rut, therefore, would not be adequately represented when the sampling was done on a larger area that included lower disturbance. For example, on plot S6, the estimated decrease in vegetative cover was 31% with 9% exposed soil, but on portions of this plot, higher disturbance was evident due to concentrated traffic. In areas of diffuse camp move trails (plots S8 and N12), disturbance occurred in narrow bands over a larger undisturbed area. In this case, disturbance ratings and vegetation estimates were confined to the tracks.

Other inconsistencies are due to the difficulty of accurately rating vegetation disturbance for all lifeforms in an area. On plot O11, much of the decrease in vegetative cover was due to decreased moss and shrub cover, which was not detected in the visual estimation. In areas with high shrub cover, the total vegetative cover of the undisturbed site may be over 100%, because individual layers may overlap. This makes it difficult for the observer to estimate the actual percentage of vegetation that has been disturbed.

The estimation of exposed soil provided by point sampling was sometimes less than that estimated by the subjective rating scheme. This is mainly due to the presence of litter or dead material on top of the exposed soil. In point sampling, the pointer often lands on small bits of litter in an area which would appear to be a patch of exposed soil for visual estimates.

Fifty-two photo trend plots were established to represent a larger range of disturbance types found during the 1984 field season. The distribution of these plots by vegetation type and type of impact is shown in Table 4. The disturbance ratings show the range of disturbance levels included in these plots. The disturbance rating scheme as previously discussed was developed as a method to quickly assess the general disturbance level of these plots. For future studies, a double sampling scheme will be established to check the accuracy of the system, and to train observers to recognize the basic disturbance levels. The double sampling scheme can also be used to calculate a correction factor for ocular estimates.

Photographic documentation

The series of aerial, ground stereo, and 1 m^2 quadrat photographs of the

Table 4. Photo trend plots Arctic NWR, Alaska, 1984.

Vegetation Type	Plot No.	Type of Disturbance	Disturbance Rating Veg. (%)	Soil (%)	Structure[1]
Wet Sedge or	T21	Supply/narrow	0	0	3
Moist/Wet	T20	Supply/narrow	25	10	3
Sedge Complex	N8	Seismic line	1-5	1-5	2
	O5	Seismic line	1-5	0	2
	O10	Seismic line	1-5	1-5	2
	T16	Seismic line	0	0	1
	N1	Camp/diffuse	1-5	1-5	2
	N2	Camp/diffuse	10	10	3
	T5	Fuel spill	100	0	1
	T6	Oil spill	75-100	0	2
	T17	Fuel spill	100	75	3
Moist Sedge,	T32	Camp/narrow	75	1-5	8
Prostrate Shrub	T25	Cat tracks	25	0	3
Tundra	T26	Cat tracks	10	1-5	3
	T27	Cat tracks	90	90	6
	T31	Nodwell turn	50	25	5
	T10	Fuel spill	90	0	1
Moist Sedge/	T19	Supply/narrow	50	25	4
Barren Tundra	T7	Seismic/narrow	25	25	3
Complex	N9	Seismic line	10	10	3
	N4	Camp/diffuse	10	10	3
	N5	Camp/diffuse	25	10	3
	N6	Camp/diffuse	50	25	4
	N7	Camp/diffuse	10	1-5	3
	T24	Campsite	50	50	4
Moist Sedge	M5	Camp+line/narrow	50	25	5
Tussock, Dwarf			75R	50R	
Shrub Tundra	T22	Camp/narrow	50	25	4
	T18	Seismic/narrow	25	10	4
	T23	Seismic/narrow	25	10	3
	T28	Drill trail	25	25	4
	T12	Seismic line	25	10	3
	T13	Seismic line	1-5	1-5	3
	T15	Seismic line	1-5	0	2
	T3	Camp/diffuse	1-5	tr	2
	T4	Camp/diffuse	25	10	3
	T8	Seismic line	10	10	4
	T11	Crater	100	100	8
	T30	Crater	100	100	8
Moist Dwarf	O8	Seismic line	50	1-5	3
Shrub, Sedge	T29	Camp/narrow	75	25	3
Tussock Tundra	S2	Seismic line	25	1-5	3
high-centered	S3	Seismic line	25	1-5	3
polygons	S7	Camp/diffuse	25	1-5	3
	N3	Camp/diffuse	50	10	3

Table 4. (Continued).

Vegetation Type	Plot No.	Type of Disturbance	Disturbance Rating Veg. (%)	Soil (%)	Structure[1]
Dry Prostrate Shrub, Lichen Tundra	T9	Nodwell-steep slope	25	25	4
	T14	Seismic line	10	10	3
Open Riparian Shrubland - Willow, Moss	T1	Seismic/narrow	25	10	3
	T2	Seismic/narrow	25	10	3
Open Riparian Shrubland - Willow, *Dryas* sp.	S9	Camp/narrow	50	10	3
Open Riparian Shrubland - Willow, Forb	02	Camp/narrow	10	1-5	2
	09	Seismic/narrow	10	1-5	2
Open Willow Slope	01	Camp/diffuse	50	10	3

R - % disturbance estimated in vehicle ruts.

1 Structure. 1. Undamaged; 2. Slight Damage; 3. Mound top scuffing; 4. Mound top destruction; 5. Ruts starting to form; 6. Ruts slightly deeper; 7. Ruts continuous; 8. Ruts with standing water

intensive study plots and photo trend plots are on file in the Refuge office. The photographs will be valuable in assessing recovery of the plots in future years.

The aerial photographs were printed at approximately 1:300 scale (4 X 6 in), and provide stereo coverage. Permanent markers, individual low shrubs, tussocks, micro-relief, and amount of soil exposed were identifiable at this scale. The photographs were useful in the interpretation of vegetation and disturbance on the smaller scale photographs. Oblique aerials were also obtained, but could be improved by taking them at a greater distance and including the horizon. This would facilitate locating the plots on smaller scale photography.

The ground stereo coverage provided good first year documentation. Photographs taken with a 35 mm focal length provided better detail of adjacent undisturbed tundra than those taken with a 55 mm focal length. Photographs taken from 0.5 m apart on the ground provided the best stereo coverage with about two thirds of the plot being in stereo without realignment. The stereo pairs aided in identifying species and structures.

The vertical ground photos of 1 m^2 quadrats were printed at approximately 1:10 scale (4 X 6 in) and provide good resolution of individual plants. These photos will be useful for documenting long term recovery of plant species and microsites and may also be used for quantitative measurements of changes in the future.

Vegetation

Vegetative cover estimates of major species and lifeforms for disturbed and control plots are presented in Appendix A, Tables A-1 through A-5. The taxonomic nomenclature follows that of Hulten (1968) and Viereck and Little (1972) for willows. Data are listed by species when cover estimates are 3% or more in either the control or disturbed plot. All species with a lower estimated cover value are listed by lifeform. Estimates of exposed ground are divided into organics, organic-mineral soil, mineral soil, litter, or water. The total amount of litter (with and without a plant canopy) is shown.

Data analysis is ongoing. Statistical significance of cover differences between disturbed and control plots will be tested using t-tests in Dixon et al. (1981). These data will serve as a base for measuring recovery rates of species in future years.

Some general observations of vegetative cover differences can be made from these data. Shrubs (Betula nana, Dryas integrifolia, Ledum palustre, and Vaccinium vitis-idaea) decreased in the disturbed plots compared to control plots in most cases, and thus appear sensitive to disturbance. Moss cover on most disturbed plots also decreased compared to control plots. Vegetative cover data for sedge tussocks (Eriophorum vaginatum) does not appear to accurately reflect the level of damage that occurs to the tussock structure. This is probably due to the large amount of litter or dead material that is present even in healthy tussocks. Live E. vaginatum tillers, as recorded by a point frame, are only a small percentage of the live, dead, and decomposed material in a tussock (Chapin et al. 1979). Small changes, then, in absolute cover of E. vaginatum may be accompanied by large changes in structure. Another rating scheme is necessary to estimate the amount of scuffing, crushing, or mound top destruction of tussocks that is present. The structural disturbance rating scheme discussed earlier addresses this problem.

On the riparian shrub plots, M4 and S5, the height of willows was measured on disturbed and control plots. The data are shown in Table 5. Shrub height will provide an estimate of recovery rates in future years.

Table 5. Changes in height of low shrubs in Riparian Willow habitats due to winter seismic exploration, coastal plain, Arctic NWR, Alaska, 1984.

Plot	Species	Height (cm) Control	Height (cm) Disturbed	Percent Difference	Difference (cm)
S5	Salix glauca	35.8±11.9 (n=30)	24.8±11.7 (n-33)	-31.7*	-11.0
S5	S. planifolia pulchra	17.2±8.9 (n=10)	18.6±10.5 (n=12)	+ 8.1	+ 1.4
S5	S. lanata	29.5± 9.0 (n=32)	23.8±10.9 (n=20)	-19.3*	- 5.7
M4	S. alaxensis	25.4±7.7 (n=13)	16.0±6.2 (n=19)	-37.0*	- 9.4
M4	S. brachycarpa niphoclada	15.6±6.2 (n=41)	13.5±6.76 (n=18)	-13.5	- 2.1
M4	S. myrtillifolia	10.3±5.4 (n=23)	11.6±5.0 (n=7)	+12.6	+ 1.3

*Statistically significant at P=.05.

Seed stores in exposed soil on disturbed sites were sampled and the results are shown in Table 6. Seedling of grasses, sedges, and Stellaria spp. grew on some of these soil samples under green house conditions. Soil samples from S5, a Closed Riparian Shrubland, had a substantial number of seedlings. These data indicate that good seed stores are present, and the decreased canopy cover on this plot will allow graminoid species to increase. Reynolds (1982) observed an increase of understory plants, including grasses and sedges, in a riparian willow area which had been impacted by winter seismic vehicles. Few seeds appear to be available for germination at other study plots (Table 6).

Table 6. Seed stores available in disturbed sites, coastal plain, Arctic NWR, Alaska, 1984.

Plot	Number of Samples	Type of Seedling	Number of Seedlings
M2	10	Graminoid	1
M3	10		0
M4	10	Stellaria sp.	1
06	20	Grass	1
		Graminoid	1
07	10	Grass	2
012	10	Grass	3
S4	10	Stellaria sp.	1
		Grass	1
S5	10	Carex sp,	16
		Grass	10
S6	10		0
S8	10		0
N12	10		0

Vegetative reproduction may play an important role in revegetation of these sites. Arctic plants have a high percentage of below ground biomass in the form of roots and rhizomes, which are important for vegetative reproduction (Billings 1973). Future studies should compare the amount of recovery by resprouting of vegetative parts to seedling growth of different plant species.

Soils

Physical Characteristics of Soils

The texture, moisture, and bulk density characteristics of the undisturbed soils of the intensive plots were determined to help understand the nature and magnitude of disturbance of the surface. These are presented in Tables 7 and 8, which summarize soil profile descriptions gathered at the plots.

The organic (peat) layer, consisting of well to poorly decomposed plant material, varied in depth from less than 1 cm at a dry, well drained site (O6) to more than 27 cm at a poorly drained, saturated site (O11). The Moist Sedge/Barren Tundra, Moist Sedge Tussock, Dwarf Shrub Tundra, and Moist Dwarf Shrub, Sedge Tussock Tundra vegetation types had intermediate organic layer depths, generally, averaging 9 to 15 cm. The organic layer depth can be extremely variable however, especially in the Moist Sedge/Barren Tundra complex sites N11 and N12. At these sites the organic layer depth ranged from 0 cm to 21 cm. The organic layer was least variable in the Moist/Wet Sedge (O11), the Riparian Shrubland (S5, M4) and the *Dryas* River Terrace (O6) plots. Moist Sedge Tussock, Dwarf Shrub Tundra and Moist Dwarf Shrub, Sedge Tussock Tundra are generally intermediate in the variability of their organic layer depths.

The organic layer may have a distinct boundary or become incorporated in the mineral material. This may result from in-situ growth and decomposition processes, cryoturbation, or fluvial and eolian deposition of mineral material onto the organic mat and incorporation over time. Ice segregation may maintain distinct boundaries (Everett and Brown 1982). Distinguishing organic and organic-mineral material can be difficult for fine-grained soils, therefore it is useful to examine both layers combined. In most cases it adds only a few centimeters to the average organic layer depth (Tables 7 and 8). In a few cases however it can be a substantial part of the organic and organic-mineral layer. This generally occurs in fluvial situations (O12, O7, S5, O6), where silts and sands are deposited on and incorporated into the organic mat. The Moist Dwarf Shrub, Sedge Tussock Tundra plot M3 also has a substantial organic-mineral layer.

The organic layer depths and textural profiles can be used to assess the level of damage done by vehicle traffic. Generally the exposing of bare soil has been limited to the organic layer (Appendix A, Tables A-1 through A-5) indicating that the surface has not been sufficiently disrupted to expose underlying material. At those sites where the organic-mineral material has been substantially exposed (O12, O6, O7) the organic layer is very thin, averaging 0 to 1.6 cm, for O6 and O7 respectively, or is extremely variable (O12) so that the organic-mineral layer is frequently near the surface. At O12, plots on low-centered polygon rims, the level of disturbance can be classified as ruts starting to form. At disturbed plots N11, N12, and M2 where mineral soil was exposed (1.2% or less), it is found in comparable amounts in the control plots. At these sites the mineral soil present can be attributed to frost boils or the stripping of the very thin organic cover on the frost boils and not to severe disruption of a thick organic mat.

Table 7. Physical characteristics of undisturbed soils of the intensive study plots in; Wet and Moist/Wet Sedge Complexes; Moist Sedge/Barren Tundra Complex; and Riparian Shrubland, coastal plain, Arctic NWR, Alaska, 1984.

	Wet and Moist/Wet Sedge Complexes			Moist Sedge/Barren Tundra Complex			Riparian Shrubland	
	M1	O11	O12	N11	N12	O7	S5	M4
Organic layer depth (cm, n=5)	13.8 ± 6.6	27.4 ± 2.2	10.8 ± 12.1	11.2 ± 8.8	11.6 ± 6.8	1.6 ± 0.5	9.4 ± 3.9	2.4 ± 0.9
Organic & Org Min depth (cm, n=5)	16.8 ± 3.4	27.4 ± 2.4	29.8 ± 8.9	11.2 ± 8.8	14.0 ± 9.1	12.0 ± 5.5	24.0 ± 3.4	3.2 ± 1.8
Texture of C Horizon	Silty clay loam	Sandy loam	Sandy loam	Fine sand w/tr gravel	Fine sand w/tr gravel	Sandy loam	Sandy loam w/s gravel	Sandy loam
Moisture (% vol.)								
Surface (3-6cm,n=5)	85.0 ± 3.4	N	62.0 ± 10.4	60.4 ± 26.3	71.5 ± 16.0	N	50.0 ± 11.5	38.0 ± 4.1
Organic	85.0 ± 3.4 (n=5)	N	70.4 ± 12.7 (n=3)	79.5 ± 2.2 (n=3)	78.6 ± 1.2 (n=4)	N	50.0 ± 11.5 (n=25)	N
Org. Min	79.0 (n=1)	N	58.9 ± 7.8 (n=3)	N	68.0 (n=1)	N	61.1 (n=1)	40.1 (n=1)
Mineral	63.0 (n=1)	N	N	34.5 ± 5.9 (n=4)	38.3 ± 6.6 (n=2)	N	52.9 (n=1)	37.5 ± 4.5 (n=4)
Bulk density (g/cm^3)								
Surface (3-6cm, n=5)	0.14 ± 0.2	N	0.48 ± 0.25	0.81 ± 0.80	0.52 ± 0.63	N	0.21 ± 0.02	0.80 ± 0.06
Organic	0.14 ± 0.02 (n=5)	N	0.29 ± 0.09 (n=3)	0.23 ± 0.03 (n=3)	0.24 ± 0.04 (n=4)	N	0.21 ± 0.02 (n=5)	N
Org. Min.	0.30 (n=1)	N	0.64 ± 0.17 (n=3)	N	0.69 (n=1)	N	0.40 (n=1)	0.82 (n=1)
Mineral	0.86 (n=1)	N	N	1.57 ± 0.22 (n=4)	1.65 ± 0.01 (n=2)	N	1.29 (n=1)	0.79 ± 0.07 (n=4)

w/tr - with trace, w/s - with some, N - no data.
Means ± SD

Table 8. Physical characteristics of undisturbed soils of the intensive study plots in: Moist Sedge Tussock, Dwarf Shrub Tundra; Moist Dwarf Shrub, Sedge Tussock Tundra; and *Dryas* River Terrace, coastal plain, Arctic NWR, Alaska, 1984.

	Moist Sedge Tussock Dwarf Shrub Tundra			Moist Dwarf Shrub, Sedge Tussock High center polygons				*Dryas* River Terrace
	M2	O3	S1	M3	S6	S8	S4	06
Organic layer depth (cm, n=5)	12.3 ± 5.4	10.4 ± 5.2	10.7 ± 2.9	9.4 ± 6.5	9.0 ± 5.2	15.7 ± 5.3	12.6 ± 5.5	1
Organic & Org Min depth (cm, n=5)	12.3 ± 5.4	10.4 ± 5.2	10.7 ± 2.9	20.0 ± 7.6	10.4 ± 6.9	15.7 ± 5.3	15.6 ± 5.9	1.3 ± 0.8
Texture of C Horizon	Silty clay loam	Silt	Silt	Silty clay loam	Silt	Silt	Silt	Sandy loam
Moisture (% vol.)								
Surface (3-6cm, n=5)	64.0 ± 7.8	55.0 ± 10.1	87.9 ± 6.7	58.0 ± 20.2	43.0 ± 13.4	62.0 ± 16.6	36.7 ± 17.0	N
Organic	65.4 ± 8.1 (n=4)	55.0 ± 10.1 N	87.9 ± 6.7 (n=5)	60.8 ± 23.0 (n=4)	41.6 ± 15.0 (n=4)	62.9 ± 16.6 (n=4)	36.7 ± 17.0 (n=5)	N
Org. Min	N	67.0 (n=1)	63.1 ± 23.1 N	80.7 (n=2)	(n=1)	N	N	N
Mineral	58.5 ± 0.6 (n=2)	43.0 ± 7.2 N	N	55.0 (n=1)	48.7 (n=1)	N	N	N
Bulk density (g/cm^3)								
Surface (3-6cm, n=5)	0.29 ± 0.42	0.24 ± 0.08	0.20 ± 0.03	0.16 ± 0.15	0.31 ± 0.47	0.15 ± 0.07	0.17 ± 0.07	
Organic	0.10 ± 0.01 (n=4)	0.24 ± 0.08 (n=5)	0.20 ± 0.03 (n=5)	0.09 ± 0.02 (n=4)	0.11 ± 0.06 (n=4)	0.15 ± 0.07 (n=5)	0.17 ± 0.07 (n=5)	N
Org. Min.	N	0.59 (n=1)	N	0.30 ± 0.17 N	0.24 (n=1)	N	N	N
Mineral	1.0 ± 0.07 (n=2)	130.5 ± 22.8 (n=4)	N	0.94 (n=1)	1.14 (n=1)	N	N	N

w/tr - with trace, w/s - with some, N - no data

Means ± SD

The texture of the parent material (C-horizon) is determined by its depositional environment and is thus closely related to genetic landforms (Tedrow 1977). The Moist/Wet Sedge plot O11 and O12 and the Moist Sedge/Barren Tundra Complex plot O7, have abandoned floodplain cover deposits that have a sandy loam texture resulting from a slow-moving water depositional environment (Table 9). The Riparian Willow plots, S5 and M4 and the Dryas River Terrace plot, O6, are gravelly floodplain deposits with shallow sandy cover deposits. The Moist Sedge/Barren Tundra Complex has a wide gradation of marine and fluvial sediments that can vary from fine sand to having some gravel. The Moist Sedge Tussock, Dwarf Shrub Tundra plots (M2, O3, S1) and the Moist Dwarf Shrub, Sedge Tussock Tundra plots (M3, S4, S6, S8) occur on fine-grained material of silt and silty clay textures. These plots are generally on wind deposited loess, although they may occur on fine-grained soils of other origins.Soil moisture (volumetric) in undisturbed tundra showed few consistent patterns among sites and was highly variable, depending on microsite conditions (Tables 7 and 8). A plot that was saturated at the surface, M1, had moisture contents of around 85%. The surface organics generally averaged 50-80% moisture, but was highly variable depending on microsite relief. Saturated sands averaged 34.5% and 38.3% at plots N11 and N12. Silts averaged 43.0% and 48.7% moisture at O3 and S6 respectively. Silty clay loams averaged 63.0%, 58.5%, and 55.0% at M1, M2, and M3 respectively.

Bulk density was also highly variable at the surface, but was more consistent within the textural classes of the various horizons (Tables 7 and 8). Organic material averaged 0.14 to 0.29 gm/cm^3. Organic-mineral soil was highly variable depending on the mineral material and varied from 0.24 to 0.82 gm/cm^3. The averages of silty clay loams ranged from 0.86 to 1.0 gm/cm^3. For sandy loams bulk density averaged 0.79 gm/cm^3. Fine sand averaged 1.57 to 1.65 gm/cm^3.

Assessing small changes in bulk density and soil moisture due to disturbance would be difficult because of the high microsite variability found for these characteristics. For bulk density there are additional problems in separating out changes in bulk density that are due to compaction versus those resulting from a different soil horizon being exposed due to scuffing. Also it is difficult to extract a constant volume from the surface without disturbing the density of the sample. Although compaction was difficult to quantify it was a visually conspicuous form of disturbance in Moist/Wet Sedge and Moist Sedge, Prostrate Shrub Tundra habitats.

In upland terrain, changes in surface soil moisture were not readily apparent. But for some terrain types, such as Moist/Wet Sedge and Moist Sedge, Prostrate Shrub Tundra, a perched water table may be at or just below the surface. Vehicle traffic that results in compaction of the moss mat below the water surface can cause significant changes to the surface thermal and radiative properties (Brown and Grave 1979, Haag and Bliss 1974). At plots T21 and T32, ponding of water had occurred in the vehicle tracks, where standing water was not prevalent in the adjacent tundra. This has resulted in statistically significant thaw increases of 4.7cm ($t=7.05$, 29df, p .001) and 5.0 cm ($t=5.24$, 78df, p .001) respectively.

Thaw Depths

Thaw depth measurements on the study plots show significant increases occurred in all habitat types as the result of disturbance (Table 10). Due to gravelly

Table 9. Landscape components of intensive study plots, coastal plain, Arctic NWR, Alaska, 1984.

Vegetation Type	Plot	Slope %	Surface Morphology	Texture Parent Material	Genetic Landform
Wet Sedge or Moist/ Wet Sedge Complexes	M1	1.5	String fen	Silty clay loam	Colluvium-Loess / ?
	011	Flat	Low centered polygon	Sandy loam	Abandoned floodplain cover deposit.
	012	Flat	Low centered polygon rim	Sandy loam	Abandoned floodplain cover deposit.
Moist Sedge/ Barren Tundra Complex	N11	3	Frost scar	Fine sand w/trace gravel	Marine sediments
	N12	2	Frost scar	Fine sand w/trace gravel	Marine sediments
	07	Flat	Hummocky	Sandy loam	Abandoned floodplain
Moist Sedge Tussock, Dwarf Shrub Tundra	M2	3	Non-patterned	Silt	Loess / ?
	03	1	High centered polygon	Silty clay loam	Loess / Marine sediments
Moist Sedge Tussock, Dwarf Shrub Tundra	S1	10	Water-track	Silt	Loess / Glacial till
Moist Dwarf Shrub, Sedge Tussock Tundra	M3	2	High centered polygons	Silty clay loam	Loess / ?
	S6	2	High centered polygons	Silt	Loess / ?
	S8	1	High centered polygons	Silt	Loess / ?
	S4	2	High centered polygons	Silt	Loess / ?
Riparian Shrubland	S5	Flat	Flat terrace	Sandy loam / Gravel	Floodplain
	M4	2.5	Flat terrace	Sandy loam / Gravel	Floodplain
Dryas River Terrace	06	Flat	Flat terrace	Sandy loam / Gravel	Floodplain

? Unknown surficial material covered by Loess soils, no data could be obtained for riparian sites. A consistent trend in thaw increases among the habitat types is not evident from the data. Statistically significant increases ranged from 12.0 - 20.0% and from 2.7 cm - 7.8 cm.

For undisturbed terrain active layer depths were the least in Moist Dwarf Shrub, Sedge Tussock Tundra, and Moist Sedge, Prostrate Shrub Tundra where the averages were generally 23 to 28 cm. The deepest and most variable thaw depths were in the Moist Sedge/Barren Tundra complex. Typical was plot N12, where thaw depths ranged from 33 to 83 cm in undisturbed tundra.

Track Depression

Track depression was calculated as the difference between the mean height of the disturbed track and the average of the means of the values for the control sections adjacent to the trail. Conspicuous track depression was visible at plot T32 in Moist Sedge, Prostrate Shrub Tundra, where the average track depression was 8.9 cm. At this site, a camp move trail, cat-trains and other seismic vehicles moved on a narrow trail causing compaction of the moss layer and probably some thaw settlement, associated with increased thaw depths. Some ponding has occurred in the trail.

In many locations, track depression measurements were not useful for determining changes in the first year due to large microsite variability. It is difficult to reconstruct the original profile or to assume that the average height of the controls approximates the original conditions, unless the ground surface is fairly smooth, such as at T32. These measurements, tied into permanent control points driven into the permafrost will serve as baseline data for future thaw settlement comparisons.

Importance of Surface Characteristics to Surface Stability

Preserving the surface organic layer is essential to protecting permafrost (Nakano and Brown 1972, Goodwin and Outcalt 1974, Brown and Grave 1979). It is important as an insulating barrier to heat flow into the ground when it is moist or dry. If the organic layer is removed soil heat flux will be increased due to a change in surface thermal and radiative properties. In addition to its function as an insulator, it also serves as a reservoir of latent heat that absorbs a large percent of the heat flow into an undisturbed soil during the thaw season. If this layer is absent, new permafrost material will need to be thawed and incorporated into the active layer.

Statistically significant thaw increases have occurred in 16 of 45 cases in spite of very little loss of material from the organic mat (Table 10). At these sites various amounts of vegetation had been destroyed and peat exposed, but the organic layer has been basically preserved (Table 4). This evidence supports models of the physical processes of heat transfer through vegetation canopies and soil (Ng and Miller 1977), which demonstrated the importance of boundary layer conditions. Also the shallowest thaw depths were measured in Moist Dwarf Shrub, Sedge Tussock Tundra and Moist Sedge, Prostrate Shrub Tundra sites suggesting the canopy has some influence on reducing soil heat flux.

The texture of the parent material is an important factor controlling thaw settlement, fluvial erosion and other types of mass movement. Sites underlain by coarse gravels, generally floodplains, can be considered to be thaw stable

Table 10. Changes in thaw depths of photo trend and intensive study plots resulting from winter seismic exploration, coastal plain, Arctic NWR, Alaska, 1984.

Vegetation Type	Plot No.	(n)	Thaw Depth (cm) Disturbed	Thaw Depth (cm) Control	Difference (cm)	Percent Change
Wet Sedge or Moist/Wet Sedge Complex	T21	(30)	35.3 ± 3.2	30.6 ± 3.6	4.7*	15.4
	O11	(40)	34.7 ± 2.0	30.6 ± 3.0	4.1*	13.4
	O12	(50)	39.0 ± 2.7	32.6 ± 3.7	6.4*	19.6
	N8	(40)	41.2 ± 4.2	36.8 ± 5.3	4.4*	12.0
	O5	(10)	37.9 ± 3.9	39.8 ± 4.6	-1.9	-4.7
	O10	(30)	30.1 ± 3.9	28.8 ± 4.6	1.3	4.5
	T16	(10)	35.1 ± 2.2	32.4 ± 3.0	2.7*	8.3
	N1	(30)	41.3 ± 7.9	43.0 ± 8.6	-1.7	-4.0
	N2	(30)	41.6 ± 7.3	39.6 ± 9.9	2.0	5.0
	T5	(10)	39.6 ± 3.8	37.7 ± 2.1	1.9	5.0
Moist Sedge, Prostrate Shrub Tundra	M1	(40)	35.1 ± 3.2	32.3 ± 8.2	2.8	6.0
	T32	(40)	32.7 ± 3.5	27.7 ± 4.7	5.0*	18.0
	T25	(30)	24.8 ± 7.2	23.3 ± 2.1	1.5	6.0
	T26	(10)	32.3 ± 3.7	28.8 ± 6.3	3.5	12.0
Moist Sedge/ Barren Tundra Complex	T19	(30)	47.7 ± 5.1	40.6 ± 4.6	7.1*	17.5
	N9	(40)	61.5 ± 10.5	54.6 ± 24.7	6.9	12.6
	N11	(40)	56.7 ± 15.0	49.0 ± 7.6	7.7*	15.7
	N4	(30)	45.0 ± 7.5	45.9 ± 12.0	0.9	-2.0
	N5	(30)	58.9 ± 13.6	54.8 ± 13.1	4.1	7.5
	N6	(40)	42.0 ± 5.8	43.8 ± 7.8	-1.8	-4.3
	N7	(40)	34.4 ± 10.1	33.0 ± 11.2	1.4	4.2
	N12	(50)	54.1 ± 17.7	54.4 ± 14.3	-0.3	-1.0
Moist Sedge Tussock, Dwarf Shrub Tundra	M2	(40)	37.0 ± 8.0	33.0 ± 6.0	4.0*	12.0
	M5	(20)	39.9 ± 4.5	32.1 ± 7.5	7.8*	24.3
	O3	(20)	28.8 ± 5.6	26.2 ± 6.4	2.6	9.9
	T22	(30)	41.7 ± 5.9	38.4 ± 8.2	3.3	8.6
	T18	(30)	36.5 ± 4.3	38.2 ± 6.1	-1.7	-4.4
	T23	(30)	41.0 ± 6.6	37.8 ± 8.3	3.2	8.5
	T28	(30)	26.5 ± 4.4	24.4 ± 5.1	2.1	9.0
	T12	(10)	41.3 ± 9.1	36.6 ± 6.4	4.7	12.8
	T13	(10)	38.0 ± 6.7	42.0 ± 6.5	-4.0	-9.5
	T15	(10)	43.3 ± 8.7	41.7 ± 6.3	1.6	3.8
	S1	(40)	36.2 ± 4.7	30.8 ± 6.3	5.4*	17.5
	T4	(10)	28.1 ± 5.8	29.7 ± 6.1	-1.6	5.4
	T8	(10)	47.2 ± 4.2	44.3 ± 7.2	2.9	6.6
	S8	(40)	26.8 ± 4.6	26.0 ± 5.5	0.8	3.1
Moist Dwarf Shrub, Sedge Tussock Tundra	M3	(40)	29.4 ± 5.7	24.4 ± 7.6	5.0*	2.0
	T29	(10)	23.0 ± 2.4	22.4 ± 3.1	0.6	3.0
	S6	(40)	25.3 ± 4.9	22.1 ± 5.3	3.2*	14.5
	O8	(10)	31.8 ± 6.6	26.2 ± 6.2	5.6*	21.3
	S2	(10)	31.5 ± 3.3	27.6 ± 3.1	3.9*	14.1
	S3	(10)	32.7 ± 6.3	27.5 ± 3.9	5.2*	18.9
	S4	(40)	27.4 ± 7.0	27.0 ± 6.3	0.4	1.5
	S7	(10)	25.5 ± 6.3	28.5 ± 5.8	-3.0	-10.5
	N3	(30)	29.1 ± 4.3	26.8 ± 6.2	2.3	8.6

*t-test: statistically significant at P .05.
Thaw depth data are means ± SD.
Intensive plots are : O3, O6, O7, O11, O12, M1, M2, M3, M4, S1, S4. S5, S6, S8, N11, N12

and will show little settlement even with severe disruption of the surface (Kreig 1977). For marine deposits that are gravelly but have a higher percentage of fines, the thaw settlement characteristics are unknown, therefore the importance of increased thaw depths is uncertain.

Silts and silty clays deposited in eolian, lacustrine, or abandoned floodplain situations which are much more sensitive to disturbance (Webber and Ives 1979). These soils have higher saturated moisture contents, higher pore pressures, and lower infiltration rates and are more prone to fluvial erosion and saturated flow. Mass movement in trails is not expected on ANWR, as extensive disruption of the organic mat and exposure of mineral material has been minimal. Fine textured soils are also prone to high amounts of thaw settlement, depending on ice content, and saturated flow when melted (Kreig 1977). These fine grained soils have the highest potential for thaw settlement.

Thaw depth measurements are widely used to assess the impacts of disturbance on permafrost (Brown and Grave 1979). The degree of increased thaw is compared to the control and represents the residual amount of mineral or organic material left after the surface of the permafrost has melted. The importance of increases in thaw depth are dependent on ice content in the permafrost. If the content of excess ice (in excess of what is present in a saturated soil) in the permafrost is moderate (say 20%), then an increase in thaw depth of 4 cm represents the residual amount of material after 5 cm of permafrost has melted. This increase would be accompanied by approximately 1 cm of surface settlement. If the excess ice content is 50%, then the 4 cm of increased thaw represents the residual soil material left after melting 8 cm of permafrost and would be accompanied by 4 cm of surface settlement. There is also some loss in volume in melting soil that is at or below saturation, so that the settlement calculations are slight underestimates. These estimates do show the importance of ice content in frozen soils. No borehole information with ice content estimates have been examined, but such information will be incorporated into the data analysis when it becomes available.

The presence of thaw lakes, beaded streams, and high and low-centered polygons are indicative of high ice contents (Johnston 1981). There also may be a thin layer of soil of very high ice content just below the active layer. Thaw depth measurements would not detect the loss of this material when it is thawed. It is possible that thaw penetration has occurred at some sites without being measured by thaw probing because the permafrost surface was so ice-rich little residual material was left after it melted.

It is difficult to predict when thermophysical equilibrium will be re-established, due to the complex interaction of the level of disturbance, the ice content, and thaw settlement properties of the materials. Haag and Bliss (1974) found a thaw depth increase of 22 cm and subsidence of 15 cm in studying hummocky low shrub-heath tundra where the vegetation and surface peat were removed. Radforth (1972) studied a variety of habitats and disturbances and noted that thaw depths generally stabilized after 2 years. The subsidence that occurred from the first to the second summer after disturbance generally amounted to 1/3 to 2/3 of the amount of increase in thaw depth. Hernandez (1972), who studied a wide range of disturbance levels, generally much more severe than those encountered in ANWR, found large differences in thaw due to winter seismic activity after 1 and 2 years. Gersper and Challinor (1975) studied a 6 year old trail in a Moist/Wet Sedge Complex and found a 10 cm increase in thaw that had resulted from compression of the surface mat and some churning in wetter areas. Lawson et al. (1978) found thaw depths for the most disturbed areas after 28 years were about 23 cm deeper than undisturbed areas, and that less disturbed areas had thaw depths comparable to undisturbed areas. He suggested that thermal equilibrium and partial recovery had occurred for the less disturbed sites.

The results of Abele's (1975) study of summer vehicle trails in Moist/Wet Sedge Tundra are for conditions and disturbance levels more comparable to those found in ANWR. He found that for all levels of disturbance, up to 50 passes of a light tracked vehicle (Weasel), thaw penetration increased for the first 2 years and then decreased rapidly until thaw depths returned to approximately those of undisturbed terrain. Added thaw increase of the second year was about 2/3 as much as that of the first year. For 25 passes of a Weasel, disturbance roughly equivalent to narrow camp move trails in Moist/Wet Sedge in ANWR, the thaw depth increase was 5 cm the first year, 8 cm the second year, and then returned to undisturbed levels the fourth year. He attributed much of this to rebounding of the compressed moss mat that returned to near natural conditions. We speculate that frost heaving and ice segregation in the freezing active layer contribute greatly to this observed expansion of the compressed organic mat.

Evidence suggests, in general, that most of the thaw penetration occurs in the first two years. Thaw depths appear to stabilize in two to four years and the amount of subsidence that occurs is one to two thirds the amount of thaw penetration. In ANWR, the significantly deeper thaw depths observed on trails in lowland wet habitats can be expected to return to normal fairly quickly. In upland habitats, where surface recovery is slower, thaw depths are expected to remain significantly deeper for a longer period of time. Minor amounts of thaw settlement could be evident in some areas the second summer.

PHOTO INTERPRETATION OF DISTURBANCE

Methods

Color infrared (CIR) and some true color aerial photographs at a scale of 1:6000 was acquired for a portion of the vehicle trails made during the 1984 seismic exploration program. The photographs were taken on 27 and 31 August. The photography mission had been planned for earlier in the season during peak vegetative growth before senescence had begun. However, good weather days only occurred one at a time earlier in the season, and the contractor was unable to predict these in time to fly to the coastal plain from Anchorage.

A sample of the 966 km of seismic line was selected by stratified random sampling. Three areas of the coastal plain, based on terrain types, were used to stratify the sample (Fig. 3). The area west of the Sadlerochit River includes low foothills extending from the Sadlerochit Mountains to the coast. The area east of the Sadlerochit River is divided into the foothill area and the coastal area with low hills and well-developed drainages. Approximate lengths of seismic lines in each area were calculated, and randomly selected line segments were distributed within each strata (Table 11). Camp move routes and campsites associated with each line segment also were photographed.

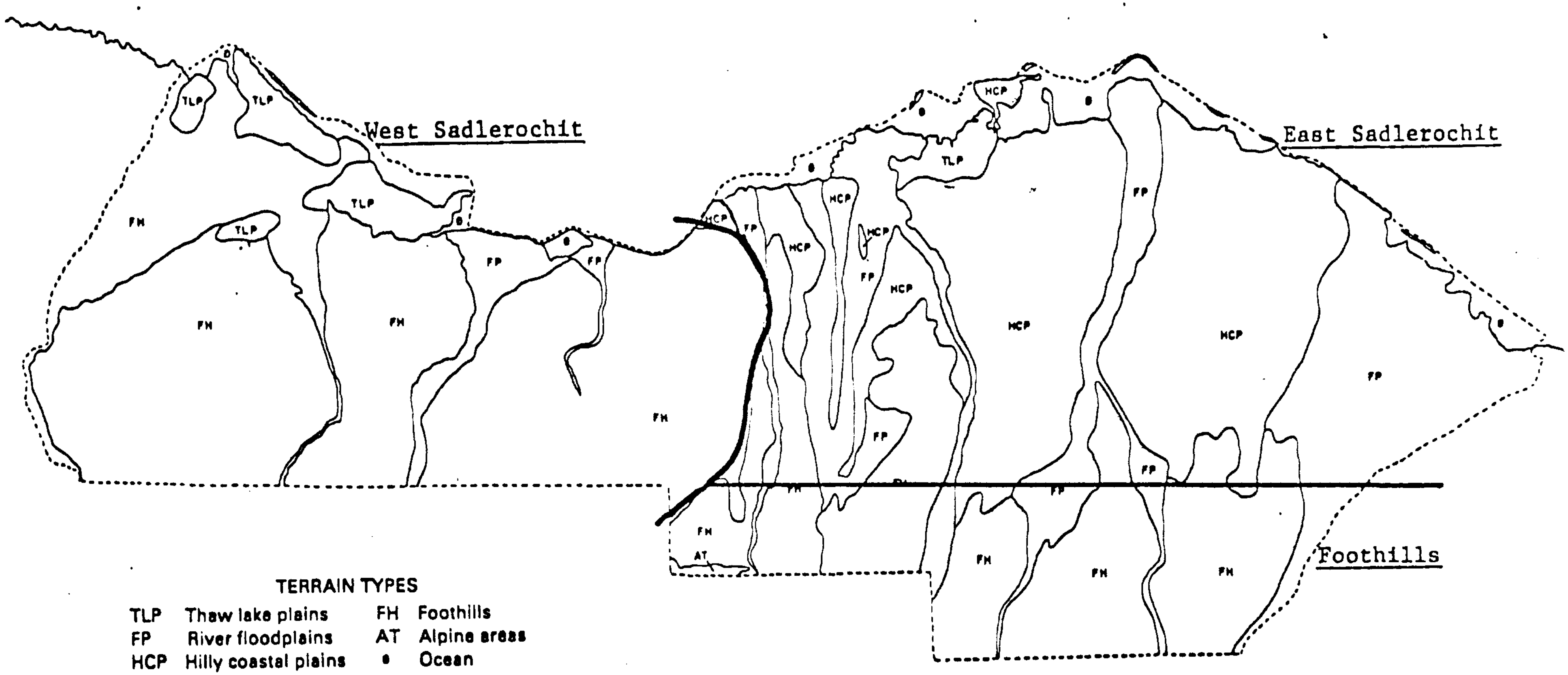

Fig. 3. Map of the terrain types of the coastal plain, Arctic NWR, Alaska. Map was used to stratify the sampling of seismic lines that were aerially photographed. Base map is from Walker et al. (1982).

Table 11. Seismic lines sampled for aerial photo acquisition on the coastal plain, Arctic NWR, Alaska, 1984.

Area	Seismic Line km/area	Line Segments Photographed Number-length	Kilometers Photographed	% of Seismic Lines Photographed
West Sadlerochit	404	6 - 16 km	96	24
East Sadlerochit Coastal Area	436	6 - 16 km	96	22
Foothills	121	1 - 16 km 1 -10.5km	26.5	22
Total	961		219.7	23

An additional line segment across Canning Delta on line 1 was photographed. This line crossed the thaw lake plain, a unique terrain type which covers only 3.1% of the coastal plain of ANWR. Four line segments were flown parallel to the coast to sample supply trails between the coast and inland campsites. Two of these supply line segments also were photographed at a scale of 1:12000 and 1:18000 to compare the differences in scale.

Good quality aerial photographs were obtained for only a portion of the line segments as shown in Table 12. The color infrared photographs taken on 27 August were of poor quality due to snow cover and cloud cover. It was not possible to use these photographs in the analysis. Some true color photographs obtained on this date could be interpreted, and were included in the analysis. The analysis included only 63% of the randomly selected line segments and included only 1 out of 6 line segments in the coastal area east of the Sadlerochit River. Therefore, interpretation of the results can not be extrapolated to the entire coastal plain.

GSI survey crews marked 3 shotholes at the beginning and end of each seismic line segment with survey lathe and rebar. These sites were relocated in July and marked with a white cross which would be visible on the aerial photographs. These crosses were made with 4.5 x 0.5 m strips of white vinyl taffeta secured to the ground with rocks.

Snow data were collected by FWS Monitors when the seismic crews arrived at each line segment. Ten random points were selected over 3 miles of each segment. At each random point, snow depth was measured at 20 points along a 100 m transect. All snow depths were measured and analyzed in inches, since management standards are written in inches. On the first of these transects, snow profile data were collected as described earlier for the intensive study plots. The evenly spaced shotpoints along the seismic line made selection of random points and relocation of these points on photographs possible.

Snow depths were measured in a number of areas along accompanying camp move routes to characterize snow depths along the route. These areas were subjectively chosen to be of typical snow conditions. They were mapped and often described to help in relocation. Random selection of these points was not possible, and relocation on the photographs was difficult. Snow depth was also measured on 3 transects at a total of 60 points at 2 campsites along each line segment.

An aerial photo interpretation key was developed based on recognizable characteristics of known points on the aerial photographs. Both intensive

Table 12. Aerial photography acquired on the coastal plain, Arctic NWR, Alaska, 1984.

Area	Seismic Line Number	Film Type	Date	Quality
W. Sadlerochit	6	CIR	8/31	Good
	7A	CIR	8/31	Good
	7B	CIR	8/31	Good
		True Color	8/27	Good
	8	CIR	8/31	Good
	12	CIR	8/31	Good
	16	CIR	8/31	Good
E. Sadlerochit-Coastal Area	3	CIR	8/31	Good
		True Color	8/27	Good
	7C	CIR	8/27	Poor
	7D	CIR	8/27	Poor
	26	CIR	8/27	Poor
	28	CIR	8/27	Poor
	32	CIR	8/27	Poor
Foothills	16E	CIR	8/31	Good
	20E	CIR	8/31	Good
Thaw Lake Plain	1	CIR	8/31	Good
Supply Lines				
#1		CIR	8/31	Good
#2		CIR	8/31	Good
#3		CIR	8/31	Good
#4		CIR	8/31	Poor

study plots and photo trend plots were used for this purpose. Ten major vegetation types, based on Landsat cover classes (Walker et al. 1982), were identified on the aerial photos. Table 13 describes these vegetation types and their appearance on the color infrared photographs. Three levels of disturbance can be recognized for most vegetation types (Table 3). The following traffic patterns were identified on photos:

- single Nodwell tracks
- seismic line - diffuse
- seismic line - narrow, width less than tracks of 2 adjacent vehicles
- Nodwell turn
- camp move - diffuse
- camp move - narrow, cat-trains follow same trail, width less than tracks of 2 adjacent vehicles
- all vehicles - diffuse
- all vehicles - narrow, width less than tracks of 2 adjacent vehicles

Each transect where snow data were collected was relocated on the photographs. Interpretations of vegetation type, traffic pattern, and disturbance level were made by viewing photo stereo pairs under a magnifying stereoscope. Often more than one trail type was observed at a location, and a disturbance level was recorded for each trail type. These multiple observations were used only to determine the relationship between traffic pattern and disturbance, and were removed from the data set for vegetation and snow depth analyses.

These data were analyzed to determine whether disturbance levels varied with snow depth, vegetation types, and traffic patterns. Frequency tables were generated and statistical significance was tested using a Pearson Chi-square test (Program 4F, Dixon et al. 1981).

Results and Discussion

Aerial Photo Interpretation Key

The photo interpretation key (Table 13) is based on disturbance levels that can be recognized on the aerial photos. Table 14 describes these disturbance levels as they relate to structure, vegetation and soil damage on the ground. These disturbance descriptions are based on data collected from the intensive study plots, photo trend plots, and field observations. The accuracy of the photo interpretation key and ground level descriptions will be checked by ground-truthing during the 1985 field season.

Trails in drier habitats are much less visible on the aerial photos than those in Wet Sedge and Moist Sedge Tundra. This is partially due to the fact that the photographs were taken late in the season after vegetation senescence had begun. In the field, trails through tussock tundra became less visible through the season as the surrounding tussocks began to turn brown. The photos were taken after the leaves of shrubs and herbaceous vegetation were turning brown and many had fallen off. Therefore, the contrast between healthy vegetation off the trails and disturbed vegetation on trails was no longer present. For this reason, slight breakage of shrubs and scuffing of tussocks is not visible on the photos and would be rated as 0 along with areas of no impact.

Table 13. Aerial photo interpretation key of vegetation types and trail disturbance levels for color infrared photographs (1:6000 scale), coastal plain, Arctic NWR, Alaska, 1984.

Vegetation Type	Photo Description	Disturbance Level 0	1	2	3
Aquatic Sedge Standing water-emergent communities or small ponds common.	Black water bodies common.	No change visible.	Slightly darker color than surrounding area.		
Wet Sedge Relatively wet areas, may have up to 50% standing water Few well-drained microsites.	Areas black to dark gray with few pink areas (dryer microsites).	No change visible.	Discontinuous to continuous darker line-same basic coloration nearby area.	Dark brown trail-basic coloration obscured.	Nearly continuous black lines - indicating standing water.
Wet Sedge (Moist Complex) and Moist/Wet Sedge	Light to dark gray and pink. Dry microsites, such as polygon rims and strangs common.	No change visible.	Same as above.	Same as above.	Same as above.
Moist Sedge, Prostrate Shrub Moist sedge (some wet sedge) with a high percentage of shrubs.	Pink and gray, smooth. Sometimes reddish pink. Locations: Foothills- between tussock areas Drainages Coast - with moist sedge/barren complex.	No change visible.	Discontinuous to continuous darker line-same basic coloration of nearby area.	Dark brown or dark red trail.	Nearly continuous black lines - indicating standing water.

Table 13. (Continued).

Vegetation Type	Photo Description	Disturbance Level 0	1	2	3
Moist Sedge/Barren Tundra Complex					
Fairly well-drained areas with frost scars common.	Pinkish gray with small to large gray grains (visible frost scars).	No change visible.	Slightly darker or lighter color. Trail may be sporatic or lightly visible.	Definite color change dark red, brown or gray. May have some black speckling.	Trail appears brown with black speckling common or in nearly continuous ruts.
Moist Sedge Tussock, Dwarf Shrub Tundra					
	Gray. Grainy. Tussocks evident. Some pink due to shrub cover.	No change visible.	Light gray or brown line, may be discontinuous.	Distinct gray or brown line may have white speckling or some black speckling.	Black speckling common or forming nearly continuous ruts.
Moist Dwarf Shrub, Sedge Tussock Tundra					
High-centered polygons with dwarf shrubs dominant.	Reddish or brownish pink. Fairly smooth, may have some tussocks. Polygonal ground pattern evident.	No change visible.	Light brown or gray line. May be discontinuous.	More distinct color change to brown or or gray. Some black speckling may be evident.	Black speckling common or forming nearly continuous ruts.

Table 13. (Continued).

Vegetation Type	Photo Description	Disturbance Level 0	1	2	3
Open Riparian Shrubland River terrace with 25-75% cover of low and tall shrubs.	River terrace. Gray and pink or brownish pink. Scattered small to to large grains.	No change visible.	Trail barely visible.	Distinct color change, smoother texture.	Distinct color change, black speckling common or forming nearly continuous ruts.
Closed Riparian Shrubland River terrace with over 75% cover of low and tall shrubs.	River terrace Gray and pink or brownish pink. Many small to large grains close together.	No change visible.	Same as above.	Same as above.	Same as above.
Dryas River Terrace. River terrace with a dense mat of *Dryas integrifolia*, other prostrate shrubs, and forbs.	River terrace. Reddish pink to reddish brown with few grains evident.	No change visible.	Lightly visible, pinkish gray line.	Distinct color change bluish-gray, may have some pink.	Bluish gray line, with black speckling common, or in nearly continuous ruts.

Table 14. Disturbance levels of winter seismic vehicle trails as recognized on color infrared aerial photographs (1:6000 scale), coastal plain, Arctic NWR, Alaska, 1984.

	Disturbance Levels			
Vegetation Type	0	1	2	3
Aquatic Sedge Tundra	No impact.	Compression of standing dead emergent vegetation.		
Wet Sedge Tundra	No impact.	Compression of standing dead to ground surface. May include slight scuffing or compression of mosses.	Compression of mosses and standing dead. Trail appears wetter than surrounding area.	Compression of mosses below water surface. Standing water apparent on trail that is not present in surrounding area.
Wet Sedge (Moist Complex) and Moist/Wet Sedge Tundra	No impact.	Same as above.	Same as above.	Same as above.
Moist Sedge Prostrate Shrub Tundra	No impact to slight breakage of shrubs.	Compression of standing dead. May include slight scuffing or compression of mosses and up to 25% broken shrubs.	Compression of mosses and standing dead, 25-50% broken shrubs. Trail appears wetter than surrounding area.	Compression of mosses below water surface. Over 50% broken shrubs. Standing water apparent on trail that is not present in adjacent area.

Table 14. (Continued).

Vegetation Type	Disturbance Levels 0	1	2	3
Moist Sedge/ Barren Tundra Complex	No impact.	Compression of standing dead. May have up to 25% vegetation damage. Some scuffing of hummocks.	Vegetation damage- 25-50%. Exposed organics or mineral soil 5-15%. Some hummock mound top destruction.	Mound top destruction of hummocks common or nearly continuous lines. Over 50% vegetation damage. Over 15% soil exposed.
Moist Sedge Tussock, Dwarf Shrub Tundra	No impact to slight scuffing of tussocks and breakage of shrubs.	Scuffing of tussocks. Vegetation damage- 10-25%. Exposed organics or mineral soil-1-5%.	Mound top destruction of tussocks. Vegetation damage- 25-50%. Exposed organics or mineral soil-5-15%.	Mound top destruction of tussocks nearly continuous. Ruts starting to form. Vegetation damage- over 50%. Exposed soil- over 15%.
Moist Dwarf Shrub, Sedge Tussock Tundra	Same as above.	Some breakage of shrubs. Scuffing of tussocks and hummocks. Vegetation damage- 10-25%. Exposed organics or mineral soil-less than 5%.	Shrub canopy substantially decreased. Mound top destruction of tussocks and hummocks. Vegetation damage- 25-50%. Exposed soil-5-15%.	Vegetation damage over 50%-nearly complete removal of shrub canopy. Exposed soil - over 15%.

Table 14. (Continued).

Vegetation Type	Disturbance Levels 0	1	2	3
Open Riparian Shrubland	No impact to slight breakage of shrubs.	Shrubs partially broken, little impact to ground cover. Less than 25% vegetation damage. Exposed soil-less than 5%.	Shrubs broken, sometimes to ground level. Ground cover partially killed or removed. Vegetation damage 25%-50%. Exposed soil 5-15%.	Vegetation damage over 50%-nearly complete removal of shrub canopy. Vegetation mat disrupted with over 15% soil exposed.
Closed Riparian Shrubland	Same as above.	Same as above.	Same as above.	Same as above.
Dryas River Terrace	No impact.	Less than 25% vegetation killed. Less than 5% soil exposed.	25-50% vegetation killed. Vegetation mat preserved. 5-15% soil exposed.	Vegetation mat disrupted with over 15% soil exposed.

In the wetter habitats levels of impact are quite visible on the photographs. Color infrared film is particularly sensitive to moisture differences on the ground. However, trails in wetter habitats were quite visible in field observations as well. Previous studies have also noted that traffic signatures are more visible on wet tundra than in drier areas (Abele 1975).

Since different types of disturbance have been observed within each vegetation type, levels of disturbance must be described by vegetation type. For example, the higher levels of disturbance for Wet Sedge and Moist Sedge Tundra show compression of the moss mat and increased moisture on the trail. Higher levels of disturbance in the dryer habitats show increased disruption of the vegetative mat and soil exposed. Although these disturbance levels are not equivalent, they do accurately reflect the high, medium, and low levels of disturbance that have been observed within each vegetation type on the coastal plain of ANWR during the 1984 field season. Therefore, the levels have been treated equivalently when grouping vegetation types for data analysis. The discussion of the factors affecting disturbance emphasizes moderate and high disturbance levels because the recovery rates of these disturbances are unknown. Low level disturbances, however, have been shown to recover quickly as discussed in the section on long term effects of disturbance.

Factors Affecting Disturbance

Traffic patterns

The types of vehicles and the concentration of traffic have a statistically significant (Chi-square = 158.5, 21df, p=0.0) influence on the level of disturbance (Table 15). Level 2 and level 3 disturbances were observed 6% of the time on diffuse seismic trails, 33% on diffuse camp move trails, 69% on narrow seismic trails, 77% on narrow camp move trails, 91% of the time when both seismic and camp move vehicles travelled on the same trail. Level 3 disturbances occurred only on camp move trails although this level of disturbance on narrow trails was observed in the field where seismic vehicles alone or seismic and camp move vehicles travelled. The disturbance caused by Nodwell turns was much higher than for straight single Nodwell trails. Nodwell turns created moderate disturbances on 42% of the observations, as compared to straight Nodwell trails that caused level 2 disturbance on only 2% of the observations.

Table 15. Frequencies of disturbance levels resulting from the various traffic patterns associated with winter seismic exploration, coastal plain, Arctic NWR, Alaska, 1984.

Traffic Pattern	Disturbance Level 0	1	2	3	Total Observations
Seismic-single	19	64	2	0	85
Seismic-diffuse	12	76	6	0	94
Seismic-narrow	0	4	9	0	13
Seismic-turns	0	11	8	0	19
Camp-diffuse	1	19	9	1	30
Camp-narrow	2	5	21	3	31
All-narrow	0	1	10	0	11
Campsites	0	11	1	0	12
Total	34	191	66	4	295

Pearson chi-square = 158.5, 21df, p=0.0, For seismic single versus seismic turns alone: Pearson chi-square = 30.9, 2df, p=0.0

Camp move vehicles, mainly cat-trains, generally caused higher disturbance than did seismic vehicles (Table 16). This was statistically significant (Chi-square = 34.5, 3df, p=0.0). For camp moves, 56% of the observed disturbances were level 2 or 3, compared to only 14% for seismic trail observations. Seismic trails were not observed to cause any level 3 disturbances, compared to 7% observed for camp moves from the photography. However, a seismic trail was observed in the field, to cause a level 3 disturbance on Dryas River Terrace.

Table 16. Frequencies of disturbance levels resulting from general vehicle types associated with winter seismic exploration, coastal plain, Arctic NWR, Alaska, 1984.

Traffic Pattern	Disturbance Level				Total
	0	1	2	3	Observations
Seismic (diffuse and narrow)	12	80	15	0	107
Camp Move	3	24	30	4	61

Pearson chi-square = 34.5, 3df, p=0.0

The concentration of traffic increased disturbance (Chi-square = 73.6, 3df, p=0.0). Disturbances of levels 2 or 3 were observed 13% of the time on diffuse trails as compared to 55% of the time for narrow trails (Table 17). Level 3 disturbance occurred in less than 1% of the observations of diffuse trails as compared to 5% of narrow trail observations.

Table 17. Frequencies for disturbance levels resulting from traffic concentration associated with winter seismic exploration, coastal plain, Arctic NWR, Alaska 1984.

Traffic Pattern	Disturbance Level				Total
	0	1	2	3	Observations
Diffuse	13	95	15	1	124
Narrow	2	10	40	3	55

Pearson chi-square = 73.6, 3df, p=0.0

Snow Depth

Overall, the data indicates the depth of snow was not a statistically significant factor (Chi-square = 18.4 15df, p=0.244) in reducing the level of disturbance, particularly within those lower snow depth levels (less than 14 in (35.6 cm) common in 1984 (Table 18). Although more data are needed it appears that at least 14 in (35.6cm) of snow is needed, before high levels of disturbance are prevented.

Table 18. Frequencies of disturbance levels at various snow depths, resulting from winter seismic exploration, coastal plain, Arctic NWR, Alaska, 1984.

Snow depth (in)	Snow depth (cm)	Disturbance level 0	1	2	3	Total Observations
Under 6	Under 15.2	3	15	8	1	27
6 to 8	15.2 to 20.3	2	36	18	1	57
8 to 10	20.3 to 25.4	2	8	15	0	25
10 to 14	25.4 to 35.6	2	19	7	2	30
14 to 20	35.6 to 50.8	1	5	2	0	8
Over 20	Over 50.8	1	3	0	0	4
Total		11	86	50	4	151

For entire table: Pearson chi-square test = 18.4, 15df, p=0.244.
For under 6 and over 6 inches, Pearson chi-square = 0.931, 3df, p=0.818.
For under 8 and over 8 inches, Pearson chi-square = 1.250, 3df, p=0.741.
For under 10 and over 10 inches, Pearson chi-square = 4.329, 3df, p=0.228.

Snow did not have a statistically significant effect on the frequency of disturbance (Tables 19 and 20) if narrow trails were eliminated and only diffuse seismic and camp move trails considered (for seismic - Chi-square = 14.66, 10df, p=0.45; for camp moves - Chi-square = 16.75, 12df, p=0.159). Level 2 disturbances were still observed with up to 14 in (35.6cm) of snow.

Table 19. Frequencies of disturbance levels at different snow depths resulting from diffuse seismic trails associated with winter seismic activity, coastal plain, Arctic NWR, Alaska, 1984.

Snow depth (in)	Snow depth (cm)	Disturbance level 0	1	2	3	Total Observations
Under 6	Under 15.2	3	17	1	0	21
6 to 8	15.2 to 20.3	4	32	0	0	36
8 to 10	20.3 to 25.4	2	6	3	0	11
10 to 14	25.4 to 35.6	1	15	2	0	18
Over 14	Over 35.6	2	6	0	0	8
Total		12	76	6	0	94

For entire table: Pearson chi-square test = 14.664, 10df, p=0.145.
For under 6 and over 6 inches, Pearson chi-square = 0.160, 2df, p=0.923.
For under 10 and over 10 inches, Pearson chi-square = 0.139, 2df, p=0.933.

Table 20. Frequencies of disturbance levels at different snow depths resulting from diffuse camp move trails associated with winter seismic activity coastal plain, Arctic NWR, Alaska, 1984.

Snow depth (in)	Snow depth (cm)	Disturbance level 0	1	2	3	Total Observations
Under 6	Under 15.2	1	1	1	1	4
6 to 8	15.2 to 20.3	0	12	4	0	16
8 to 10	20.3 to 25.4	0	4	2	0	6
10 to 14	25.4 to 35.6	0	1	2	0	3
Over 14	Over 35.6	0	1	0	0	1
Total		1	19	9	1	30

For entire table: Pearson chi-square test = 16.754, 12df, p=0.159.
For under 10 and over 10 inches, Pearson chi-square = 14.664, 10df, p=0.145.

The relationship between snow depth and disturbance needs to be examined within vegetation types, however, since the nature of disturbance varies between types. Adequate distributions of snow depth observations were available only in Moist Sedge, Prostrate Shrub Tundra and Moist Sedge Tussock, Dwarf Shrub Tundra to allow a more detailed analysis of the importance of snow depths (Tables 21 and 22). There appears to be a reduction in the level of disturbance for Moist Sedge, Prostrate Shrub, when snow is deeper than 10 in (25.4cm), although no statistically significant relationship between snow depth and disturbance was found (a Chi-square test was not possible, because of too many empty cells). There is no evidence of an adequate snow depth less than 14 in (35.6cm), that eliminated level 2 disturbances for Moist Sedge Tussock, Dwarf Shrub Tundra. Although the distribution of the frequencies of disturbance is statistically significant (Chi-square = 30.06, 12df, p=0.003) due to the high incidence of moderate disturbances at 8 to 10 in (20.3 to 25.4cm) snow depths, this trend does not appear meaningful.

Table 21. Frequencies of disturbance levels at different snow depths, within Moist Sedge, Prostrate Shrub Tundra resulting from winter seismic exploration, coastal plain, Arctic NWR, Alaska, 1984.

Snow depth		Disturbance level				Total
(in)	(cm)	0	1	2	3	Observations
Under 6	Under 15.2	0	2	0	0	2
6 to 8	15.2 to 20.3	0	20	4	0	24
8 to 10	20.3 to 25.4	0	3	2	0	5
10 to 14	25.4 to 35.6	0	11	0	0	11
Over 14	Over 35.6	0	6	0	0	6
Total		0	42	6	0	48

No chi-square test, too many empty cells

Table 22. Frequencies of disturbance levels at different snow depths within Moist Tussock Dwarf Shrub Tundra, resulting from winter seismic exploration, coastal plain, Arctic NWR, Alaska, 1984.

Snow depth		Disturbance level				Total
(in)	(cm)	0	1	2	3	Observations
Under 6	Under 15.2	11	12	2	1	26
6 to 8	15.2 to 20.3	4	21	9	1	35
8 to 10	20.3 to 25.4	4	7	15	0	26
10 to 14	25.4 to 35.6	4	23	7	2	36
Over 14	Over 35.6	1	3	2	0	6
Total		24	66	35	4	129

Pearson chi-square test = 30.06, 12 df, p=0.003.

The lack of a relationship between snow depth and disturbance within Moist Sedge Tussock, Dwarf Shrub Tundra can partially be attributed to micro-relief, in that mounds and tussocks have less snow cover and are areas to be contacted first by vehicle tracks. It appears then that this vegetation type needs deeper snow than was commonly available in ANWR in 1984 to prevent level 2 disturbance.

The distribution of snow depth levels for the various vegetation types (Table 23) indicate differences exist among them. The Wet Sedge and Moist/Wet Sedge vegetation types had less snow cover, generally under 8 in (20.3cm). This can partially be attributed to their occurrence predominantly in lower elevation areas, on flatter terrain with less macrorelief and micro-relief. Snow depths within Moist Sedge, Prostrate Shrub Tundra and Moist Sedge Tussock, Dwarf Shrub Tundra types were extremely variable due to the wide range of topographic settings in which the types occur. Moist Sedge, Prostrate Shrub Tundra often occurs in gullies and swales where snow drifts. Moist Sedge/Barren Complexes, which occurred at lower elevations on coarser marine and fluvial sediments, generally had snow depths less than 8 in (20.3cm), but variable. Moist Dwarf Shrub, Sedge Tussock Tundra of high-centered polygons had snow depths between 6 and 10 in (15.2 to 25.4 cm), but observations were too few to allow supportable generalizations. Overall 71% of all observations in the area sampled had snow depths of less than 10 in (25.4cm) and 92% of the observations had less than 14 in (35.6cm)(Table 23).

A reliable understanding of the relationship between snow depth and disturbance has not been achieved. High levels of snow are needed to prevent level 2 disturbances for some vegetation types with high micro-relief, particularly Moist Sedge/Barren Tundra Complex and Moist Sedge Tussock, Dwarf Shrub Tundra. These snow levels were not commonly available in 1984. An adequate snow depth also is unclear for Wet Sedge and Moist/Wet Sedge Complexes. The 6 in (15.2cm) average snow depth parameter for 1984 was apparently sufficient to prevent level 2 disturbances on diffuse trails in Wet Sedge and Moist/Wet Sedge Complexes.

The high variability of snow depths within a site, with snow accumulating in depressions and being swept off of protrusions, is not adequately represented by snow depth averages. Other factors such as the percent depth hoar, crystal grain size, hardness, and density also complicate the analysis (Rice 1984). For example, the high percentage of depth hoar, as compared to fresh or windpacked snow, ranged from 39 to 91 percent, lowering the amount of snow mass available to protect the ground surface. The original snow depth was compacted and the surface slab or crust disrupted by the first vehicle to go over any given point, reducing the protective cover for additional vehicle passes. Limited data on these factors have been collected, but have not yet been analyzed in relation to snow depths and disturbance.

Routing of cat-trains and locating campsites in drainages and other areas of high snow accumulation during the 1984 seismic exploration program was effective in reducing disturbance. Snow, then, was effective in reducing disturbance when found in sufficient amounts. There were not enough observations at the deeper snow levels, however, to adequately define the relationship between snow depth and disturbance.

Vegetation Types

The frequencies of disturbance levels within vegetation types resulting from seismic and camp move trails are presented in Table 24. Aquatic and Wet Sedge types were disturbed only at a low level. Disturbances of level 2 or 3 occurred in 17% of the observations in Moist/Wet Sedge; 17% in Moist Sedge, Prostrate Shrub Tundra; 65% in Moist Sedge/Barren Tundra Complex; 39% in Moist Sedge Tussock, Dwarf Shrub Tundra, and 50% in Moist Dwarf Shrub, Sedge Tussock Tundra. Too few observations occurred in the other types to allow comparisons. Mound top destruction was prevalent in the Moist Sedge/Barren Tundra Complex because of the hummocky micro-relief and the very thin vegetative mat that often occurs on frost boils and hummocks. Tussocks are particularly susceptible to destruction in the Moist Sedge Tussock, Dwarf

Table 23. Frequencies of snow depth levels within vegetation types encountered during winter seismic exploration, coastal plain, Arctic NWR, Alaska, 1984.

Vegetation Types	Snow Depths (inches) Under 6 (Under 15.2cm)	6 to 8 (15.2 - 20.3cm)	8 to 10 (20.3 - 25.4cm)	10 to 14 (25.4 - 35.6cm)	14 to 20 (35.6 - 50.8cm)	Over 20 (Over 50.8cm)	Total Observations
Aquatic Sedge	0	1	1	1	0	0	3
Wet Sedge	1	2	0	0	0	0	3
Moist/Wet Sedge	1	5	0	0	0	0	6
Moist Sedge, Prostrate Shrub	0	7	1	4	2	1	15
Moist Sedge/Barren Tundra Complex	6	6	1	1	0	1	15
Moist Sedge Tussock Dwarf Shrub Tundra	10	11	10	14	3	1	49
Moist Dwarf Shrub, Sedge Tussock Tundra	0	1	4	0	0	0	5
Total	18	33	17	20	5	3	96

No random observations for Open and Closed Riparian Shrubland, *Dryas* River Terrace.
Pearson chi-square = 43.61, 30df, p=0.052.

Shrub Tundra accounting for high levels of disturbance. The birch and ericaceous shrubs in Moist Dwarf Shrub, Sedge Tussock Tundra are particularly sensitive and the high centered polygonal relief makes scuffing and mound top destruction common.

Table 24. Frequencies of disturbance levels within vegetation types, resulting from winter seismic exploration, coastal plain, Arctic NWR, Alaska, 1984.

Vegetation Type	Disturbance level				Total Observations
	0	1	2	3	
Aquatic Sedge	0	4	0	0	4
Wet Sedge	0	8	0	0	8
Moist/Wet Sedge	0	10	2	0	12
Moist Sedge, Prostrate Shrub	0	20	4	0	24
Moist Sedge/Barren Complex	2	5	13	0	20
Moist Tussock, Dwarf Shrub	8	36	27	4	75
Moist Dwarf Shrub, Tussock	0	3	3	0	6
Open Riparian Shrubland	1	0	1	0	2
Closed Riparian Shrubland	0	0	0	0	0
Dryas River Terrace	0	0	0	0	0
Total	11	86	50	4	151

No chi-square test, too many empty cells.

The response of vegetation types to diffuse seismic and camp move traffic is presented in Tables 25 and 26. The same pattern of sensitivities applies as previously mentioned, but adds emphasis to the sensitive nature of Moist Sedge Tussock, Dwarf Shrub Tundra and possibly to Moist Dwarf Shrub, Sedge Tussock Tundra. For diffuse camp move trails 57% of the observations and 12% of the diffuse seismic trail observations in Sedge Moist Tussock, Dwarf Shrub Tundra were level 2 or 3 disturbances.

In summary, the level of impact from seismic activity can be markedly reduced by eliminating narrow traffic patterns based on these data. Snow cover alone, in the amounts received in ANWR in 1984, was insufficient to prevent moderate and high levels of disturbance. High level disturbances are known to exist in nearly every vegetation type from photo interpretation and field observations.

Table 25. Frequencies of disturbance levels within vegetation types, resulting from diffuse seismic trails associated with winter seismic exploration, coastal plain, Arctic NWR, Alaska, 1984.

Vegetation Type	Disturbance levels				Total Observations
	0	1	2	3	
Aquatic Sedge	0	4	0	0	4
Wet Sedge	0	4	0	0	4
Moist/Wet Sedge	0	8	0	0	8
Moist Sedge, Prostrate Shrub	0	14	0	0	14
Moist Sedge/ Barren Complex	3	13	1	0	17
Moist Tussock, Dwarf Shrub	8	28	5	0	41
Moist Dwarf Shrub, Tussock	0	4	0	0	4
Open Riparian Shrubland	1	1	0	0	2

No observations for Closed Riparian Shrubland, Dryas River Terrace.
No chi-square test, too many empty cells.

Table 26. Frequencies of disturbance levels within vegetation types, resulting from diffuse camp move trails associated with winter seismic exploration, coastal plain, Arctic NWR, Alaska, 1984.

Vegetation Type	Disturbance levels 0	1	2	3	Total Observations
Aquatic sedge	0	1	0	0	1
Wet sedge	0	5	0	0	5
Moist/Wet Sedge	0	2	0	0	2
Moist Sedge, Prostrate Shrub	0	5	0	0	5
Moist Tussock, Dwarf Shrub	0	6	7	1	14
Moist Dwarf Shrub, Tussock	0	0	1	0	1
Open Riparian Shrubland	1	0	1	0	2

No observations for Moist Sedge/Barren Tundra Complex, Closed Riparian Shrubland, and *Dryas* River Terrace.
No chi-square test, too many empty cells.

Moderate levels of disturbance can still be expected to occur in some vegetation types even if narrow traffic patterns are eliminated . These include: Moist Sedge/Barren Tundra Complex; Moist Sedge Tussock, Dwarf Shrub Tundra; Moist Dwarf Shrub, Sedge Tussock Tundra; Riparian Shrubland; and *Dryas* River Terrace. It appears that snow depths common to ANWR in 1984 were not adequate to prevent some moderate disturbance within these vegetation types even for diffuse trails.

Cat-trains (camp moves and supply moves) are the main concern due to their greater impact, even when trails are diffuse. It appears that the only way to prevent moderate impacts to the previously mentioned vegetation types is to avoid those types when possible. Careful attention to routing could help reduce moderate levels of disturbance caused by cat-trains.

Photo-interpretation of lines occurring primarily on the eastern portion of ANWR could not be completed due to poor photo quality. Therefore, the results cannot be directly extrapolated to the entire area. Wet Sedge and Moist/Wet Sedge Complexes were undersampled so the relationship of disturbance to traffic patterns and snow depths are poorly understood for these types.

More information on the number of miles of the various levels of disturbance in each vegetation type, for seismic lines, camp moves, and supply routes could be estimated from the existing photos. A comparative analysis of photo scales and true color vs. CIR also remains to be done.

SUMMARY OF THE EFFECTS OF WINTER SEISMIC EXPLORATION

The terms low, moderate, and high used in this report to describe relative levels of disturbance observed on ANWR this field season, need to be put into a broader perspective. The disturbance levels described by Rickard and Brown's (1974) review of vehicle traffic on the tundra are listed below for comparison.

1. Aesthetically objectionable disturbance - vehicles leave a green strip or belt that persists for several years. This level of disturbance is caused by single or few passes of low-pressure vehicles.

2. Vegetation disturbance - crushing and shearing of shrubby vegetation, but no measurable impacts to soil properties.

3. Significant destruction of plant cover and breakage or compaction of the organic mat - measurable increase in thaw depth and start of erosion. This level of disturbance is caused by multiple passes of winter vehicles over low snow cover or summer vehicle traffic.

4. Disruption of the organic mat with actual displacement or removal, followed by subsidence, ponding, and erosion on slopes. This level of disturbance is caused by blading, improper construction and use of winter roads and multiple passes of moderate to high ground pressure vehicles in the summer.

Level 3, of Rickard and Brown (1974), describes the highest level of disturbance observed on ANWR. The start of erosion has occurred as minor subsidence in some areas, but slope erosion is not expected to occur on ANWR. Moderate levels of disturbance on ANWR fall between their levels 2 & 3, while low levels of disturbance fall between their levels 1 & 2, being mainly aesthetic with some vegetation disturbance.

Effects Summarized By Vegetation Type

The following narrative briefly describes the effects of vehicle traffic on each vegetation type. More detail is given in Appendix B, Table B-1. The vegetation impacts are based on data from study plots and field observations. The description of thermal impacts is based on study plot data, and knowledge of the literature. Visual impacts are described and rated as highly visible, visible, slightly visible, or not visible based on field observations . Data on frequency and traffic patterns are based on field observations and aerial photography. Frequency is rated as common, uncommon, or rare within each vegetation type. More quantitative data will be obtained from the aerial photography as time permits. For more information on summer observations of the vegetational impacts of seismic exploration, reference should be made to the Narrative Trip Reports of Moitoret and Miller (1984), Felix (1984), and the Preliminary Assessment of Impacts Resulting from Winter Seismic Exploration on the Arctic NWR Coastal Plain prepared by ANWR staff,(1984).

Wet Sedge, Moist/Wet Sedge, and Moist Sedge, Prostrate Shrub Tundra.

Low level disturbance in this vegetation type is due to compression of standing dead to the ground surface. The main impact of this type of disturbance is to aesthetic values. Higher levels of disturbance lead to compression of the moss mat to varying degrees. This causes the trails to appear darker, becoming highly visible to an observer in a low-level aircraft (less than 300m). Increased thaw depths can be expected in areas where compression has occurred, and track depression may be measurably deeper due to compression of mosses and minor subsidence. On plot T32 in Moist Sedge, Prostrate Shrub Tundra, statistically significant thaw depths and track depression were measured.

Moist Sedge/Barren Tundra Complex.

Hummocks commonly found in this vegetation type are easily disturbed by vehicle traffic due to their high micro-relief. Under low level disturbance, hummocks were scuffed or slightly crushed, while under the highest level, hummocks were removed at ground level. The cover of Dryas integrifolia, mosses, and lichens is particularly sensitive to disturbance. These trails are not highly visible due to the natural dark coloration and patchy appearance of frost scars. Upon close inspection, bare patches of peat and soil were apparent in disturbed areas. Thaw depth and track depression are extremely difficult to measure in this vegetation type due to its high variability.

Moist Sedge Tussock, Dwarf Shrub Tundra.

In low level disturbances, tussock tops were scuffed and appeared light brown. Few cottongrass (tussock) blooms were present on trails, but some green growth was present on the scuffed tussocks this year. Moderate disturbance resulted in mound top destruction caused by crushing or scraping of tussock tops. Peat was exposed in the center of these tussocks, and only a few green sprouts were found on the outer perimeters. In the highest disturbance level, mound top destruction occurred in nearly continuous lines appearing as ruts starting to form. The most severely damaged tussocks were cracked open and fell apart when touched. Mosses are an important component of this vegetation type and appear particularly sensitive to vehicle traffic. Cleat marks of vehicles and compression of mosses were often visible. Brown tussock trails were evident compared to the greenish cast of the surrounding areas. These trails were much less visible later in the season when the plants began to senesce and turn brown. When mound top destruction was common, the dark appearance of exposed peat gave a striking appearance to the trail when observed from low level aircraft. Where mound top destruction had occurred, statistically significant increases in thaw depth were measured. Minor subsidence may occur on these trails in the future.

Moist Dwarf Shrub, Sedge Tussock Tundra.

This vegetation type is dominated by dwarf birch, Betula nana, and ericaceous shrubs, including Ledum palustre ssp. decumbens and Vaccinium vitis-idaea. Cover of these shrubs decreased substantially with increasing disturbance levels. Tussocks and hummocks are often present with disturbance levels ranging from scuffing to mound top destruction. Mosses are also an important component in this plant community and brown patches of dead moss were frequently found in disturbed areas. A couple of areas were observed where the vegetation cover on top of high-centered polygons was almost completely dead. In these areas, the dead vegetative mat was nearly complete with few patches of exposed soil. Trails in this vegetation type are sometimes hard to find from the air and ground, as we observed at the Sadlerochit study plots. There is little contrast between the disturbed trail and the naturally dark appearance of the habitat. The highest level of disturbance appears as a dark brown trail that is highly visible from low level aircraft.

Statistically significant increases in thaw depths were measured in all disturbance levels of this vegetation type. It appears that thaw depth may be sensitive to removal of the shrub canopy.

Riparian Shrubland.

Vehicle trails were routed to avoid riparian shrublands, and all traffic kept to a narrow trail when these areas were crossed. Willows were broken to various heights at different locations. The brittleness of willow twigs appears to vary with temperature. At plot S5, many willows bent rather than snapped, when vehicles traveled over them in April with temperatures between -7° and -18° C (0° and 20° F). In other areas willow twigs appeared to snap easily, sometimes at ground level.

Cover of Dryas integrifolia, forbs, and mosses decreased with increasing levels of disturbance. No sites were found where high level disturbance or widespread disruption of the vegetative mat had occurred.

Dryas River Terrace

These areas are extremely sensitive to vehicle traffic. In the winter, we observed 2-5 cm (1-2 in) of snow at these sites. Vehicle tracks (even bombardiers) dig through this thin snow cover and into the vegatative mat. The organic mat at these sites is less than 5 cm deep and is easily torn and scattered. Areas revisited this summer showed up to 90% decrease in live vegetative cover and 25% exposure of peat and mineral soil. Trails with a moderate or high level of disturbance are highly visible as brown strips of dead vegetation.

Observations of Slope Erosion and Fuel Spills

Slope Erosion

Vehicles were routed around steep slopes whenever possible. Several areas where cat-trains had traveled up slopes out of drifted river bottoms were re-examined during the summer. Patches of exposed peat and mineral soil were present where tractors had spun their tracks. These patches of bare soil were small and localized on well-vegetated slopes of less than 20%, and surface erosion is not expected.

One slope on the north fork of the Sikrelurak River had more extensive damage on a 30% slope. The gravelly soils at this site are expected to be stable, but the site will be monitored for any evidence of erosion.

Fuel Spills

Spills of diesel fuel were evident at many campsites. These spills completely killed vegetation over areas ranging from 1-6 m in diameter. The largest spill observed was estimated to be 225-450 l, and killed vegetation in a wet sedge community over an area 6 m in diameter.

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

EXPECTED LONG-TERM EFFECTS OF WINTER SEISMIC EXPLORATION

Based on existing literature, it is difficult to accurately predict recovery times for each level of disturbance that has been observed on the coastal plain. Much of the existing literature has concentrated on the long-term effects of severe tundra disturbances, and often the exact history of studied trails is unknown. Few studies have gathered first year data, and then followed trails through recovery. Without first year data, it is hard to know how studied disturbances compare to the disturbance levels observed on ANWR this year.

The following discussion summarizes the information that is available on recovery of tundra disturbance. The main emphasis of this section is on recovery of vegetation and visual impacts, since thermal impacts were discussed in an earlier section.

Natural revegetation and growth of plants in the arctic are slow (Billings 1973, Rickard and Brown 1974). Recovery is dependent on the extent of disturbance. When the organic mat remains in place, vegetative parts are available for recolonization (Hernandez 1972, Rickard and Brown 1974). Many arctic plants rely on vegetative reproduction by roots and rhizomes rather than seed production and establishment (Bliss and Wien 1972, Billings 1973, Rickard and Brown 1974).

Changes in species composition have been observed in many disturbed areas. Grasses and sedges are often more abundant on disturbed sites than undisturbed areas. (Bliss and Wein 1972, Lawson et al. 1978, Chapin and Shaver 1981). Chapin and Chapin (1980) observed Carex bigelowii and Eriophorum vaginatum establish from seed on organic tundra soil, and complete vegetative cover mainly of these species was present after 10 years. Hernandez (1973) noted that sedges and grasses readily recover through vegetative reproduction from roots and rhizomes. Grasses colonizing a bladed summer trail were observed to be large plants on the trail as compared to single culms in nearby undisturbed sites. Cover of Carex bigelowii and Eriophorum vaginatum was greater on a vehicle trail and the number of seed heads also was increased on the trail (Hernandez 1972). Reynolds (1982) observed an increase in grasses when the shrub canopy of a riparian willow stand was partially removed by vehicle traffic.

Shrub species have been reported to be sensitive to vehicle disturbance. Ericaceous shrubs, such as Vaccinium vitis-idaea, Ledum palustre and Cassiope tetragona and dwarf birch, Betula nana, are often rare in disturbed sites. (Hernandez 1972, Lawson et al. 1978, Chapin, and Shaver 1981). Chapin and Chapin (1980) reported that Ledum palustre and Betula nana were present but inconspicuous 10 years after disturbance of a tussock tundra site. Willow species are also decreased by disturbance. (Hernandez 1972, Lawson et al. 1978, Chapin and Shaver 1981). Reynolds (1982) observed bending of willows due to winter seismic vehicles and breakage due to cat-trains. Bent willows recovered after a year, while broken willows have resprouted and are slowly recovering. After 5 years the trail remains visually evident from the ground and air.

Hernandez (1972) reported that mosses are rare in disturbed areas, while Lawson et al. (1978) reported a change in species composition of mosses in disturbed sites. In studies of air-cushion vehicles, Sterrett (1976) observed that mosses are more sensitive to abrasion than sedges or grasses. In wet habitats, compressed mosses show the ability to rebound within a couple seasons (Abele 1976).

Slow regrowth of certain arctic species can be expected on ANWR. Ericaceous shrubs, dwarf birch, and mosses showed the greatest decrease in plant cover in study plots this year and can be expected to recover slowly. Willow was observed resprouting in the first season, and gradual recovery is expected to continue. No studies on recovery rates of Dryas integrifolia are available, but researchers have noted slow recovery on dry river terraces (Johnson pers. comm.). One area was found this summer where cleat marks were evident in a Dryas mat from tracks that reportedly were made 20 years ago (Audi pers. comm.).

Rapid regrowth of sedges and grasses can be expected. In fact, the proportion of graminoid species in disturbed sites may become higher than that in undisturbed areas. A good seed store of graminoids in soil samples from a Riparian Shrubland plot was found. In other areas, sprouting may occur from roots and rhizomes.

Winter vehicle trails nave been reported to be less damaging in wet and moist sedge habitats than in shrub or tussock tundra (Bliss and Wein 1972, Hernandez 1972, Reynolds 1982). Sterrett (1976) noted that tracks were more visible on wet, level tundra than in drier areas which have more vegetation and surface relief variations. Trails in wet and moist sedge tundra on ANWR were highly visible this year. Sedges did not appear to be damaged by winter traffic, since roots and rhizomes remained undisturbed in the organic mat. At high levels of disturbance, mosses were compressed, sometimes below the water surface. Abele (1976) observed similar compression of moss layers due to multiple passes of light tracked vehicles (Weasels) in the summer. In the worst case, a track depression of 15 cm was measured originally and rebounded to within 1 cm of the surface in 4 years. However, the traffic signature remained visible on both ground and aerial photographs.

Reynolds (1982) studied recovery of trails in tussock tundra in the National Petroleum Reserve-Alaska (NPR-A). The seismic line appeared as a faint brown line the first year and vegetation differences on and off the trail were not statistically significant after 16 months. More damage occurred on the camp move trail, and vegetation differences remained statistically significant after 28 months. The camp move was barely visible when visited 5 years later. Snow cover was deeper when these trails were made, than that observed in ANWR last season according to Reynolds (1984). Therefore, ANWR trails probably have a higher initial percentage of crushed and broken tussocks.

Hok (1971) reported that the slow decay of broken tussocks may interfere with seedling establishment. Racine (1977) observed regrowth of shoots on damaged tussocks and roots and shoots on uprooted tussocks. Rubus chamaemorus (cloudberry) was observed growing on scraped tussocks.

We noted some green sprouts on scuffed tussocks this year on ANWR trails. Only a few sprouts remained along the outside perimeter where mound top destruction occurred. Tussocks were completely crushed and broken apart at the base in some areas.

Racine (1977) saw little or no evidence of revegetation on scraped mound tops after two growing seasons. Bliss and Wein (1972) reported slow recovery of these areas, since needle-ice formation creates a barrier to seedling establishment. Needle-ice formation was observed in some bare patches of soil at the end of August, and recovery is expected to be slow on disturbed hummocks.

Environmental changes in vehicle trails can affect vegetation. Increased plant biomass and nutrient levels have been observed on old trails, causing a green appearance (Gersper and Challinor 1975, Chapin and Shaver 1981). Increases in nutrients and plant growth may occur in future years on ANWR seismic trails, causing them to be visible for a longer period of time. Increased flowering of Eriophorum vaginatum and Carex bigelowii have been observed in disturbed areas (Bliss and Wein 1972, Hernandez 1973). Soil moisture changes which lead to changes in species composition have been reported in intensely disturbed sites (Lawson et al. 1978).

Diesel spills showed little recovery of vegetation after 28 years at the Fish Creek study site in northern Alaska. At two fuel spills observed, 5% and 15% plant cover of graminoid species was found (Lawson et al. 1978).

Few studies have considered the visual impacts of seismic trails. Lawson et al. (1978) noted that trails were visible even when the surface mat had not been broken and vegetation was substantially unchanged. Even single vehicle trails (probably summer trails) were visible after 28 years. Hok (1971) was unable to find any winter trails made by light personal carriers, and concluded that they have no lasting effect. Low ground pressure vehicles did cause noticeable vegetation changes. Reynolds (1982) noted that cat-trains pulling camp sleds left a more visible and longer lasting trail than low-pressure seismic vehicles.

Abele (1976) rated the relative visibility of traffic signatures on aerial and ground photographs. Visibility of summer trails of air-cushion vehicles and Weasels began to decrease within a year, and continued to decrease gradually over the 4 year study period. Traffic signatures remained visible after thaw depths had returned to normal levels. One to five passes of a Weasel over wet sedge tundra were not visible or barely perceptible after 4 years. Twenty-five to 50 passes decreased in visibility from easily visible to visible over the 4 year period.

All vehicle trails were visible this summer on ANWR, including single passes of Bombardiers. Visibility varied with disturbance level and vegetation type as described previously. Low level disturbances should be considerably less noticeable next year and difficult to locate in 5 years. Higher levels of disturbance will begin a gradual recovery process, and it is difficult to estimate how much time will be required before they are no longer visible.

RECOMMENDATIONS

Low level disturbances as described in Appendix B, Table B-1 should be considered an acceptable level of disturbance due to winter seismic exploration. Based on previous studies, this level of disturbance can be expected to recover within 5 years. Moderate and high level disturbances should be avoided. The available literature does not provide a good basis for estimating recovery times of these levels. High level disturbances can be nearly eliminated and moderate disturbances minimized by avoiding narrow vehicle trails and sensitive vegetation types. Limitations on the number of vehicles and number of miles of seismic line are needed to further reduce moderate level disturbances.

The following recommendations should be incorporated into special use permit stipulations and the monitoring guidelines for the 1985 winter seismic exploration.

1. Vehicles should follow diffuse traffic patterns and avoid narrow trails.

   Diffuse traffic patterns cause a lower level of disturbance spread over a larger area. Lower level disturbance is less damaging to vegetation, less visible the first year, and less likely to cause thermal impacts. Also, lower levels of disturbance can be expected to recover more quickly and more completely. Therefore, although a larger area is impacted the first year, long-term effects will be less.

2. Route vehicles around areas of Dryas River Terrace.

This vegetation type is extremely sensitive to vehicle traffic due to its low snow cover and thin vegetative mat. If Dryas River Terrace must be crossed, the shortest route should be located.

3. Route vehicles around Riparian Shrubland whenever possible.

A narrow path should be followed when Riparian Shrubland must be crossed.

4. Require all vehicles to travel on the main trails, and not create unnecessary new trails across the tundra.

All vehicles should travel on a main diffuse trail. This will limit the amount of area impacted by vehicles. Although we can reasonably expect single vehicle tracks to disappear quickly, the visual impact of many single tracks over an area is great the first couple of years.

5. Prohibit unnecessary vehicle turns. Require all vehicles, especially Nodwells and tractors to turn slowly and with a wide radius. Turning vehicles consistently caused a higher level of disturbance than those traveling in a straight line. Turning vehicles dig deeper into the vegetative mat, leaving a more visible trail.

6. Locate campsites on sea ice whenever possible or in drifted areas that are large enough to contain the main flow of traffic.

Vehicle use is concentrated in camp areas, but impact can be minimized by well-located campsites. Some of the most damaging campsites we observed have a high level of disturbance at the actual campsite, and are surrounded by vehicle trails radiating from the camp in all directions. One such camp was located within 1 mile of the sea ice.

7. Route camp moves and supply moves over sea ice or through drifted drainages when possible.

Routing cat-trains through drifted drainages proved to be an effective means of minimizing impacts. Narrow trails can be followed in drainages without causing high levels of disturbance. However, care must be taken to assure that cat-trains spread out when high spots without deep snow are crossed.

8. Route camp move routes through Wet Sedge, Moist/Wet Sedge, and Moist Sedge, Prostrate Shrub Tundra vegetation types when possible, and avoid areas of high micro-relief, such as Moist Sedge Tussock, Dwarf Shrub Tundra and Moist Sedge/Barren Tundra Complex.

Aerial photo data showed fewer observations of high and moderate disturbance in wet habitats. Crushing and scraping of mound tops occurs frequently in areas of high micro-relief.

9. Avoid steep slopes (over 20%). Require cat-trains to use two tractors when traveling up slopes or out of drifted areas, to prevent spinning of tracks and exposure of bare patches of soil.

Route planning by GSI surveyors, party managers, and FWS monitors allowed crews to avoid steep slopes in most cases this year. Tractor tracks spun when pulling camp sleds out of drifted drainages even on shallow slopes in some areas.

10. Require that fuel tanks be strictly maintained to prevent leaks.

    Fuel spills killed vegetation over areas ranging from 1-6 m at many campsites. Fuel tanks should be immediately fixed when any dripping of fuel is evident. Also, crew members should be more careful to avoid small spills when refueling vehicles.

11. Require use of absorbents to catch dripping oil from vehicles, and require crews to clean up any oil drips found on the snow.

    Small oil drips from vehicles commonly occur. Last year use of absorbents, and clean-up by crew members helped to limit this problem.

12. Locate air strips on lakes when possible. Require that packing and blading of snow by cats be limited when air strips are located on tundra.

    One tundra airstrip was highly visible this summer, due to compression by tractors and evident turns at both ends of the runway.

13. The required average snow depth should remain at 6 in.

    An average snow depth of 6 in will prevent vehicle tracks from digging into the vegetative mat in most cases. It appears that a much higher snow depth than can be expected in ANWR would be necessary to eliminate moderate level disturbances, particularly in vegetation types with high micro-relief.

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Appendix A. Vegetation Cover on Intensive Study Plots

Table A-1. Vegetative cover on disturbed and control sites on Moist/Wet Sedge Tundra and Moist Sedge, Prostrate Shrub Tundra, on the coastal plain, Arctic NWR, Alaska, 1984.

Vegetative Cover	Moist/Wet Sedge				Moist Sedge, Prostrate Shrub	
	011		012		M1	
	D	C	D	C	D	C
SHRUBS						
Andromeda polifolia	0.0	4.5				
Arctostaphylos rubra						
Betula nana exilis						
Cassiope tetragona			7.0	8.0		
Dryas integrifolia integrifolia			2.5	7.0		
Ledum palustre decumbens						
Salix alaxenis						
Salix brachycarpa niphoclada*						
Salix glauca*						
Salix lanata richardsonii						
Salix myrtillifolia*						
Salix phlebophylla						
Salix planifolia pulchra	3.0	3.0	1.0	6.0	16.2	13.7
Salix reticulata	0.0	3.0	0.5	5.5		
Vaccinium vitis-idaea						
Other Shrubs	2.0	2.0	2.5	7.5	2.3	0.8
SHRUBS (Total)	5.0	12.5	13.5	34.0	18.5	14.5
GRASSES						
Poa alpina						
Other grasses						
GRASSES (total)	0.0	0.0	0.0	0.0	0.0	0.0
SEDGES						
Carex aquatilis	8.0	11.5	6.5	2.5		
Carex bigelowii			3.5	5.5		
Carex rariflora	0.5	4.0				
Eriophorum angustifolium triste						
Eriophorum vaginatum						
Other sedges	4.0	2.5	4.0	5.0	11.0	12.3
SEDGES (total)	12.5	18.0	14.0	13.0	11.0	12.3
RUSHES (total)						
FORBS						
Astragalus alpinus						
Equisetum arvense						
Equisetum variegatum						
Hedysarum Mackenzii						
Lupinus arcticus						
Oxytropis campestris						
Oxytropis nigrescens						
Pyrola grandiflora						
Rubus chamaemorus						
Other forbs		0.5		2.5		0.8
FORBS (total)	0.0	0.5	0.0	2.5	0.0	0.8

Table A-1. (Continued).

Vegetative Cover	Moist /Wet Sedge				Moist Sedge, Prostrate Shrub	
	011		012		M1	
	D	C	D	C	D	C
MOSSES						
Aulacomnium acuminatum						
Aulacomnium turgidum	2.0	9.5	6.0	15.5		
Distichium capillaceum						
Dicranum spp.			7.0	2.5		
Drepanocladus spp.	3.0	10.5				
Hylocomium splendens			9.5	14.5		
Oncophorus wahlenbergii	1.5	12.5	0.5	4.5		
Polytrichum juniperinum						
Paludella squarrosa						
Sphagnum spp.			0.5	4.5		
Rhitidium rugosum						
Tomenthypnum nitens	17.0	17.5	6.5	14.0		
Other mosses	11.5	17.5	6.0	16.5	3.3	7.2
MOSS (total)	35.0	67.5	36.0	72.0	3.3	7.2
LICHENS						
Cetraria cuculata						
Cetraria islandica			1.0	3.0		
Cladonia spp.						
Nephroma arcticum						
Peltigera aphthosa			3.0	2.5		
Peltigera malacea						
Sphaerophorus globosus						
Thamnolia subuliformis						
Other lichens	0.5		0.0	2.5		
LICHENS (total)	0.5	0.0	4.0	8.0		
Ptilidium ciliare						
HEPATICS (total)	0.0	0.5				
ALGAE						
FUNGI						
TOTAL VEGETATIVE COVER	53.0	99.0	67.5	129.5	32.8	34.8
EXPOSED GROUND (no plant cover)						
Organics	11.0	1.0	17.5	0.5	2.2	0.8
Organic-Mineral Soil			3.5	0.0		
Mineral Soil						
Litter	35.0	15.5	27.5	7.5	N	N
Water	4.0	1.0				
TOTAL LITTER	65.5	67.0	54.5	57.0	85.3	80.3

D - Disturbed, C - Control, N - No data
* - Verification pending.

Table A-2. Vegetative cover on disturbed and control sites, on Moist Sedge/Barren Tundra Complex, coastal plain, Arctic NWR, Alaska, 1984.

Vegetative Cover	Moist Sedge/Barren Tundra Complex					
	07		N11		N12	
	D	C	D	C	D	C
SHRUBS						
Andromeda polifolia						
Arctostaphylos rubra						
Betula nana exilis						
Cassiope tetragona						
Dryas integrifolia integrifolia	3.0	11.0	3.5	12.5	5.0	8.5
Ledum palustre decumbens						
Salix alaxenis						
Salix brachycarpa niphoclada						
Salix glauca						
Salix lanata richardsonii						
Salix myrtillifolia						
Salix phlebophylla	3.0	5.5	0.0	3.5		
Salix planifolia pulchra						
Salix reticulata	6.5	12.5				
Vaccinium vitis-idaea						
Other Shrubs	2.0	1.0	3.0	4.0	2.0	5.5
SHRUBS (Total)	14.5	30.0	6.5	20.0	7.0	14.0
GRASSES						
Poa alpina						
Other grasses	0.0	0.0	1.0	1.0	1.0	0.5
GRASSES (total)	0.0	0.0	1.0	1.0	1.0	0.5
SEDGES						
Carex aquatilis						
Carex bigelowii	4.0	1.0	4.5	7.0	3.0	9.5
Carex rariflora						
Eriophorum angustifolium triste			4.0	5.5	4.5	6.5
Eriophorum vaginatum			1.0	3.5		
Other sedges	4.5	8.0			1.5	2.0
SEDGES (total)	8.5	9.0	9.5	16.0	9.0	18.0
RUSHES (total)						
FORBS						
Astragalus alpinus						
Equisetum arvense						
Equisetum variegatum	2.5	9.5				
Hedysarum Mackenzii						
Lupinus arcticus						
Oxytropis campestris						
Oxytropis nigrescens						
Pyrola grandiflora						
Rubus chamaemorus						
Other forbs	3.0	2.0	2.5	2.0	1.0	2.0
FORBS (total)	5.5	11.5	2.5	2.0	1.0	2.0

Table A-2. (Continued).

Vegetative Cover	Moist Sedge/Barren Tundra Complex					
	07		N11		N12	
	D	C	D	C	D	C
MOSSES						
Aulacomnium acuminatum			3.0	0.5		
Aulacomnium turgidum			1.0	3.0		
Distichium capillaceum			1.5	3.0		
Dicranum spp.	4.5	8.5	1.5	5.0	4.0	6.5
Drepanocladus spp.	0.5	7.0			0.5	3.0
Hylocomium splendens			2.5	5.0	0.5	4.0
Oncophorus wahlenbergii						
Polytrichum juniperinum	5.0	0.5				
Paludella squarrosa						
Sphagnum spp.						
Rhitidium rugosum						
Tomenthypnum nitens	16.0	18.0	21.0	24.0	12.0	17.5
Other mosses	0.0	21.0	9.0	12.5	13.0	19.5
MOSS (total)	26.0	55.0	39.5	53.0	30.0	50.5
LICHENS						
Cetraria cuculata						
Cetraria islandica						
Cladonia spp.						
Nephroma arcticum						
Peltigera aphthosa						
Peltigera malacea						
Sphaerophorus globosus			0.0	3.0		
Thamnolia subuliformis	1.5	5.5	1.5	3.5	3.5	2.0
Other lichens	1.0	3.0	5.5	13.5	6.5	9.5
LICHENS (total)	2.5	8.5	7.0	20.0	10.0	11.5
Ptilidium ciliare			7.5	8.5	3.5	9.0
HEPATICS (total)			7.5	8.5	3.5	9.5
ALGAE	0.0	0.5			1.0	1.0
FUNGI						
TOTAL VEGETATIVE COVER	57.0	114.5	73.5	120.5	62.5	107.0
EXPOSED GROUND (no plant cover)						
Organics	6.0	0.0	4.0	0.0	6.5	1.5
Organic-Mineral Soil	5.0	0.0				
Mineral Soil			0.5	0.5	0.5	1.5
Litter	35.5	14.0	31.5	10.5	40.5	14.5
Water						
TOTAL LITTER	58.5	63.5	50.5	45.5	65.5	56.5

D - Disturbed, C - Control, N - No data
* - Verification pending.

Table A-3. Vegetative cover on intensive study plots, on Moist Sedge Tussock, Dwarf shrub Tundra, coastal plain, Arctic NWR, 1984.

Vegetative Cover	Moist Sedge Tussock, Dwarf Shrub Tundra							
	M2		O3		S2		S8	
	D	C	D	C	D	C	D	C
SHRUBS								
Andromeda polifolia								
Arctostaphylos rubra								
Betula nana exilis	5.2	14.0					2.5	6.0
Cassiope tetragona					9.5	6.0		
Dryas integrifolia integrifolia					3.0	2.5		
Ledum palustre decumbens	1.4	6.0					6.5	12.5
Salix alaxenis								
Salix brachycarpa niphoclada								
Salix glauca								
Salix lanata richardsonii								
Salix myrtillifolia								
Salix phlebophylla			0.0	15.0				
Salix planifolia pulchra	9.0	8.8	4.0	3.0	1.0	3.5		
Salix reticulata					2.0	7.5		
Vaccinium vitis-idaea	1.2	5.0	3.5	10.5			7.0	18.5
Other Shrubs	1.4	1.0	3.5	4.0	5.0	5.5	1.5	2.5
SHRUBS (Total)	18.2	34.8	11.0	32.5	20.5	25.0	17.5	39.5
GRASSES								
Poa alpina								
Other grasses	0.6		1.0	1.0	1.0			1.0
GRASSES (total)	0.6	0.0	1.0	1.0	1.0	0.0	0.0	1.0
SEDGES								
Carex aquatilis								
Carex bigelowii			8.5	12.5	4.0	4.0		
Carex rariflora								
Eriophorum angustifolium triste								
Eriophorum vaginatum	8.2	16.0	5.5	5.0	2.0	12.0	3.0	4.5
Other sedges	2.0	2.8	2.5	2.0			1.0	1.0
SEDGES (total)	10.2	18.8	16.5	19.5	6.0	16.0	4.0	5.5
RUSHES (total)			0.0	0.5				
FORBS								
Astragalus alpinus								
Equisetum arvense								
Equisetum variegatum								
Hedysarum Mackenzii								
Lupinus arcticus								
Oxytropis campestris								
Oxytropis nigrescens								
Pyrola grandiflora								
Rubus chamaemorus								
Other forbs	2.2	3.8	2.5	4.0	2.0	2.0	4.0	3.0
FORBS (total)	2.2	3.8	2.5	4.0	2.0	2.0	4.0	3.0

Table A-3. (Continued).

Vegetative Cover	Moist Sedge Tussock, Dwarf Shrub Tundra							
	M2		03		S2		S8	
	D	C	D	C	D	C	D	C
MOSSES								
Aulacomnium acuminatum								
Aulacomnium turgidum			7.0	11.0	4.5	9.0	8.5	11.0
Distichium capillaceum								
Dicranum spp.			8.5	15.5	3.5	1.0	13.0	27.5
Drepanocladus spp.			0.0	3.0				
Hylocomium splendens			6.5	9.5	15.0	18.5	9.0	14.0
Oncophorus wahlenbergii								
Polytrichum juniperinum			2.5	5.0			1.5	3.5
Paludella squarrosa								
Sphagnum spp.							7.5	9.5
Rhitidium rugosum								
Tomenthypnum nitens			9.0	3.0	11.0	14.5		
Other mosses	8.8	20.5	1.0	6.0	11.0	17.0	3.0	3.5
MOSS (total)	8.8	20.5	34.5	53.0	45.0	60.0	42.5	69.0
LICHENS								
Cetraria cuculata								
Cetraria islandica								
Cladonia spp.								
Nephroma arcticum							3.0	3.0
Peltigera aphthosa			3.0	4.5	8.0	4.0	2.5	4.5
Peltigera malacea								
Sphaerophorus globosus								
Thamnolia subuliformis								
Other lichens	1.4	4.8	5.0	7.5	3.0	1.5	5.0	7.0
LICHENS (total)	1.4	4.8	8.5	12.0	11.0	5.5	10.5	14.5
Ptilidium ciliare								
HEPATICS (total)			0.0	2.0	0.0	0.5		
ALGAE								
FUNGI								
TOTAL VEGETATIVE COVER	41.4	82.5	74.0	124.5	85.5	109.0	78.5	132.5
EXPOSED GROUND (no plant cover)								
Organics	2.4	0.0	15.0	3.0	2.0	0.0	10.5	0.0
Organic-Mineral Soil	0.2	0.0						
Mineral Soil	1.2	0.3						
Litter	N	N	27.5	9.0	29.5	17.0	29.0	9.5
Water								
TOTAL LITTER	87.2	76.3	52.5	47.5	70.5	65.0	54.5	43.5

D - Disturbed, C - Control, N - No data
* - Verification pending.

Table A-4. Vegetative cover on intensive study plots, on Moist Dwarf Shrub, Sedge Tussock Tundra, coastal plain, Arctic NWR, 1984.

Vegetative Cover	Moist Dwarf Shrub, Sedge Tussock Tundra					
	M3		S4		S6	
	D	C	D	C	D	C
SHRUBS						
Andromeda polifolia						
Arctostaphylos rubra						
Betula nana exilis	8.0	14.7	11.5	20.5	6.5	11.5
Cassiope tetragona						
Dryas integrifolia integrifolia						
Ledum palustre decumbens	3.3	12.3	5.5	11.5	9.5	10.5
Salix alaxenis						
Salix brachycarpa niphoclada						
Salix glauca						
Salix lanata richardsonii						
Salix myrtillifolia						
Salix phlebophylla						
Salix planifolia pulchra			4.0	1.5		
Salix reticulata						
Vaccinium vitis-idaea			11.0	22.0	8.5	20.0
Other Shrubs	3.7	18.3	0.0	2.5	0.5	3.0
SHRUBS (Total)	15.0	45.3	32.0	58.0	25.0	45.0
GRASSES						
Poa alpina						
Other grasses					0.5	1.0
GRASSES (total)	0.0	0.0	0.0	0.0	0.5	1.0
SEDGES						
Carex aquatilis						
Carex bigelowii			2.5	6.5		
Carex rariflora						
Eriophorum angustifolium triste						
Eriophorum vaginatum	4.7	9.0				
Other sedges	1.6	0.0	4.0	1.0	1.0	2.0
SEDGES (total)	6.3	9.0	6.5	7.5	1.0	2.0
RUSHES (total)						
FORBS						
Astragalus alpinus						
Equisetum arvense						
Equisetum variegatum						
Hedysarum Mackenzii						
Lupinus arcticus						
Oxytropis campestris						
Oxytropis nigrescens						
Pyrola grandiflora						
Rubus chamaemorus					0.5	5.0
Other forbs	1.3	1.3	2.5	5.0	2.5	2.0
FORBS (total)	1.3	1.3	2.5	5.0	3.0	7.0

Table A-4. (Continued).

Vegetative Cover	Moist Dwarf Shrub, Sedge Tussock Tundra					
	M-3		S-4		S-6	
	D	C	D	C	D	C
MOSSES						
Aulacomnium acuminatum						
Aulacomnium turgidum			10.5	13.0	12.0	12.0
Distichium capillaceum						
Dicranum spp.			18.5	19.5	18.0	27.0
Drepanocladus spp.						
Hylocomium splendens			12.5	13.0	10.0	13.5
Oncophorus wahlenbergii						
Polytrichum juniperinum			2.0	4.0		
Paludella squarrosa						
Sphagnum spp.			4.0	0.5		
Rhitidium rugosum			2.5	3.0	5.5	4.5
Tomenthypnum nitens						
Other mosses	7.3	23.7	2.5	5.5	10.0	12.0
MOSS (total)	7.3	23.7	52.5	58.5	55.5	69.0
LICHENS						
Cetraria cuculata					2.5	3.0
Cetraria islandica						
Cladonia spp.			1.0	3.5	1.5	3.0
Nephroma arcticum						
Peltigera aphthosa			11.5	9.0	6.0	14.5
Peltigera malacea						
Sphaerophorus globosus						
Thamnolia subuliformis						
Other lichens	2.3	5.3	7.0	8.5	8.0	4.5
LICHENS (total)	2.3	5.3	19.5	21.0	18.0	25.0
Ptilidium ciliare						
HEPATICS (total)			0.5	0.0		
ALGAE						
FUNGI			0.5	0.0		
TOTAL VEGETATIVE COVER	32.3	84.7	114.0	149.5	103.0	149.0
EXPOSED GROUND (no plant cover)						
Organics	4.0	0.7	1.0	0.0	8.5	0.0
Organic-Mineral Soil						
Mineral Soil						
Litter	N	N	17.5	10.5	16.0	4.0
Water						
TOTAL LITTER	85.7	66.7	54.0	49.5	43.0	31.5

D - Disturbed, C - Control, N - No data
* - Verification pending.

Table A-5. Vegetative cover on disturbed and control sites, on *Dryas* River Terrace and Riparian Shrubland coastal plain, Arctic NWR, Alaska, 1984.

Vegetative Cover	Dryas River Terrace		Riparian Shrubland			
	06		M4		S5	
	D	C	D	C	D	C
SHRUBS						
Andromeda polifolia						
Arctostaphylos rubra			10.7	14.0		
Betula nana exilis						
Cassiope tetragona						
Dryas integrifolia integrifolia	1.0	25.5	3.3	11.0		
Ledum palustre decumbens						
Salix alaxenis			4.0	3.0		
Salix brachycarpa niphoclada			5.3	9.0		
Salix glauca					20.0	18.2
Salix lanata richardsonii					12.1	19.4
Salix myrtillifolia			1.0	5.0		
Salix phlebophylla						
Salix planifolia pulchra					7.3	6.1
Salix reticulata	0.5	7.0	5.0	1.7	3.0	8.5
Vaccinium vitis-idaea						
Other Shrubs	1.0	1.5	1.0	0.0	2.4	1.1
SHRUBS (Total)	2.5	34.0	29.3	43.7	44.8	53.3
GRASSES						
Poa alpina					6.1	4.8
Other grasses			0.3		3.6	6.1
GRASSES (total)	0.0	0.0	0.3	0.0	9.7	10.9
SEDGES						
Carex aquatilis						
Carex bigelowii					7.9	5.5
Carex rariflora						
Eriophorum angustifolium triste						
Eriophorum vaginatum						
Other sedges	0.0	1.0				
SEDGES (total)	0.0	1.0	0.0	0.0	7.9	5.5
RUSHES (total)						
FORBS						
Astragalus alpinus	0.0	3.0				
Equisetum arvense					0.0	3.0
Equisetum variegatum			1.0	3.3		
Hedysarum Mackenzii			5.0	5.3		
Lupinus arcticus			1.5	3.3	0.6	6.1
Oxytropis campestris	0.5	3.5				
Oxytropis nigrescens	0.0	6.5				
Pyrola grandiflora					0.0	7.3
Rubus chamaemorus						
Other forbs		1.0	3.2	10.0	3.0	6.0
FORBS (total)	0.5	14.0	10.7	22.0	3.6	22.4

Table A-5. (Continued).

Vegetative Cover	*Dryas* River Terrace 06		Riparian Shrubland M4		Riparian Shrubland S5	
	D	C	D	C	D	C
MOSSES						
Aulacomnium acuminatum					1.8	3.0
Aulacomnium turgidum						
Distichium capillaceum						
Dicranum spp.	6.5	9.5				
Drepanocladus spp.					10.3	9.1
Hylocomium splendens					6.1	5.5
Oncophorus wahlenbergii						
Polytrichum juniperinum						
Paludella squarrosa					7.3	10.3
Sphagnum spp.						
Rhitidium rugosum						
Tomenthypnum nitens	0.5	25.5			10.3	19.4
Other mosses	1.5	8.0	20.0	40.0	27.8	24.8
MOSS (total)	8.5	43.0	20.0	40.0	63.6	72.1
LICHENS						
Cetraria cuculata						
Cetraria islandica						
Cladonia spp.						
Nephroma arcticum						
Peltigera aphthosa						
Peltigera malacea						
Sphaerophorus globosus						
Thamnolia subuliformis						
Other lichens	1.0	6.0	6.3	15.7	0 0	2.4
LICHENS (total)	1.0	6.0	6.3	15.7	0 0	2.4
Ptilidium ciliare						
HEPATICS (total)					1.2	3.0
ALGAE						
FUNGI						
TOTAL VEGETATIVE COVER	12.5	98.0	62.7	121.0	130.9	169.7
EXPOSED GROUND (no plant cover)						
Organics					1.2	0.0
Organic-Mineral Soil 3.5	26.5	1.0				
Mineral Soil			0.0	0.3		
Litter	62.0	17.5	N	N	11.5	3.6
Water						
TOTAL LITTER	68.0	57.0	84.0	58.7	61.8	47.2

D - Disturbed, C - Control, N - No data
* - Verification pending.

Appendix B. Summary of Vehicle Disturbance by Vegetation Type

Table B-1. Summary of vehicle disturbances due to winter seismic exploration coastal plain Arctic NWR, Alaska, 1984.

Vegetation Types: Wet Sedge, Moist/Wet Sedge, and Moist Sedge, Prostrate Shrub Tundra.

	Disturbance Levels		
	Low	Moderate	High
Vegetation Impacts	Compression of standing dead to surface. Slight scuffing or compression of moss mat. Up to 25% breakage of prostrate willows.	Compression of mosses and standing dead. Trail appears wetter than surrounding area. 50% breakage of prostrate willows.	Compression of mosses below water level. Standing water apparent in tracks that is not present in surrounding area. Almost complete removal of willows.
Visual Impacts	Trails appear greener than surrounding area. Visible from the air and slightly visible on the ground.	More distinct green trail. Visible from air and on ground.	Trail appears dark due to standing water. Highly visible from air and visible on ground.
Thermal Impact	May have slight increase in thaw depth due to change in reflectance values.	Increase in thaw depth, and minor increases in track depression due to compression of mosses and possible subsidence.	Increase in thaw depth and minor increase in track depression due to compression of mosses and subsidence.
Frequency	Common	Uncommon	Rare
Traffic Patterns	Single vehicle Seismic-diffuse	Vehicle turn Seismic - diffuse Camp - diffuse Seismic - narrow	Seismic - narrow Camp - narrow

Table B-1. (Continued).

Vegetation Types: Moist Sedge/Barren Tundra Complex.

	Disturbance Levels		
	Low	Moderate	High
Vegetation Impacts	Compression of standing dead and scuffing of hummocks. Up to 25% vegetation damage, with decreased cover of <u>Dryas integrifolia</u>, mosses and lichens.	Hummocks crushed. 25-50% vegetation damage, 5-15% exposed organic or mineral soil.	Hummocks removed at ground level. Over 15% soil exposed and over 50% vegetation damage.
Visual Impacts	Slightly darker trail. Slightly visible due to variability and natural bare spots.	Brown trail, slightly visible from air and ground due to patchiness of natural coloration.	Trail appears dark with patches of bare soil evident. Can be highly visible from air, and visible on ground.
Thermal Impacts	No measurable impact.	Increase in thaw depth difficult to measure due to high variability in frost scar areas.	Increase in thaw depth. Minor increase in track depression possible.
Frequency	Common	Common	Rare
Traffic Patterns	Single vehicle Seismic - diffuse	Seismic - diffuse Vehicle turn Camp - diffuse	Camp - narrow Seismic - narrow

Table B-1. (Continued).

Vegetation Types: Moist Sedge Tussock, Dwarf Shrub Tundra .

	Disturbance Levels		
	Low	Moderate	High
Vegetation Impacts	Scuffing of tussocks. Up to 25% vegetation damage. Up to 5% exposed peat or mineral soil. Branches of ericaceous shrubs, birch, and willow broken, but many shrubs protected between tussocks.	Tussock mound top destruction. Peat exposed in center of tussocks. 25-50% vegetation damage, 5-15% exposed peat or mineral soil. Shrub canopy substantially reduced. Moss mat compressed and broken, decrease in live moss cover.	Tussock mounds scraped almost to ground level in nearly continuous lines, ruts starting to form. Vegetation damage over 50%. Exposed peat and soil over 15%.
Visual Impacts	Light brown trail. Cottongrass blooms evident around trail, but not on trail. Visible from air and slightly visible on ground. Trail less visible late in the season when vegetation has begun to senesce.	Darker brown trail due to patches of exposed peat. Visible from air and ground.	Brown trail with nearly continuous black ruts. Highly visible from air and visible on ground.
Thermal Impacts	No measurable impact.	Increase in thaw depth. May be slight track depression, but difficult to measure due to micro relief.	Significant increase in thaw depth with possible minor subsidence.
Frequency	Common	Common	Rare
Traffic Patterns	Single vehicle Seismic diffuse	Vehicle turn Camp - diffuse Seismic - diffuse	Seismic - narrow Camp - narrow

Table B-1. (Continued).

Vegetation Types: Moist Dwarf Shrub, Sedge Tussock Tundra .

	Disturbance Levels		
	Low	Moderate	High
Vegetation Impacts	Branches of dwarf birch and ericaceous shrubs broken. Scuffing of tussocks and hummocks. Vegetation damage less than 25%. Slight breakage of vegetative mat with exposed peat and soil less than 5%.	Shrubs broken, sometimes to ground level. Mound top destruction of tussocks and hummocks. Moss mat compressed, and patches overturned. Vegetation damage - 25-50%. Exposed peat and soil - 5-15%.	Nearly complete removal of shrub canopy. Moss mat mostly dead. Disruption of vegetation mat with over 15% organics or mineral soil exposed. Vegetation damage over 50%.
Visual Impacts	Slightly darker trail. Slightly visible due to naturally dark coloration and patchiness of this vegetation type.	Brown trail. Visible from air and slightly visible on ground.	Dark brown trail. Highly visible from air and visible on ground.
Thermal Impacts	May have slight increase in thaw depth due to removal of shrub canopy.	Increase in thaw depth.	Increase in thaw depth with possible minor subsidence.
Frequency	Common	Common	Rare
Traffic Patterns	Single vehicle Seismic - diffuse Vehicle turn	Seismic - diffuse Camp - diffuse Vehicle turn	Camp - narrow Seismic - narrow

Table B-1. (Continued).

Vegetation Types: Riparian Shrubland.

	Disturbance Levels		
	Low	Moderate	High
Vegetation Impacts	Willows partially broken, little impact to ground cover. Less than 25% vegetation damage.	Willows broken, sometimes to ground level. *Dryas* forbs, and mosses partially killed or remove. Vegetation damage - 25-50% Exposed soil - 5-15%.	Nearly complete removal of shrub canopy. Vegetation damage over 50%. Moss mat mostly dead. Vegetation mat disrupted with over 15% soil exposed.
Visual Impacts	Line of broken willows visible from air and ground.	Line of broken willows highly visible from air and visible on ground.	Highly visible brown line through willows due to removal of shrub canopy, dead mosses, and exposed organics and mineral soil.
Thermal Impacts	Not expected to be a problem due to gravel soils and deep active layer of river beds.	Same as low	Same as low
Frequency	Rare	Common	Rare
Traffic Patterns	Single vehicle Seismic - narrow	Seismic - narrow Camp - narrow	Camp - narrow

Table B-1. (Continued).

Vegetation Types: *Dryas* River Terrace.

	Disturbance Levels		
	Low	Moderate	High
Vegetation Impacts	Less than 25% decrease in vegetative cover, especially for *Dryas integrifolia*.	Decrease in vegetative cover of *Dryas integrifolia* forbs, and mosses; overall vegetation damage is 25-50%. Vegetative mat remains mostly intact with 5-15% organic or mineral soil exposed.	Over 50% vegetation killed. Vegetation mat disrupted with over 15% soil exposed. Wind could lead to removal of more of the vegetative mat.
Visual Impacts	Light brown stripe. Visible from air and slightly visible on ground.	Brown stripe of dead vegetation. Highly visible from air and visible on ground.	Brown stripe of dead vegetation and exposed soil. Highly visible from air and ground.
Thermal Impacts	Not expected to be a problem due to gravel soils and deep active layer of river beds.	Same as low	Same as low
Frequency	Rare	Uncommon	Common
Traffic Patterns	Single vehicle	Seismic -diffuse Camp - diffuse Vehicle turn	Seismic - narrow and diffuse Camp - narrow and diffuse

DWRC Progress Report: Sub-work Unit 5
PROBE: SPATIAL AND TEMPORAL DISTRIBUTION OF BITING AND PARASITIC INSECTS ON THE COASTAL PLAIN AND ADJOINING FOOTHILLS OF THE ANWR

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Key Words: Porcupine caribou herd, summer range, insects, insect relief habitat, traps, model

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Abstract: Progress is reported for second year studies of the spatial and temporal distributions of biting and parasitic insects on the coastal plain and adjoining foothills of the ANWR. Objectives for the 1984 study season were: 1) determine if levels of mosquito activity and harassment of humans and caribou differ between coast, plains and foothills sites, and between insect relief and insect sites, 2) determine if differences in mosquito activity and harassment are associated with topography, distance from riparian habitat (river and coast) and weather, 3) define and determine if diel patterns of mosquito activity and weather at coast, plains and foothills sites are related, 4) Develop a method and sampling protocol to indirectly assess and predict the level of mosquito harassment of caribou, and 5) assess the accuracy and define the limitations of the White et al. (1975) model for predicting insect harassment of caribou. Totals of 28, 12, and 19 trap sites were established on the coast, plains and foothills, respectively. Data were collected daily from each of these three cells between 22 June and 14 July. Mosquito activity was assessed by catch size from sticky traps and sweep nets, and by objectively assigned levels of human and caribou harassment by mosquitoes. Weather data included relative humidity, minimum, maximum and current ambient air temperature, wind speed, soil temperature and cloud cover. Elevation, slope, aspect and land cover class (Walker et al. 1983) were recorded for each site, and all sites were classified as insect or insect relief habitat. Data were recorded hourly for seven 24 hour periods to quantify diel patterns. Trap sites were gridded to determine if mosquito catches were related to distance from the coast (coastal sites) and distance to riparian habitat (plains sites). Traps were deployed across terrain to assess the effect of topography on catch (foothills). Preliminary conclusions of the 1984 data indicate that mosquitoes were the dominant insect modifier of PCH behavior on the ANWR based on trap results and caribou observations. Mosquitoes emerged earlier in the foothills than on the coast. The level of mosquito activity increased from the coast to the foothills. The period of mosquito activity within a day was shorter on the coast than the plains. Of the four measures of insect activity tested, sweep net catch was the best estimator of behavioral response in caribou to mosquitoes. A corridor of low mosquito activity was present along a major river. Diel patterns of weather and insect activity were pronounced. The coast provided the greatest relief from mosquito harassment. The predictive capability of the model can be improved by defining and incorporating insect relief habitat.

Spatial and temporal distributions of biting and parasitic insects on the coastal plain and adjoining foothills of the ANWR.

Introduction:

The temporal and spatial distribution of biting and parasitic Dipterans are central to the ecology of the Porcupine Caribou Herd (PCH). Insect harassment and infestation are primary modifiers of caribou behavior, condition and habitat during periods of critical energy balance. The insect-caribou literature and the justification for insect research on the summer range of the PCH were addressed in the first progress report (Pank et al. 1984). In summary, the adverse effects of insects on caribou, the importance and potential loss of insect relief habitat with development, and the potential for development and increased human activity on the summer range of the PCH, combine to emphasize the need to 1) identify and locate the insect relief habitats on the Arctic coastal plain, 2) confirm the importance of insect/PCH interactions and 3) develop quidelines that prevent or mitigate the loss of insect relief habitat if development occurs. This study is the second year of ongoing work to address the following long range objectives.

1. Define the spatial and temporal distribution of biting and parasitic Dipterans on the summer range of the PCH.

2. Correlate the spatial and temporal distribution of insects and caribou at multiple scales of measure (i.e., site specific to summer range).

3. Define and map the insect relief habitat on the summer range of the PCH.

4. Define the correlations between weather variables, insect activity and harassment levels (caribou, human).

5. Develop a predictive model for the potential spatial and temporal distribution of the PCH on the summer range based on insect and weather variables.

6. Determine if the models that define the behavioral responses of caribou to insect harassment are applicable to the PCH.

The extensive sampling in 1983 produced an overview of the temporal and spatial distribution of five families of biting and parasitic Dipterans over the entire coastal plain and adjoining foothills of the Arctic National Wildlife Refuge (ANWR) (Pank et al. 1984). Based on the 1983 results, mosquitoes (Culicidae) were the principal insect modifier of PCH behavior within the study area. The research in 1984 shifted from the 1983 extensive sampling to intensive sampling of insect activity and weather in three areas during the period of peak caribou-mosquito interaction (Fig. 1).

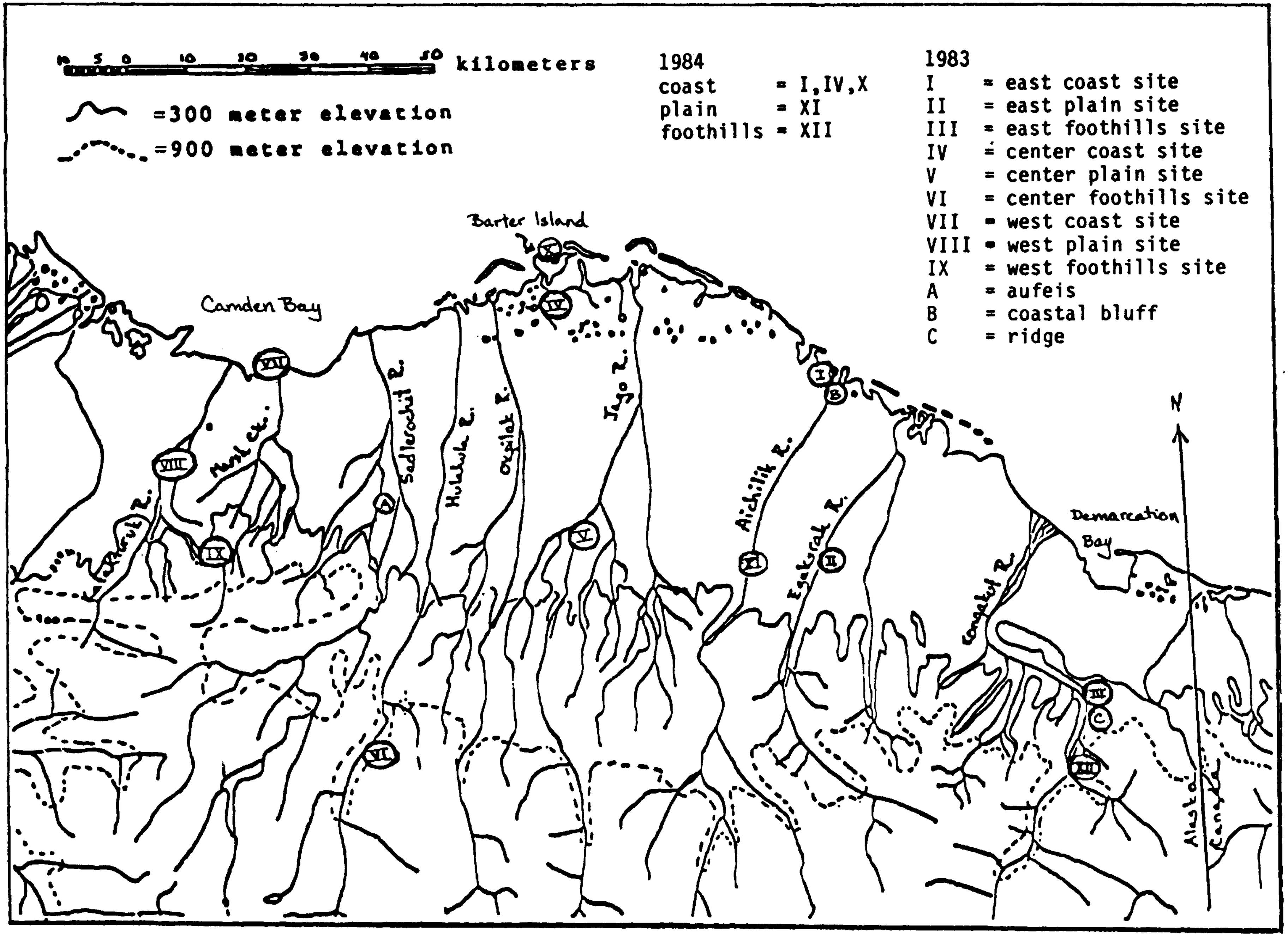

Figure 1. General locations of insect and insect relief trapsites in the Arctic National Wildlife Refuge, 1983 and 1984.

Specific objectives included:

1. Determine if levels of mosquito activity and harassment of humans and caribou differ between coast, plains and foothills sites, and between insect relief and insect sites.

2. Determine if differences in mosquito activity and harassment are associated with topography, distance from riparian habitat (river and coast) and weather.

3. Define and determine if diel patterns of mosquito activity and weather at coast, plains and foothills sites are related.

4. Develop a method and sampling protocol to indirectly assess and predict the level of mosquito harassment of caribou.

5. Assess the accuracy and define the limitations of the White et al. (1975) model for predicting insect harassment of caribou.

Materials and methods:

The coastal plain and adjoining foothills of the ANWR were partitioned into three cells - coast, plains and foothills - duplicating the 1983 latitudinal cells. Operations were based out of camps within each cell. Totals of 28, 12 and 19 trap sites were established in the coast, plains and foothills cells, respectively. Specific objectives within each cell dictated site placement. Two 1983 sites and a grid (three rows of four sites each at increasing distance from the coast) were established in 1984 at both Barter Island and Beaufort Lagoon to define the width of the coastal relief zone. A grid (three rows of four sites at increasing distance from riparian habitat) was established along the Aichilik River in the plains to determine if an insect relief zone exists along riparian habitat. Trap sites in the foothills were distributed in valley, slope or ridge terrain in three drainages on Whale Mountain to determine if ridges function as insect relief habitat. Distances to the coast and to riparian habitat, elevation, slope, aspect, terrain and landcover class (Walker et al. 1983) were recorded for each site. All trap sites were classified as insect relief or insect habitat based on published descriptions of insect relief habitat (barren ground, aufeis, snow patches, glaciers, open water, off shore islands, ridges, gravel bars and coastal areas), (Banfield 1954, Kelsal 1968, Skoog 1968, Curatolo 1975, Roby 1978 and White et al. 1975). General descriptions of all trap sites are listed in Table 1.

The level of mosquito harassment of humans was recorded subjectively and objectively during each site visit. The subjective levels matched those used for 1983 human harassment assessment in this study and for ongoing insect research on the Central Arctic Herd (Pank et al. 1984, Curatolo pers. comm.). Objective measurements of harassment were collected with sweep nets having a 1 m handle and a 0.4 m diameter hoop. The muslin bag (0.6 m without tip) was equipped with a 0.25 m net tip attached with velcro. Captured insects were counted on site or, if time did not permit, the tip was removed and tied for later investigation. Sweeps were performed by facing downwind, positioning the left hand at the pivot point marked 0.7 m from the bottom of the hoop, and swinging the net in a 180 degree arc in a vertical plane starting and ending

Table 1. Characteristics of landcover, location and topography for individual insect trap sites in the Arctic National Wildlife Refuge, Alaska, 1984

LOCATION	TRAP NUMBER	INSECT HAB.[1]	LAND COVER (A)	LAND COVER (B)	LAND COVER (C)	DIST. NORTH TO COAST (km)[2]	DIST. TO RIPARIAN HABITAT (km)	MOISTURE REGIME	TOPOGRAPHY ELEV. (m)	SLOPE (degrees)	ASPECT (degrees)	(TERRAIN)
COAST												
FISH CREEK	15	IR	E	X	a	7.50	7.50	DRY	6	0	-	
	16	I	B	III	a	7.50	7.50	WET OR LOWLAND	6	0	0	
BARTER ISLAND	18	IR	C	V	a	0.00	0.00	MOIST, WELL DRAINED	10	0	0	
	19	IR	C	V	a	0.03	0.03	MOIST, WELL DRAINED	10	0	0	
	20	IR	C	V	a	0.05	0.05	AQUATIC	10	0	0	
	21	IR	C	IV	a	0.08	0.08	MOIST, WELL DRAINED	10	0	0	
	22	IR	C	IV	a	0.01	0.01	MOIST, WELL DRAINED	3	0	0	
	23	IR	C	IV	a	0.03	0.03	MOIST, WELL DRAINED	10	0	0	
	24	IR	C	IV	a	0.05	0.05	MOIST, WELL DRAINED	10	0	0	
	25	IR	C	IV	a	0.08	0.08	MOIST, WELL DRAINED	10	0	0	
	26	IR	C	IV	a	0.10	0.10	MOIST, WELL DRAINED	10	0	0	
	27	IR	C	IV	a	0.15	0.15	MOIST, WELL DRAINED	10	0	0	
	28	IR	C	IV	a	0.10	0.10	MOIST, WELL DRAINED	10	0	0	
	29	IR	C	IV	a	0.15	0.15	MOIST, WELL DRAINED	10	0	0	
BEAUFORT LAGOON	30	IR	C	V	e	0.05	0.05	MOIST, WELL DRAINED	4	0	0	
	31	I	B	III	b	0.30	0.30	WET OR LOWLAND	3	0	0	
	32	IR	C	IV	a	0.00	0.00	MOIST, WELL DRAINED	4	0	0	
	33	IR	C	IV	a	0.02	0.02	MOIST, WELL DRAINED	4	0	0	
	34	IR	C	IV	a	0.05	0.05	MOIST, WELL DRAINED	4	0	0	
	35	IR	C	IV	a	0.08	0.08	WET OR LOWLAND	4	0	0	
	36	IR	C	IV	a	0.00	0.00	MOIST, WELL DRAINED	4	0	0	
	37	IR	C	IV	a	0.02	0.02	MOIST, WELL DRAINED	4	0	0	
	38	IR	C	IV	a	0.05	0.05	MOIST, WELL DRAINED	4	0	0	
	39	IR	B	III	a	0.08	0.08	WET OR LOWLAND	4	0	0	
	40	IR	C	IV	a	0.10	0.10	WET OR LOWLAND	4	0	0	
	41	IR	C	IV	a	0.15	0.15	MOIST, WELL DRAINED	4	0	0	
	42	IR	C	IV	a	0.10	0.10	MOIST, WELL DRAINED	4	0	0	
	43	IR	C	IV	a	0.15	0.15	MOIST, WELL DRAINED	4	0	0	
PLAIN	1	IR	E	X	a	47.0	<0.1	DRY	194	0	-	
	2	IR	C	V	c	47.0	0.1 - 0.2	DRY	194	0	-	
	3	I	B	III	a	47.0	1.4	WET OR LOWLAND	194	0	-	
	4	I	C	V	b	47.0	2.0	MOIST, WELL DRAINED	209	0	-	
	5	IR	E	X	a	47.0	<0.1	WET OR LOWLAND	194	0	-	
	6	IR	C	V	c	47.0	0.3	DRY	194	0	-	
	7	I	B	III	a	47.0	0.7	WET OR LOWLAND	204	0	-	
	8	I	C	V	b	47.0	1.7	MOIST, WELL DRAINED	209	4	135	
	9	IR	E	X	a	47.0	<0.1	WET OR LOWLAND	194	0	-	
	10	IR	C	V	c	47.0	0.2 - 0.3	DRY	209	0	-	
	11	I	B	III	a	47.0	1.0	WET OR LOWLAND	209	0	-	
	12	I	C	V	b	47.0	1.6	MOIST, WELL DRAINED	216	4	135	
FOOTHILLS	44	I	D	VIII	c	58.0	<0.1	WET OR LOWLAND	380	5	222	(VALLEY)
	45	I	E	X	a	58.0	0.1	MOIST, WELL DRAINED	386	5	248	(VALLEY)
	46	I	C	IV	a	58.0	0.3	WET OR LOWLAND	388	0	-	(VALLEY)
	47	I	C	V	d	58.0	0.6	MOIST, WELL DRAINED	411	15	253	(VALLEY)
	48	I	C	IV	a	58.0	0.5	WET OR LOWLAND	410	13	285	(SLOPE)
	49	I	C	V	e	58.0	0.8	MOIST, WELL DRAINED	385	13	281	(VALLEY)
	50	I	C	IV	a	58.0	1.0	MOIST, WELL DRAINED	503	28	298	(VALLEY)
	51	IR	C	V	d	58.0	1.0	MOIST, WELL DRAINED	516	30	236	(SLOPE)
	52	IR	C	V	d	58.0	1.0	MOIST, WELL DRAINED	509	44	343	(SLOPE)
	53	IR	E	IX	j	58.0	1.0	DRY	543	37	304	(RIDGE)
	54	I	C	V	b	58.0	1.0	WET OR LOWLAND	495	15	278	(VALLEY)
	55	IR	C	V	d	58.0	1.0	MOIST, WELL DRAINED	540	28	210	(SLOPE)
	56	IR	C	V	d	58.0	1.0	MOIST, WELL DRAINED	528	42	325	(SLOPE)
	57	IR	E	IX	j	58.0	1.0	DRY	570	29	272	(RIDGE)
	58	IR	C	V	d	58.0	1.0	MOIST, WELL DRAINED	568	45	226	(RIDGE)
	59	IR	C	V	d	58.0	1.0	MOIST, WELL DRAINED	540	37	328	(SLOPE)
	60	IR	C	V	d	58.0	1.0	MOIST, WELL DRAINED	465	15	280	(VALLEY)
	61	IR	C	V	d	58.0	0.9	MOIST, WELL DRAINED	511	29	293	(GRAVEL BAR)
	62	IR	E	X	a	58.0	<0.1	DRY	380	0	-	(RIDGE)

1 IR = Insect relief, I = Insect habitat
2 Landcover classifications and moisture regimes based on Walker et al. (1983)

at the height of the pivot point (approximately 0.8 m above the ground) at a rate of one swing per second, for 100 swings. The volume of air processed by one 180 degree sweep was 0.32 cubic meters.

Caribou activity and response to insect harassment were recorded at the trap sites from which caribou were visible. Weather data recorded at each site included relative humidity, minimum, maximum and current ambient air temperature, insulation temperature (not shaded), mean and gust wind speed, wind direction, soil temperature, fog cover, cloud cover, ceiling height and visibility. Weather measurements were taken at approximately 0.9 m above ground level. Soil temperature was recorded at a depth of 5 cm. Thermometers were standardized across the temperature ranges encountered with individual regressions against a single mercury thermometer. Wind directions at each trap were plotted onto a wind rose, and the modal value was selected. Relative humidity (RH) and dry bulb temperature (T) were used to determine the saturation deficit (SATD), defined as the pressure exerted by water vapor in the air when saturated (e_s) minus the pressure exerted by water vapor in the air at the time of inspection (e), expressed in millibars (Linsley Jr. et al. 1975). The following formulae were used to provide an approximation of the saturation deficit accurate to within 1 millibar:

$$e_s = 33.8639[(0.00738T+0.8272)^8 - 0.000019|1.8T+48|+0.001316]$$
$$SATD = e_s-(RH/100)(e_s)$$

Mosquito harassment and weather data were collected daily from sites in the three cells (App. A). The sticky traps were initially set within a day of 23 June 1984 and pulled within two days of 13 July. Sticky papers were collected at intervals of two to twelve days, and averaged six days between collection. Although Barter Island was the main coastal location, two additional coastal locations were visited five times each throughout the study. At all locations, order of trap attendance was varied daily to minimize the effects of diel patterns.

Data were recorded hourly for 24 hours seven times during the study period to quantify diel patterns. Observations were collected for three 24 hour periods at both the plains and foothills, and only one 24 hour period on the coast due to limited mosquito activity. All times were recorded as Yukon Daylight Savings Time (YDST), which was approximately 2 hours behind solar time.

Interim analyses of the results were limited to comparisons of summary statistics. Contrasts between years were restricted to data from the same areas collected within similar periods. The 1984 sites were paired with the 1983 east and central-coast, east-plains, and east-foothills sites. The 1984 data were paired with 1983 data collected between 25 June and 10 July.

Preliminary Results and Discussion:

Mosquito Activity

All sites within each cell were ranked by sweep net and sticky trap catches to initially determine if mosquito activity was related to site characteristics (Table 2). Catch was low at all coastal sites and differences attributed to distance form coast were minor. Results suggest that the coastal relief zone was equal to or greater than 7.5 km during the 1984 field season. The clearest relationship between mosquito catch and site characteristics occurred at the plains sites, where sweep net captures and, to a lesser extent, sticky trap catches increased as the distance from the riparian habitat of the Aichilik River increased and as elevation increased. The landcover shifted from gravel bar to Dryas river terrace to wet sedge to moist tussock tundra; typical of many drainages on the coastal plain. These data, as well as similar low catches from the foothills gravel bar site on the Kongakut River in 1984 and the gravel bar sites on the Hulahula River and on creeks along the coast in 1983 confirm that gravel bars and Dryas river terraces associated with arctic riparian habitats provide areas of low mosquito activity available to caribou as long corridors of insect relief habitat. The only cell containing distinctly different terrain types was the foothills, where trap sites were identified as valley, slope or ridge. Ridge sites are commonly referred to as insect relief habitat, but the 1984 catch data did not confirm this. Ridge, slope and valley sites ranked both high and low for mosquito capture rates, and the rank for any one site differed between the two collection techniques. The effect of the interaction between weather and site characteristics on mosquito activity was more apparent in the foothills cell than eithr the coast or plains cells. For example, at site 53 in the foothills, a dry ridgetop defined as insect relief habitat, sweep net catches averaged 11 mosquitoes per 100 sweeps until 2310 YDST 12 July 1984 when 360 mosquitoes were caught in a single sample. This catch, and all other sweep net mosquito captures at this site, only occurred each and every time the wind blew less than 1.6 km per hour.

Based on the monthly weather reports from the Barter Island weather station, June was warmer and July cooler in 1983 than in 1984. Between June 25 and July 10 however, the weather in 1983 was generally cooler, with more precipitation and wind but less heavy fog and cloud cover than in 1984.

The first appearance of more than a few mosquitoes at the 1984 study sites occurred 12 June at the foothills, 16 June at the plains and 18 June on the coast. Sticky traps caught mosquitoes during the first trapping period, beginning 22 to 24 June and ending 27 to 28 June, in all locations except Barter Island, where no catch occurred until after 3 July (App. B). The first sticky trap catch of mosquitoes in the study area in 1983 occurred between 17-26 June on the plains, between 25-30 June in the foothills and between 30 June to 10 July on the coast. Within the 1984 field season the peak mean mosquito catches with sweep nets occurred on 8 July on the coast (8 mosquitoes), 7 July in the plains (191 mosquitoes) and 12 July in the foothills (187 mosquitoes) (App. C). Minor peaks (mean >70 mosquitoes) occurred on 6 and 8 July on the plains and on 8 and 9 July in the foothills. Within the comparison period the 1983 foothills catch peaked earlier (26-30 June), and the plains and coast peaked approximately the same time as in 1984.

Mosquito activity was low at the coastal sites and progressively increased from the plains to the foothills sites during the comparison period in both 1983 and 1984 (Table 3, App. B to D). The only exception to this trend was the high sticky trap catch in the plains in 1984. Weather parameters exhibited similar trends (Table 3, App. E to J). Soil temperature, and ambient and maximum air temperature were lowest at the coast and became progressively higher toward the foothills in both 1983 and 1984. Relative humidity and wind speed were the reverse in 1983, with the lowest in the foothills and progressively higher toward the coast. Soil temperatures in all three cells were warmer in 1983 than in 1984. These values were consistent with the NOAA data from Barter Island. The soil acted as a heat reservoir during the sunnier, more cloud free days of late June 1983.

Table 2. Ranked mean mosquito numbers caught by sweep nets and sticky traps, and the environmental characteristics of each insect trap site in the Arctic National Wildlife Refuge, Alaska, 1984.

SITE	MEAN SWEEPS	STICKY TRAPS MEAN	STICKY TRAPS RANK	INSECT RELIEF VS. INSECT	LAND COVER CLASS[1]	MOISTURE	DIST. TO COAST OR RIPARIAN (km)	TOPOGRAPHY ELEV. (m)	TOPOGRAPHY SLOPE (degrees)	TOPOGRAPHY ASPECT (TERRAIN) (degrees)
COAST - EARLY[2]										
33	1.00	0.00	5	IR	C IV a	MOIST, WELL DRAINED	0.02	4	0	-
35	0.67	0.00	5	IR	C IV a	WET OR LOWLAND	0.08	4	0	-
36	0.33	0.20	1	IR	C IV a	MOIST, WELL DRAINED	0.00	4	0	-
37	0.00	0.20	2	IR	C IV a	MOIST, WELL DRAINED	0.02	4	0	-
32	0.00	0.10	3	IR	C IV a	MOIST, WELL DRAINED	0.00	4	0	-
34	0.00	0.10	3	IR	C IV a	MOIST, WELL DRAINED	0.05	4	0	-
38	0.00	0.10	3	IR	C IV a	MOIST, WELL DRAINED	0.05	4	0	-
16	0.00	0.02	4	I	B III a	WET OR LOWLAND	7.50	6	0	-
15	0.00	0.00	5	IR	E X a	DRY	7.50	6	0	-
18	0.00	0.00	5	IR	C V a	MOIST, WELL DRAINED	0.00	10	0	-
19	0.00	0.00	5	IR	C V a	MOIST, WELL DRAINED	0.03	10	0	-
20	0.00	0.00	5	IR	C V a	AQUATIC	0.05	10	0	-
21	0.00	0.00	5	IR	C IV a	MOIST, WELL DRAINED	0.08	10	0	-
22	0.00	0.00	5	IR	C IV a	MOIST, WELL DRAINED	0.01	3	0	-
23	0.00	0.00	5	IR	C IV a	MOIST, WELL DRAINED	0.03	10	0	-
24	0.00	0.00	5	IR	C IV a	MOIST, WELL DRAINED	0.05	10	0	-
25	0.00	0.00	5	IR	C IV a	MOIST, WELL DRAINED	0.08	10	0	-
26	0.00	0.00	5	IR	C IV a	MOIST, WELL DRAINED	0.10	10	0	-
27	0.00	0.00	5	IR	C IV a	MOIST, WELL DRAINED	0.15	10	0	-
28	0.00	0.00	5	IR	C IV a	MOIST, WELL DRAINED	0.10	10	0	-
29	0.00	0.00	5	IR	C IV a	MOIST, WELL DRAINED	0.15	10	0	-
30	0.00	0.00	5	IR	C V e	MOIST, WELL DRAINED	0.05	4	0	-
31	0.00	0.00	5	IR	B III b	WET OR LOWLAND	0.30	3	0	-
33	0.00	0.00	5	IR	C IV a	MOIST, WELL DRAINED	0.02	4	0	-
35	0.00	0.00	5	IR	C IV a	WET OR LOWLAND	0.08	4	0	-
39	0.00	0.00	5	IR	B III a	WET OR LOWLAND	0.08	4	0	-
COAST - LATE										
36	12.67	2.08	10	IR	C IV a	MOIST, WELL DRAINED	0.00	4	0	-
42	11.67	8.51	4	IR	C IV a	MOIST, WELL DRAINED	0.10	4	0	-
38	4.33	11.09	1	IR	C IV a	MOIST, WELL DRAINED	0.05	4	0	-
41	4.00	8.81	3	IR	C IV a	MOIST, WELL DRAINED	0.15	4	0	-
34	3.67	9.11	2	IR	C IV a	MOIST, WELL DRAINED	0.05	4	0	-
32	3.67	0.69	13	IR	C IV a	MOIST, WELL DRAINED	0.00	4	0	-
40	3.00	7.92	6	IR	C IV a	WET OR LOWLAND	0.10	4	0	-
43	0.33	8.02	5	IR	C IV a	MOIST, WELL DRAINED	0.15	4	0	-
29	0.27	1.92	11	IR	C IV a	MOIST, WELL DRAINED	0.15	10	0	-
20	0.18	0.10	18	IR	C V a	AQUATIC	0.05	10	0	-
24	0.09	0.31	15	IR	C IV a	MOIST, WELL DRAINED	0.05	10	0	-
30	0.00	5.68	7	IR	C V e	MOIST, WELL DRAINED	0.05	10	0	-
31	0.00	4.53	8	I	B III b	WET OR LOWLAND	0.30	3	0	-
27	0.00	3.54	9	IR	C IV a	MOIST, WELL DRAINED	0.15	10	0	-
28	0.00	1.01	12	IR	C IV a	MOIST, WELL DRAINED	0.10	10	0	-
26	0.00	0.61	14	IR	C IV a	MOIST, WELL DRAINED	0.10	10	0	-
15	0.00	0.14	16	IR	E X a	DRY	7.50	6	0	-
16	0.00	0.14	16	I	B III a	WET OR LOWLAND	7.50	6	0	-
18	0.00	0.10	17	IR	C V a	MOIST, WELL DRAINED	0.00	10	0	-
22	0.00	0.00	19	IR	C IV a	MOIST, WELL DRAINED	0.01	3	0	-
PLAINS - EARLY										
7	75.00	11.35	3	I	B III a	WET OR LOWLAND	0.7	204	0	-
12	24.17	7.16	7	I	C V b	MOIST, WELL DRAINED	1.6	216	4	135
4	22.38	22.97	1	I	C V b	MOIST, WELL DRAINED	2.0	209	0	-
8	16.42	15.78	2	I	C V b	MOIST, WELL DRAINED	1.7	209	4	135
11	14.50	3.64	8	I	B III a	WET OR LOWLAND	1.0	209	0	-
3	13.63	7.28	6	I	B III a	WET OR LOWLAND	1.4	194	0	-
2	7.56	7.55	5	IR	C V c	DRY	0.1-0.2	194	0	-
6	4.29	11.01	4	IR	C V c	DRY	0.3	194	0	-
10	2.00	2.50	9	IR	C V c	DRY	0.2-0.3	209	0	-
1	1.00	0.59	10	IR	E X a	DRY	<0.1	194	0	-
5	0.29	0.11	12	IR	E X a	WET OR LOWLAND	<0.1	194	0	-
9	0.00	0.23	11	IR	E X a	WET OR LOWLAND	<0.1	194	0	-

Table 2. (Continued).

SITE	MEAN SWEEPS	STICKY TRAPS MEAN	STICKY TRAPS RANK	INSECT RELIEF VS. INSECT	LAND COVER CLASS[1]	MOISTURE	DIST. TO COAST OR RIPARIAN (km)	TOPOGRAPHY ELEV. (m)	SLOPE (degrees)	ASPECT (degrees)	(TERRAIN)
PLAINS - LATE											
4	66.00	31.93	2	I	C V b	MOIST, WELL DRAINED	2.0	209	0	-	
12	43.50	43.15	1	I	C V b	MOIST, WELL DRAINED	1.6	216	0	-	
7	34.57	13.52	8	I	B III a	WET OR LOWLAND	0.7	204	0	-	
3	31.63	20.00	6	I	B III a	WET OR LOWLAND	1.4	194	0	-	
8	29.29	27.78	3	I	C V b	MOIST, WELL DRAINED	1.7	209	4	135	
11	28.67	16.96	7	I	B III a	WET OR LOWLAND	1.0	209	0	-	
6	16.63	21.89	4	IR	C V c	DRY	0.3	194	0	-	
2	15.13	7.95	9	IR	C V c	DRY	0.1-0.2	194	0	-	
10	11.56	21.63	5	IR	C V c	DRY	0.2-0.3	209	0	-	
1	4.25	0.00	12	IR	E X a	DRY	<0.1	194	0	-	
5	3.78	0.34	11	IR	E X a	WET OR LOWLAND	<0.1	194	0	-	
9	2.50	0.54	10	IR	E X a	WET OR LOWLAND	<0.1	194	0	-	
FOOTHILLS - EARLY											
56	11.00	0.74	4	IR	C V d	MOIST, WELL DRAINED	1.0	528	42	325	(SLOPE)
53	8.80	0.27	8	IR	E IX j	DRY	1.0	543	37	304	(RIDGE)
46	7.40	0.09	12	I	C IV a	WET OR LOWLAND	0.3	388	0	-	(VALLEY)
55	6.80	0.36	6	IR	C V d	MOIST, WELL DRAINED	1.0	540	28	210	(SLOPE)
54	5.80	2.04	1	I	C V b	WET OR LOWLAND	1.0	495	15	278	(VALLEY)
47	5.20	0.08	13	I	C V d	MOIST, WELL DRAINED	0.6	411	15	253	(VALLEY)
59	4.86	0.00	14	IR	C V d	MOIST, WELL DRAINED	1.0	540	37	328	(SLOPE)
49	4.40	0.25	9	I	C V e	MOIST, WELL DRAINED	0.8	385	13	281	(VALLEY)
57	4.20	1.48	2	IR	E IX j	DRY	1.0	570	29	272	(RIDGE)
58	3.20	0.46	5	IR	C V d	MOIST, WELL DRAINED	1.0	568	45	226	(RIDGE)
45	3.10	0.09	12	I	E X a	MOIST, WELL DRAINED	0.1	386	5	248	(VALLEY)
50	2.60	0.18	10	I	C IV a	MOIST, WELL DRAINED	1.0	503	28	298	(VALLEY)
44	2.40	0.36	6	I	D VIII c	WET OR LOWLAND	<0.1	380	5	222	(VALLEY)
48	2.20	1.36	3	I	C IV a	WET OR LOWLAND	0.5	410	13	285	(SLOPE)
52	2.20	0.17	11	IR	C V d	MOIST, WELL DRAINED	1.0	509	44	343	(SLOPE)
60	1.43	0.29	7	IR	C V d	MOIST, WELL DRAINED	1.0	465	15	280	(VALLEY)
51	1.20	0.09	12	IR	C V d	MOIST, WELL DRAINED	1.0	516	30	236	(SLOPE)
FOOTHILLS - LATE											
50	177.33	2.81	6	I	C IV a	MOIST, WELL DRAINED	1.0	503	28	298	(VALLEY)
46	104.33	2.07	10	I	C IV a	WET OR LOWLAND	0.3	388	0	-	(VALLEY)
47	87.60	1.98	11	I	C V d	MOIST, WELL DRAINED	0.6	411	15	253	(VALLEY)
62	82.33	7.75	1	IR	E X a	DRY	<0.1	380	0	-	(RIDGE)
53	72.67	1.95	12	IR	E IX j	DRY	1.0	543	37	304	(RIDGE)
60	59.00	2.47	7	IR	C V d	MOIST, WELL DRAINED	1.0	465	15	280	(VALLEY)
52	57.33	1.48	15	IR	C V d	MOIST, WELL DRAINED	1.0	509	44	343	(SLOPE)
55	46.67	2.99	5	IR	C V d	MOIST, WELL DRAINED	1.0	540	28	210	(SLOPE)
48	42.00	2.32	9	I	C IV a	WET OR LOWLAND	0.5	410	13	285	(SLOPE)
51	32.67	2.33	8	IR	C V d	MOIST, WELL DRAINED	1.0	516	30	236	(SLOPE)
54	30.67	3.30	4	I	C V b	WET OR LOWLAND	1.0	495	15	278	(VALLEY)
56	24.33	1.59	14	IR	C V d	MOIST, WELL DRAINED	1.0	528	42	325	(SLOPE)
45	21.33	1.30	16	I	E X a	MOIST, WELL DRAINED	0.1	386	5	248	(VALLEY)
44	19.00	0.11	17	I	D VIII c	WET OR LOWLAND	<0.1	380	5	222	(VALLEY)
59	18.67	1.69	13	IR	C V d	MOIST, WELL DRAINED	1.0	540	37	328	(SLOPE)
58	11.33	3.56	3	IR	C V d	MOIST, WELL DRAINED	1.0	568	45	226	(RIDGE)
57	9.00	5.91	2	IR	E IX j	DRY	1.0	570	29	272	(RIDGE)
61	0.40	0.00	18	IR	C V d	MOIST, WELL DRAINED	0.9	511	29	293	(GRAVEL BAR)

[1] Land cover classification based on Walker et al. (1983).
[2] Data sets were divided midseason.

Mosquito activity on insect relief sites was generally lower than on insect sites. Exceptions were human harassment and sweep net catch from the coast and the sticky trap data from the foothills in 1984. The hypothesis was forwarded (Pank et al. 1984) that the differences were related to the active (attractant present) versus passive (attractant absent) nature of the two methods and to soil temperatures. Higher soil temperatures on insect relief sites may create thermals that dissipate attractants vertically. The 1984 sweep net and harassment results continued to support this hypothesis. Before snow-melt all sites have sub-freezing temperatures. After melt-off, the moist and densely vegetated insect sites heat more slowly than the drier, more sparsely vegetated insect relief sites. Clearer weather (increased insolation) in late June 1983 accentuated this temperature difference, making the change in soil temperatures from insect relief to insect sites greater in 1983 than 1984 (Table 3). According to the hypothesis, higher soil temperatures would accentuate vertical dispersal of the attractant, resulting in lower mosquito catches on insect relief sites. Sweep net catch and human harassment trends followed this pattern in 1984 (Table 3). In every cell, the lower sweep net catch occurred at the site, insect or insect relief, which had the warmer average soil temperature. This held true even on the coast, where the soil temperatures unexpectedly averaged cooler on the insect relief than on the insect sites.

Eleven warble flies were caught on sticky traps in 1984. Warbles appeared on the sticky sheets on 4 July at the foothills sites, 7 July at the plains sites and 13 and 14 July at the coast (App. K). Warble appearance dates on the 1983 sticky sheets were similar except form the foothills site, where warbles were not collected until mid August. As in 1983, the majority of warbles was caught after the PCH left the ANWR.

Caribou observations

The number of caribou-insect-habitat interactions observed in 1984 was restricted by the early departure of the PCH from the study area. Emigration of the majority of the herd occurred by 1 June, before the insect population peaked. Twenty-three observations of caribou were recorded between 21 June and 9 July at the three locations (Table 4). Caribou response to insect harassment was noted in 8 of the 23 observations. Mosquitoes were active (sweep net and human harassment observations) in all cases when harassment was observed, and in 5 additional samples when no caribou response was noted. Caribou behavior indicative of Oestrid harassment was not observed until 8 July, and then only once. Caribou were headed into the wind (90 degree departure) in 77% of the samples when mosquitoes were active, and 40% of the samples when mosquitoes were inactive. Sample size was inadequate to contrast harassment with landcover and weather variables.

Sampling protocol

Ground access and caribou distributions limited sample size in 1983 when 9 widely distributed locations were periodically monitored via fixed-wing aircraft out of one basecamp. The absence of caribou at three intensively monitored sites limited sample size in 1984. Use of a helicopter in 1984 resolved the access problems, although location, landcover and weather

Table 3. Mosquito catches, mosquito harassment and weather data collected during each trap visit in the Arctic National Wildlife Refuge, Alaska, in 1984, compared with 1983 data collected during trap visits of similar dates (25 June to 10 July), and expressed as mean, standard deviation and sample size. The complete tables for 1984 can be found in Appendicies B to J.

	COAST			PLAIN			FOOTHILLS		
Date (Julian day)	Insect Relief	Insect	Combined	Insect Relief	Inscect	Combined	Insect Relief	Insect	Combined
Sticky paper traps[a]									
1983	0.0,0.0(6)	0.1,0.2(6)	0.1,0.2(12)	0.0,0.0(3)	0.1,0.2(3)	0.1,0.1(6)	0.1,0.2(3)	0.6,0.0(2)	0.3,0.3(5)
1984	2.1(359.6)	2.2(41.0)	2.1(400.6)	6.2(109.7)	18.4(107.9)	12.3(217.6)	1.7(187.3)	1.2(152.8)	1.4(340.1)
Human harassment									
1983	0.2,0.4(6)	0.2,0.4(6)	0.2,0.4(12)	0.3,0.6(3)	0.3,0.6(3)	0.3,0.5(6)	1.2,0.3(3)	1.5,0.5(3)	1.3,0.4(6)
1984[b]	0,0.3,0.6(214)	0,0.0,0.0(6)	0,0.2,0.6(220)	1,0.8,0.8(99)	1,1.2,0.8(91)	1,1.0,0.8(190)	1,1.0,0.8(149)	1,1.1,0.8(121)	1,1.1,0.8(270)
Sweep net catches									
1984	0.7,4.0(207)	0.0,0.0(7)	0.7,3.9(214)	5.8,12.2(99)	33.3,63.5(90)	18.9,46.6(189)	19.5,52.9(149)	27.0,93.0(122)	22.4,73.3(270)
Soil temperature (°C)									
1983	8.3,5.3(6)	4.4,1.5(6)	6.3,4.3(12)	12.4,3.6(3)	3.5,3.7(3)	8.0,5.8(3)	19.6,7.5(3)	6.4,1.2(3)	13.6,8.3(6)
1984	2.9,2.4(214)	4.6,1.8(7)	2.9,2.4(221)	8.2,4.7(98)	1.4,1.4(90)	5.0,4.9(188)	9.2,3.1(144)	6.5,3.4(119)	8.0,3.5(263)
Relative humidity (%)									
1983			79.3,10.0(6)			75.0,20.2(3)			57.7,21.0(3)
1984	95.4,11.7(44)	91.7,15.3(3)	95.2,11.8(47)	55.1,13.4(85)	55.1,13.9(78)	55.1,13.6(163)	62.5,17.9(149)	64.4,18.1(122)	63.4,18.0(271)
Ambient temperature (°C)									
1983			6.1,2.1(6)			10.5,7.0(3)			13.9,7.6(3)
1984	4.9,2.5(58)	6.4,3.1(7)	5.1,2.6(65)	12.0,3.8(100)	12.6,3.3(91)	12.3,3.6(191)	13.5,4.4(149)	13.5,4.3(122)	13.5,4.4(271)
Maximum air temperature (°C)									
1983 max.	20.1	19.1		28.9	28.1		36.7	32.3	
1984 max.	16.1	13.0		25.5	35.1		34.2	37.6	
Minimum air temperature (°C)									
1983 min.	-1.3	-9.8		-0.5	-0.7		1.1	-4.6	
1984 min.	-11.4	-4.8		-5.5	-3.2		-5.9	-3.6	
Wind speed (kph)									
1983			12.2,4.1(6)			7.0,2.6(3)			4.3,5.1(3)
1984	6.3,4.2(215)	5.3,3.0(7)	6.2,4.2(222)	11.4,6.6(100)	12.0,6.4(91)	11.7,6.4(191)	8.3,6.6(150)	4.4,3.4(122)	6.5,5.7(272)
Cloud cover[c]									
1984	5,3.9,1.7(215)	5,4.0,1.7(7)	5,3.9,1.7(222)	5,4.1,1.2(100)	5,3.8,1.4(91)	5,4.0,1.3(191)	4,4.0,1.2(148)	4,3.8,1.3(121)	4,3.9,1.2(269)

[a] 1983 sticky paper catches expressed as mean catch per day, standard deviation and number of sticky paper sheets. 1984 sticky catches expressed as mean catch per day and number of trap days.
[b] 1984 human harassment data expressed as median, mean, standard deviation and sample size.
[c] Cloud cover expressed as median, mean, standard deviation and sample size.

Table 4. Caribou-insect-habitat interactions observed between 21 June and 9 July at the coast, plains and foothills insect sampling sites in the Arctic National Wildlife Refuge, Alaska, 1984.

Date	Time	Location	Land Cover[1]	Temp. (°C)	Wind Km/H	Wind Dir.	Caribou No.	Caribou Activity	Caribou Heading	Mosquito harassment HH[2]	Mosquito harassment Caribou ObHC[3]	Mosquito harassment Caribou PrHC[4]	Mosquitoes per 100 sweeps
6-22	1440	Foothills	CVIIa	17	6	N	16	trot	N	1	1	2	
	2312	Plains	CVc	5	3	NE	20	walk	NE	0	0	0	0
23	0630	Plains	CVc	7	10	NW	700	mix	NE	0	0	0	0
	0700	Plains	CVc	7	10	NW	300	feed	-	0	0	0	0
24	1135	Foothills	CVIIa	17	11	SE	9	trot	N	0	0	2	0
	1430	Plains	CVa	18	16	NE	1	feed	SW	0	0	2	0
	1445	Coast	BIIIc	4	2	E	3	feed	-	0	0	0	0
25	1005	Plains	CVc	12	3	N	1	walk	N	1	0	1	0
	1005	Plains	CVc	12	3	N	20	walk	SW	1	0	1	0
	1105	Plains	CVa	12	3	N	7	mix	NE	2	1	1	6
	1125	Plains	EIXb	12	3	N	4	mix	NE	2	1	1	6
27	2015	Foothills	EIXa	7	16	N	100	lying	-	1	0	0	
	2100	Foothills	CVa	4	8	N	100	walk	E	1	1	0	
28	1730	Foothills	CVa	11	5	S	2	walk	E	1	0	1	2
	1830	Foothills	CVIIa	11	5	S	36	feed	E	0	0	1	0
29	1505	Foothills	CVIIa	15	3	NW	2	feed	N	1	1	2	10
	1540	Foothills	CVIIa	13	3	NW	3	feed	N	1	0	1	0
7-2	1445	Plains	CVa	13	29	E	1	lying	-	0	0	0	0
	1512	Plains	CVa	14	21	E	1	trot	E	0	0	0	0
	1530	Plains	CVa	10	21	E	1	feed	SE	0	0	0	0
8	1115	Coast	CIVa	9	8	N	4	trot	N	2	3	1	15
	1140	Coast	EXc	9	10	N	4	walk	N	1	1	1	1
	1150	Coast	BIIIa	9	11	N	2	feed	-	1	1	1	1

[1] Walker et al. 1983
[2] Human harassment levels 0-3 (Curatolo and Murphy 1983)
[3] Observed caribou harassment levels 0-3 (Thompson 1973)
[4] Predicted caribou harassment levels 0-2 based on model (White et al. 1975)

sampling was still limited by inadequate distribution of caribou across all variables. A reliable and time efficient estimator of caribou harassment is required to adequately define insect relief habitat across the related variables encountered on the summer range of the PCH within the ANWR.

Four techniques to measure mosquito activity were evaluated during the 1983 and 1984 field seasons. Sticky traps provided an objective interval estimate of mosquito activity in the absence of an attractant. Sweep nets also provided an objective interval estimate but in the presence of a mammalian attractant. The level of harassment of humans provided a subjective ordinal measure of harassment in the presence of a mammalian attractant. The empirical model (White et al. 1975) gave an ordinal estimate of caribou harassment on the basis of wind and temperature. With the exception of sticky traps, the only non-point estimator, all possible contrasts between the indirect technique and the observed harassment of caribou are listed in Table 5. The sweep net technique had the highest level of agreement plus the desirable attributes of objectivity and repeatability. Agreement was slightly lower with the subjective measure of human harassment. Inconsistent classification between and within observers over time, noted during the 1984 field season, was the most likely cause. Agreement between predicted and observed harassment of caribou was sufficient to justify continued development of the model. Predicted harassment, strictly a function of wind and temperature, is oblivious to insect habitat. The differences in human harassment on insect and insect relief sites observed during 1983 and 1984 suggested that agreement can be improved by incorporating habitat information into the model.

Table 5. Percent agreement (n) between techniques to assess and predict the presence or absence of harassment by mosquitoes.

	1983[2]		1984	
Contrasts[1]	Caribou obs.	All obs.	Caribou obs.	All obs.
HH vs. PrHC	67(18)	77(120)	78(23)	76(690)
HH vs. Sw			85(20)	84(836)
Sw vs. PrHC			70(20)	67(688)
HH vs. ObHC	83(18)		78(23)	
Sw vs. ObHC			95(20)	
PrHC vs. ObHC	61(18)		65(23)	

[1] HH = Harassment of humans (0, 1-3)
ObHC = Observed harassment of caribou (0, 1-3), Thompson 1973
Sw = Sweep net catch (0, >0)
PrCH = Predicted harassment of caribou (0, 1-2), White et al. 1975
[2] Pank et al. 1984

Except for ridges, the published descriptions of insect relief habitats were all associated with land cover types. Both 1983 and 1984 harassment levels within land cover classes generally confirmed the association. Digital data bases for land cover and terrain have been completed for the entire U.S. range of the PCH. All that is lacking to create a map of insect relief habitat over the U.S. portion of the PCH summer range is a measure of expected harassment within land cover and terrain classes. The measurement is feasible with sweep net sampling and access to land cover and terrain classes by helicopter. Site characteristics i.e. coast, plains and foothills (Table 2) and annual, seasonal and daily variations in weather (Table 3, Fig 2) interact with land cover and terrain classes to modify insect activity. Main effect and interactions other than land cover and terrain have to be controlled or removed to establish relative measures of harassment across cover and terrain classes. Regression of sweep net results on raw weather data from the 24 hour counts (Fig. 2, App. L) failed to explain catch (r=0.12), but indicated the presence of thresholds and a non-linear response. Analysis of the entire data set gave similar results. Transformation of the raw data will not be attempted until the literature on the response of mosquitoes to weather has been reviewed. In the absence of adequate correlations to adjust catch, sampling designs will have to be relied on to minimize confounding from non-land cover and terrain effects.

Preliminary conclusions from the 1984 data indicate that mosquitoes were the dominant insect modifier of PCH behavior on the ANWR based on trap results and caribou observations. Mosquitoes emerged earlier in the foothills than on the coast. The level of mosquito activity increased from the coast to the foothills. The period of mosquito activity within a day was shorter on the coast than the plains. Of the four measures of insect activity tested, sweep net catch was the best estimator of behavioral response in caribou to mosquitoes. A corridor of low mosquito activity was present along rivers. Diel patterns of weather and insect activity were pronounced. The coast provided the greatest relief from mosquito harassment. The predictive capability of the model can be improved by defining and incorporating insect relief habitat. Mapping insect relief habitat over the entire summer range of the PCH within the ANWR is feasible.

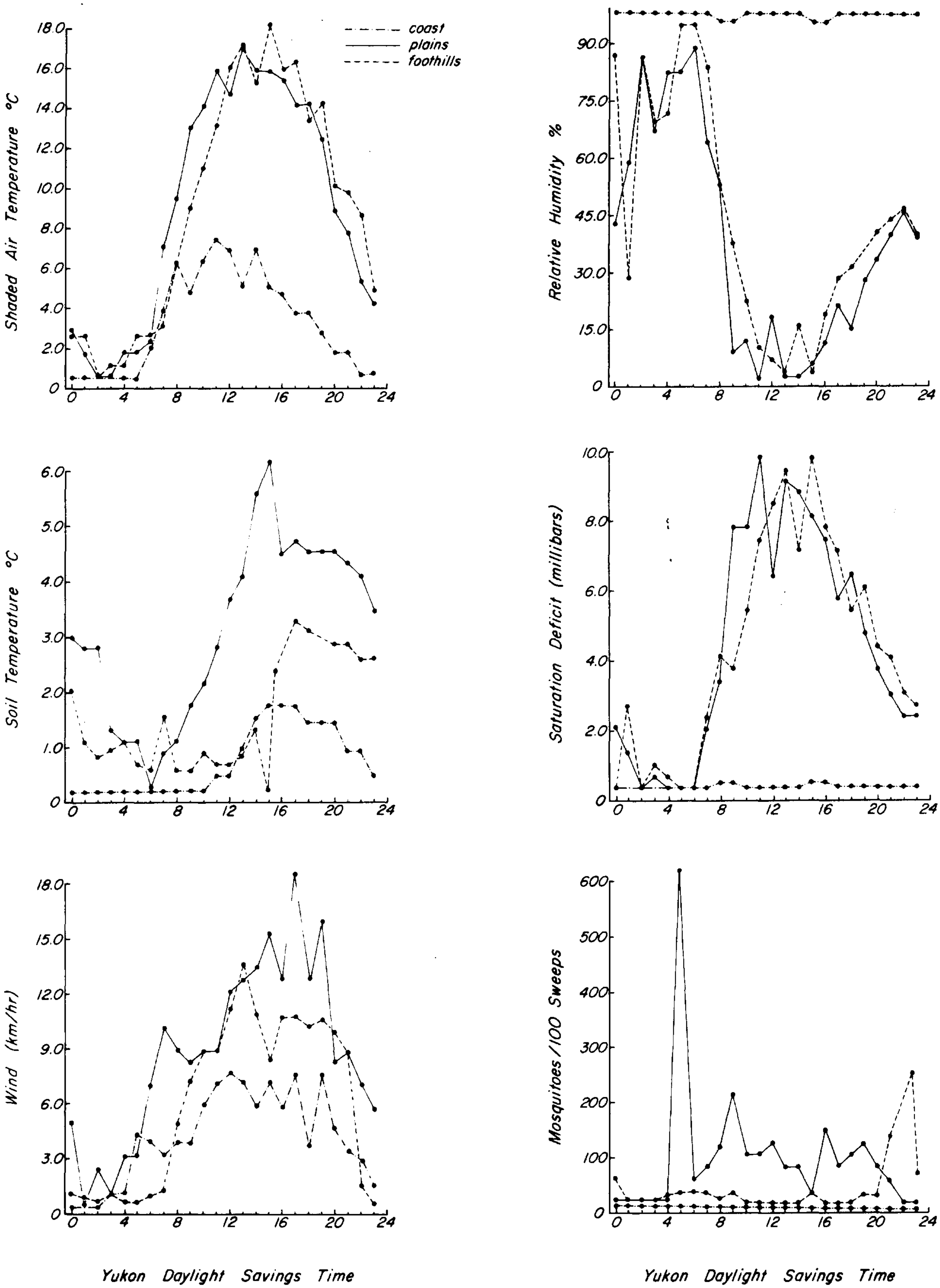

FIGURE 2. DIEL PATTERNS OF WEATHER AND CATCH DATA FROM COAST (N=1), PLAINS (N=3) AND FOOTHILLS (N=3) OF THE ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, 1984.

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APPENDIX

Appendix A. Weather and insect data collection schedule for individual trap sites in the Arctic National Wildlife Refuge, Alaska, 1984.

TRAP NUMBER	JUNE 22	23	24	25	26	27	28	29	30	JULY 1	2	3	4	5	6	7	8	9	10	11	12	13	14
COAST																							
FISH CREEK																							
15	P,*								P,W									W				P,W	
16	P,W								P,W									W	24			P,W	
BARTER ISLAND																							
18		P,*		W	W	W		W	P,W	W	W	W,P,W	W	W	W	W	W	W	W	W	W	P,W	
19		P,*		W	W	W		W	P,W	W	W	P,W											
20		P,W		W	W	P,W		W	P,W	W	W	W,P,W	W	W	W	W	W	W	W	W	W	P,W	
21		P,*		W	W	W		W	P,W	W	W	P,W											
22		P,*		W	W	W		W	P,W	W	W	W,P,W	W	W	W	W	W	W	W	W	W	P,W	
23		P,*		W	W	W		W	P,W	W	W	P,W											
24		P,*		W	W	W		W	P,W	W	W	W,P,W	W	W	W	W	W	W	W	W	W	P,W	
25		P,*		W	W	W		W	P,W	W	W	P,W											
26												P,W	W	W	W	W	W	W	W	W	W	P,W	
27												P,W	W	W	W	W	W	W	W	W	W	P,W	
28												P,W	W	W	W	W	W	W	W	W	W	P,W	
29												P,W	W	W	W	W	W	W	W	W	W	P,W	
BEAUFORT LAGOON																							
30			P,W						P,W														P,W
31			P,W						P,W														P,W
32			P,W							P,W			W,P,W				W						P,W
33			P,W							P,W			P,W										
34			P,W							P,W			W,P,W				W						P,W
35			P,W							P,W			P,W										
36			P,W							P,W			W,P,W				W						P,W
37			P,W							P,W			P,W										
38			P,W							P,W			W,P,W				W						P,W
39			P,W							P,W			P,W										
40													P,W				W						P,W
41													P,W				W						P,W
42													P,W				W						P,W
43													P,W				W						P,W
PLAIN																							
1		P,W	W	W		P,W	W	W	W	W	P,W	W	W	W	W	P,*	W	W	W	P,W			
2		P,W	W	W		P,W	W	W	W	W	P,W	W	W	W	W	P,*	W	W	W	P,W			
3		P,W	W	W			P,W	W	W	W	P,W	W	W	W	W	P,*	W	W	W	P,W			
4		P,W	W	W			P,W	W	W	W	P,W	W	W		W	P,W	W	W	W	P,W			
5		P,W	W	W		P,*		W	W	W	P,W	W	W	W	W	P,W	W	W	W	P,W			
6		P,W	W	W		P,*		W	W	W	P,W	W	W	W	W	P,*	W	W	W	P,W			
7		P,W	W	W			P,*	W	W	W	24 P,W	24W	W	24	W	P,*	W	W	W	P,W			
8		P,W	W	W			P,*	W	W	W	P,W	W	W		W	P,*	W	W	W	P,W			
9		P,W	W	W		P,*			W	W	P,W	W	W	W	W	P,*	W	W	W	P,W			
10		P,W	W	W		P,*			W	W	P,W	W	W	W	W	P,W	W	W	W	P,W			
11		P,W	W	W			P,*		W	W	P,W	W	W	W	W	P,W	W	W	W	P,W			
12		P,W	W	W			P,*		W	W	P,W	W	W		W	P,W	W	W	W	P,W			
FOOTHILLS																							
44		P,W	W	W	W		P,W		W,W	W	W	W	P,W	W	W	W	W	P,W			W	P,*	
45		P,W	W	W	W		P,W		W,W	W	W	W	P,W	W	W	W	W	P,W			W	P,*	
46		P,W	W	W	W		P,W		W,W	W	W 24	W	P,W24	W	W	W	W	P,W		24	W	P,*	
47		P,W	W	W	W	P,*	W	W	W	W	W	W		P,W	W	W	W	P,W			W	P,*	
48		P,W	W	W	W	P,*	W	W	W	W	W	W	P,W	W	W	W	W	P,W			W		P,*
49		P,W	W	W	W	P,*	W	W	W	W	W	W		P,W									
50		P,W	W	W	W	P,*	W	W	W	W	W	W	P,W	W	W	W	W		P,W		W	P,*	
51		P,W	W	W	W	P,*	W	W	W	W	W	W	P,W	W	W	W	W		P,W		W	P,*	
52		P,W	W	W	W	P,*	W	W	W	W	W	W	P,W	W	W	W	W		P,W		W	P,*	
53		P,W	W	W	W	P,*	W	W	W	W	W	W	P,W	W	W	W	W		P,W		W	P,*	
54		P,W	W	W	W	P,*	W	W	W	W	W	W	P,W	W	W	W	W	P,W	P,W		W	P,*	
55		P,W	W	W	W	P,*	W	W	W	W	W	W	P,W	W	W	W	W	P,W			W	P,*	
56		P,W	W	W	W	P,*	W	W	W	W	W	W	P,W	W	W	W	W	P,W			W	P,*	
57		P,W	W	W	W	P,*	W	W	W	W	W	W	P,W	W	W	W	W	P,W			W	P,*	
58		P,W	W	W	W	P,*	W	W	W	W	W	W	P,W	W	W	W	W	P,W			W	P,*	
59						P,*	W	W	W	W	W	W	P,W	W	W	W	W	P,W			W	P,*	
60						P,*	W	W	W	W	W	W	P,W	W	W	W	W		P,W		W	P,*	
61													P,W	W	W,*	W		P,W			W	P,*	
62														P,W	W	W	W	P,W			W	P,*	

P = Change sticky paper
W = Collect weather data
24 = Collect 24 hour data hourly
* = No sweep net collection

Appendix B. Number of mosquitoes caught per trap day on sticky traps in the Arctic National Wildlife Refuge, Alaska, in 1984, expressed as mean and number of trap days.

	COAST		PLAINS		FOOTHILLS		ROW TOTALS	
Date (Julian day)	Insect Relief	Insect	Insect Relief	Insect	Insect Relief	Insect	Insect Relief	Insect
22 June (174)								
23 June (175)								
24 June (176)								
25 June (177)								
26 June (178)								
27 June (179)	0.00,4.3		3.91,23.3		1.12,28.5	1.47,21.1	2.19,56.1	1.47,21.1
28 June (180)			0.00,2.2	14.39,29.6		0.13,15.3	0.00,2.2	9.53,44.9
29 June (181)								
30 June (182)	0.00,64.8	0.07,14.2					0.00,64.8	0.07,14.2
1 July (183)	0.06,51.2						0.06,51.2	
2 July (184)			3.80,30.3	7.77,24.2			3.80,30.3	7.77,24.2
3 July (185)	0.00,24.7						0.00,24.7	
4 July (186)	0.14,28.0				0.14,62.8	0.42,38.5	0.14,90.8	0.42,38.5
5 July (187)						0.13,15.0		0.13,15.0
6 July (188)								
7 July (189)			7.62,30.7	10.95,31.7			7.62,30.7	10.95,31.7
8 July (190)								
9 July (191)					1.54,35.1	1.10,29.9	1.54,35.1	1.10,29.9
10 July (192)					1.22,22.2	0.89,5.6	1.22,22.2	0.89,5.6
11 July (193)			10.34,23.2	45.85,22.4			10.34,23.2	45.85,22.4
12 July (194)								
13 July (195)	1.07,91.9	1.86,12.9			4.94,38.7	3.22,23.0	2.21,130.6	2.73,35.9
14 July (196)	6.83,94.7	4.53,13.9				2.95,4.4	6.83,94.7	4.15,18.3
COLUMN TOTALS	2.09,359.6	2.15,41.0	6.20,109.7	18.42,107.9	1.67,187.3	1.15,152.8	2.66,656.6	7.46,301.7
GRAND TOTALS	2.10,400.6		12.26,217.6		1.44,340.1		4.17,958.3	

Appendix C. Number of mosquitoes per 100 sweeps caught during site visits in the Arctic National Wildlife Refuge, Alaska, in 1984, expressed as mean, standard deviation and sample size.

Date	COAST		PLAINS		FOOTHILLS		ROW TOTALS	
(Julian day)	Insect Relief	Insect	Insect Relief	Insect	Insect Relief	Insect	Insect Relief	Insect
22 JUNE (174)		0.00, (1)	0.00, (1)				0.00, (1)	0.00, (1)
23 JUNE (175)	0.00, (1)		3.8,4.1(7)	39.17,20.33(6)		26.00,0(1)	3.38,4.03(8)	37.29,19.22(7)
24 JUNE (176)	0.00,0.00(9)	0.00, (1)	0.00,0.00(6)	0.00,0.00(6)	0.00,0.00(7)	4.25,7.44(8)	0,0(22)	2.27,5.70(15)
25 JUNE (177)	0.00,0.00(8)		5.12,6.18(8)	130.17,139.32(6)	2.86,3.44(7)	2.38,2.61(8)	2.65,4.49(23)	57.14,108.52(14)
26 JUNE (178)	0.00,0.00(8)		1.00, (1)		0.00,0.00(7)	0.00,0.00(8)	0.06,0.25(16)	0.00,0.00(8)
27 JUNE (179)	0.00,0.00(8)		0.00,0.00(2)				0.00,0.00(10)	
28 JUNE (180)			0.00,0.00(2)	0.00,0.00(2)	0.00,0.00(9)	0.25,0.71(8)	0.00,0.00(11)	0.20,0.63(10)
29 JUNE (181)	0.00,0.00(8)		6.25,11.21(4)	34.25,29.78(4)	1.56,3.28(9)	0.00,0.00(5)	1.86,5.33(21)	15.22,25.66(9)
30 JUNE (182)	0.00,0.00(10)	0.00,0.00(2)	5.67,11.6(6)	1.17,1.94(6)	0.00,0.00(9)	0.00,0.00(11)	1.36,5.84(25)	0.37,1.16(19)
1 JULY (183)	0.00,0.00(16)		0.00,0.00(6)	0.00,0.00(6)	0.67,1.41(9)	3.00,7.71(8)	0.19,0.79(31)	1.71,5.86(14)
2 JULY (184)	0.00,0.00(8)		0.00,0.00(6)	0.00,0.00(7)	21.56,21.28(9)	23.67,49.32(9)	8.43,16.74(23)	13.31,38.00(16)
3 JULY (185)	0.00,0.00(16)		0.00,0.00(6)	0.00,0.00(6)	2.45,2.19(9)	13.75,15.69(8)	0.71,1.60(31)	7.86,13.51(14)
4 JULY (186)	0.25,0.74(24)		0.67,1.21(6)	2.67,6.53(6)	16.20,29.52(10)	7.33,10.56(6)	4.30,15.81(40)	5.00,8.72(12)
5 JULY (187)	0.00,0.00(8)		14.83,7.63(6)	25.50,3.54(2)	36.60,30.24(10)	38.00,36.79(7)	18.96,25.21(24)	35.22,32.36(9)
6 JULY (188)	0.75,1.16(8)		16.67,15.27(6)	73.00,39.15(6)	0.36,1.21(11)	1.71,3.73(7)	4.40,9.95(25)	34.61,44.87(13)
7 JULY (189)	0.00,0.00(8)		0.00,0.00(2)	190.67,117.98(3)	43.82,60.95(11)	24.86,30.66(7)	22.95,48.58(21)	74.60,100.67(10)
8 JULY (190)	8.12,12.24(16)		31.83,30.73(6)	40.67,39.48(6)	19.40,13.96(10)	86.00,56.24(3)	16.09,19.10(32)	78.92,47.90(13)
9 JULY (191)	0.00,0.00(9)	0.00, (1)	5.00,5.66(6)	34.83,52.32(6)	75.14,124.60(7)	69.00,142.92(6)	25.27,75.26(22)	47.92,100.75(1
10 JULY (192)	0.00,0.00(8)		0.83,1.60(6)	0.33,0.82(6)	22.50,22.71(4)	42.00, (1)	5.28,13.48(18)	6.29,15.77(7)
11 JULY (193)	0.00,0.00(8)		4.50,4.85(6)	20.33,18.55(6)			1.93,3.79(14)	20.33,18.55(6)
12 JULY (194)	0.00,0.00(8)				74.91,129.82(11)	186.57,323.77(7)	43.37,103.95(19)	186.57,323.77(7)
13 JULY (195)	0.00,0.00(9)	0.00, (1)					0.00,0.00(9)	0.00, (1)
14 JULY (196)	0.00,0.00(9)	0.00, (1)					0.00,0.00(9)	0.00, (1)
COLUMN TOTALS	0.69,3.96(207)	0.00,0.00(7)	5.80,12.20(99)	33.27,63.49(90)	19.49,52.88(149)	26.95,92.97(122)	7.96,31.93(455)	28.68,80.50(219)
GRAND TOTALS	0.66,3.90(214)		18.88,46.64(189)		2.37,73.34(270)		14.69,53.68(674)	

Appendix D. Mosquito harassment of humans recorded during site visits as level 0 to 3 in the Arctic National Wildlife Refuge, Alaska, in 1984, expressed as median, mean, standard deviation and sample size.

	COAST		PLAINS		FOOTHILLS	
Date (Julian day)	Insect Relief	Insect	Insect Relief	Insect	Insect Relief	Insect
22 June (174)	0,0.0, (1)	0,0.0, (1)	0,0.0, (1)			
23 June (175)	0,0.0,0.0(8)		1,1.0,1.0(7)	2,2.0,0.0(6)		2,2.0, (1)
24 June (176)	1,0.9,0.3(9)	0,0.0, (1)	0,0.0,0.0(6)	0,0.0,0.0(6)	0,0.4,0.8(7)	1,0.8,0.5(8)
25 June (177)	0,0.0,0.0(8)		1,1.1,0.6(8)	2,2.0,0.0(6)	1,0.9,0.4(7)	1,1.0,0.0(8)
26 June (178)	0,0.0,0.0(8)		1,1.0, (1)		0,0.0,0.0(7)	0,0.1,0.4(8)
27 June (179)	0,0.0,0.0(8)		0,0.0,0.0(2)			
28 June (180)			0,0.0,0.0(2)	0,0.0,0.0(2)	0,0.3,0.5(9)	0,0.1,0.4(8)
29 June (181)	0,0.0,0.0(8)		1,1.0,0.8(4)	2,2.0,0.0(4)	0,0.4,0.5(9)	0,0.2,0.4(5)
30 June (182)	0,0.0,0.0(10)	0,0.0,0.0(2)	1,1.0,0.9(6)	1,1.0,0.6(6)	0,0.2,0.4(9)	0,0.4,0.5(11)
1 July (183)	0,0.0,0.0(16)		0,0.0,0.0(6)	0,0.5,0.6(6)	0,0.4,0.5(9)	1,0.8,0.5(8)
2 July (184)	0,0.0,0.0(8)		0,0.0,0.0(6)	1,0.6,0.5(7)	2,1.3,0.9(9)	2,1.8,0.5(8)
3 July (185)	0,0.0,0.0(16)		0,0.0,0.0(6)	0,0.5,0.6(6)	2,1.4,0.7(9)	2,1.8,0.5(8)
4 July (186)	0,0.6,0.9(24)		1,0.8,0.4(6)	1,1.0,0.6(7)	1,1.2,0.6(10)	1,1.0,0.6(6)
5 July (187)	0,0.0,0.0(8)		2,2.0,0.0(6)	2,2.0,0.0(2)	2,1.9,0.3(10)	2,2.0,0.0(7)
6 July (188)	2,2.0,0.0(8)		2,1.7,0.5(6)	2,2.0,0.0(6)	0,0.5,0.7(11)	1,1.0,0.8(7)
7 July (189)	0,0.0,0.0(8)		1,1.0,1.4(2)	3,2.7,0.6(3)	2,1.6,0.7(11)	2,1.6,0.8(7)
8 July (190)	1,1.0,1.0(16)		1,1.3,0.5(6)	2,2.0,0.0(6)	2,2.0,0.0(10)	2,2.0,0.0(7)
9 July (191)	0,0.0,0.0(8)		1,0.8,0.4(6)	2,1.3,0.8(6)	1,1.1,0.9(7)	2,1.7,0.5(6)
10 July (192)	0,0.0,0.0(8)		1,0.7,0.5(6)	1,0.7,0.5(6)	2,1.5,1.0(4)	2,2.0, (1)
11 July (193)	0,0.0,0.0(8)		1,1.0,0.6(6)	2,1.7,0.5(6)		
12 July (194)	0,0.0,0.0(8)				2,1.4,0.8(11)	2,1.7,0.5(7)
13 July (195)	0,0.0,0.0(9)	0,0.0, (1)				
14 July (196)	0,0.0,0.0(9)	0,0.0, (1)				
COLUMN TOTALS	0,0.3,0.6(214)	0,0.0,0.0(6)	1,0.8,0.8(99)	1,1.2,0.8(91)	1,1.0,0.8(149)	1,1.1,0.8(121)
GRAND TOTALS	0,0.2,0.6(220)		1,1.0,0.8(190)		1,1.1,0.8(270)	

Harassment levels 0 = Mosquitoes not present
1 = Mosquitoes present but not biting
2 = Mosquitoes biting
3 = Mosquitoes so numerous they are easily inhaled.

Appendix E. Ambient air temperatures (degrees Celcius) at insect trap sites in the Arctic National Wildlife Refuge, Alaska, in 1984, expressed as mean, standard deviation and sample size.

Date (Julian day)	COAST Insect Relief	COAST Insect	PLAINS Insect Relief	PLAINS Insect	FOOTHILLS Insect Relief	FOOTHILLS Insect
22 June (174)		10.8, (1)	5.5, (1)			
23 June (175)	11.5, (1)		11.9,2.6(7)	13.5,1.0(6)		17.0, (1)
24 June (176)	10.7, (1)		12.6,1.9(6)	15.4,2.4(6)	16.4,1.3(7)	16.9,1.3(8)
25 June (177)	10.0, (1)		11.8,1.7(8)	12.3,1.4(6)	14.1,1.5(7)	13.4,1.1(8)
26 June (178)	2.0, (1)		4.5,2.1(2)		3.1,0.8(7)	5.1,3.5(8)
27 June (179)	1.5, (1)		3.8,0.4(2)			
28 June (180)			11.2,0.4(2)	7.0,0.0(2)	11.2,0.8(9)	13.0,2.4(8)
29 June (181)	1.5, (1)		8.8,2.1(4)	10.1,1.2(4)	14.2,1.2(9)	12.8,2.8(5)
30 June (182)	7.1,3.8(3)	6.8,4.6(2)	9.8,3.3(6)	8.2,1.5(6)	7.8,0.6(8)	9.5,2.8(11)
1 July (183)	2.8,1.1(2)		11.6,1.9(6)	12.6,1.8(6)	14.7,2.4(9)	13.2,1.6(8)
2 July (184)	6.5, (1)		14.1,2.1(6)	13.6,1.9(7)	15.1,5.0(9)	17.1,3.9(9)
3 July (185)	6.0,2.1(2)		13.2,1.8(6)	12.8,1.3(6)	18.9,1.0(9)	17.8,2.7(8)
4 July (186)	4.4,1.4(7)		10.8,1.6(6)	13.4,1.6(7)	16.8,1.9(10)	17.0,1.7(6)
5 July (187)	7.5,1.1(2)		20.0,1.6(6)	19.0,3.5(2)	19.3,1.1(11)	18.6,1.1(7)
6 July (188)	5.0,0.0(2)		17.4,1.5(6)	19.1,0.7(2)	17.6,1.1(11)	18.1,0.9(7)
7 July (189)	5.8,0.4(2)		11.2,3.2(2)	13.2,0.3(3)	9.8,0.4(11)	10.3,2.9(7)
8 July (190)	6.2,2.2(2)		13.2,1.4(6)	14.1,0.9(6)	11.6,2.3(10)	10.8,1.5(7)
9 July (191)	3.0,0.9(3)	3.6, (1)	12.4,1.7(6)	12.6,1.5(6)	11.4,1.3(7)	13.2,2.1(6)
10 July (192)	2.4,0.6(2)		8.6,1.9(6)	7.7,1.6(6)	9.0,0.4(4)	9.0, (1)
11 July (193)	4.4,0.8(2)	7.2, (1)	9.2,1.7(6)	10.0,0.9(6)		
12 July (194)	4.3,1.4(2)				11.8,1.8(11)	11.6,0.8(7)
13 July (195)	4.9,1.4(3)	5.6, (1)				
14 July (196)	3.1,1.2(9)	3.9, (1)				
COLUMN TOTALS	4.9,2.5(58)	6.4,3.1(17)	12.0,3.8(100)	12.6,3.3(91)	13.5,4.4(149)	13.5,4.3(122)
GRAND TOTALS	5.1,2.6(65)		12.3,3.6(191)		13.5,4.4(271)	

Appendix F. Soil temperatures (degrees Celcius) at insect trap sites in the Arctic National Wildlife Refuge, Alaska, in 1984, expressed as mean, standard deviation and sample size.

Date	COAST		PLAINS		FOOTHILLS	
(Julian day)	Insect Relief	Insect	Insect Relief	Insect	Insect Relief	Insect
22 June (174)	5.5, (1)	5.5, (1)	6.0, (1)			
23 June (175)	4.4,1.4(8)		8.0,4.4(7)	0.9,0.7(6)		15.0, (1)
24 June (176)	5.4,1.8(9)	6.5, (1)	7.9,5.3(6)	1.5,2.0(6)	10.0,2.2(7)	2.9,8.5(8)
25 June (177)	2.8,1.3(8)		9.2,4.1(8)	1.6,1.1(6)	8.2,1.7(7)	5.9,3.6(8)
26 June (178)	2.6,1.3(8)		6.0, (1)		6.2,1.5(6)	4.6,2.7(8)
27 June (179)	1.5,1.1(8)		2.8,2.5(2)			
28 June (180)			6.5,6.4(2)	0.2,0.4(2)	6.4,1.5(8)	4.8,2.3(7)
29 June (181)	0.2,0.5(8)		6.6,3.1(4)	2.4,1.7(4)	7.6,1.8(8)	4.6,0.8(5)
30 June (182)	3.4,2.6(10)	4.5,2.8(2)	6.8,3.7(6)	0.8,1.1(6)	6.2,1.5(9)	5.8,3.6(11)
1 July (183)	1.6,0.9(16)		7.8,4.3(6)	1.4,1.3(6)	9.2,3.3(9)	6.1,2.4(8)
2 July (184)	1.6,0.8(8)		9.1,5.8(6)	1.6,1.6(6)	10.3,2.6(9)	6.6,3.6(9)
3 July (185)	2.8,1.3(16)		8.5,5.4(6)	0.8,0.9(6)	9.9,3.2(9)	7.6,4.2(7)
4 July (186)	3.8,2.8(23)		6.7,3.8(6)	1.3,1.2(7)	10.5,3.0(10)	7.0,3.7(6)
5 July (187)	2.2,1.3(8)		12.3,8.3(6)	1.5,0.7(2)	11.7,3.8(11)	7.0,3.7(7)
6 July (188)	1.2,1.2(8)		12.5,6.6(6)	2.2,1.8(6)	11.3,3.7(11)	8.3,3.8(7)
7 July (189)	2.2,1.1(8)		6.8,2.5(2)	1.3,1.9(3)	9.2,2.1(11)	6.8,3.9(7)
8 July (190)	3.6,2.8(16)		9.2,4.4(6)	1.2,1.7(6)	8.8,2.2(9)	7.1,4.4(7)
9 July (191)	2.4,2.5(9)	4.0, (1)	8.6,3.6(6)	1.8,1.5(6)	9.6,3.2(6)	7.5,4.0(6)
10 July (192)	1.5,0.9(8)		7.0,2.4(6)	1.4,1.3(6)	8.4,2.1(4)	5.5, (1)
11 July (193)	7.8,3.4(8)		5.8,2.6(5)	1.2,1.5(6)		
12 July (194)	1.4,1.0(8)				9.2,3.9(10)	6.3,3.2(6)
13 July (195)	3.2,2.2(9)	5.0, (1)				
14 July (196)	2.9,1.3(9)	2.0, (1)				
COLUMN TOTALS	2.9,2.4(214)	4.6,1.8(7)	8.2,4.7(98)	1.4,1.4(90)	9.2,3.1(144)	6.5,3.4(119)
GRAND TOTALS	2.9,2.4(221)		5.0,4.9(188)		8.0,3.5,(268)	

Appendix G. Relative humidity (percent) at insect trap sites in the Arctic National Wildlife Refuge, Alaska, in 1984, expressed as mean, standard deviation and sample size.

Date	COAST		PLAINS		FOOTHILLS	
(Julian day)	Insect Relief	Insect	Insect Relief	Insect	Insect Relief	Insect
22 June (174)						
23 June (175)			59.5,13.1(6)	57.5,8.0(6)		60.0, (1)
24 June (176)			39.7,13.7(6)	24.0,9.5(6)	50.6,1.8(7)	54.0,5.5(8)
25 June (177)			47.1,11.1(7)	44.7,11.7(6)	59.9,3.8(7)	63.8,3.8(8)
26 June (178)			63.0, (1)		94.7,2.2(7)	94.4,3.8(8)
27 June (179)			59.5,0.7(2)			
28 June (180)			36.5,0.7(2)	58.0,0.0(2)	58.4,9.9(9)	54,8,7.5(8)
29 June (181)			57.2,17.6(4)	51.0,10.5(4)	60.9,9.2(9)	61.8,10.4(5)
30 June (182)			54.3,15.8(6)	58.8,11.1(4)	94.9,2.2(8)	83.5,16.3(11)
1 July (183)					54.1,7.0(9)	59.8,7.3(8)
2 July (184)			49.0, (1)	50.0,0.0(2)	42.3,11.8(9)	38.1,9.9(9)
3 July (185)			50.8,11.7(6)	56.7,8.5(6)	39.8,3.3(9)	44.1,11.2(8)
4 July (186)	101.0,0.0(7)		55.0,9.9(6)	66.7,6.1(7)	56.9,11.2(10)	63.0,15.7(6)
5 July (187)	86.0,19.8(2)		47.2,8.1(6)	55.5,19.1(2)	46.7,6.3(11)	51.4,9.3(7)
6 July (188)	100.0,0.0(7)		58.5,7.2(6)	51.7,6.4(6)	48.4,3.0(11)	52.0,2.5(7)
7 July (189)	100.5,0.7(2)		82.0,15.6(2)	72.7,2.9(3)	72.5,10.6(11)	80.6,11.5(7)
8 July (190)	89.1,15.2(10)		69.5,8.4(6)	62.7,6.7(6)	73.7,16.9(10)	80.4,13.0(7)
9 July (191)	100.3,0.6(3)	100.0, (1)	63.0,13.1(6)	62.8,9.6(6)	80.1,5.9(7)	73.3,7.2(6)
10 July (192)	101.0,0.0(2)		55.5,11.0(6)	61.8,13.7(6)	86.5,0.6(4)	86.0, (1)
11 July (193)	101.0,0.0(2)		56.3,5.8(6)	53.0,6.5(6)		
12 July (194)	101.0,0.0(2)				69.4,6.0(11)	71.3,6.1(7)
13 July (195)	100.3,0.6(3)	101.0 (1)				
14 July (196)	91.2,15.9(9)	74.0, (1)				
COLUMN TOTALS	95.4,11.7(44)	91.7,15.3(3)	55.1,13.4(85)	55.1,13.9(78)	62.5,17.9(149)	64.4,18.1(122)
GRAND TOTALS	95.2,11.8(47)		55.1,13.6(163)		63.4,18.0(271)	

Appendix H. Maximum and minimum air temperatures (degrees Celcius) at insect trap sites in the Arctic National Wildlife Refuge, Alaska, in 1984, recorded at each site visit.

	COAST		PLAINS		FOOTHILLS	
Date (Julian day)	Insect Relief	Insect	Insect Relief	Insect	Insect Relief	Insect
22 June (174)						
23 June (175)			12.2/2.4	15.0/1.2		37.6/-0.1
24 June (176)			17.2/-0.6	15.0/0.2	32.1/5.3	27.5/2.5
25 June (177)			15.7/0.4	19.9/-1.3	27.2/3.2	29.1/-3.5
26 June (178)	10.3/-3.2		/0.0		28.0/0.5	20.6/1.1
27 June (179)	10.3/-3.2		14.2/-2.5			
28 June (180)			8.8/-1.5	18.8/-3.2	21.4/-5.9	29.1/-0.8
29 June (181)	10.3/-3.2		21.5/0.4	11.5/-0.3	28.0/1.2	34.2/-2.5
30 June (182)	10.7/-11.4	13.0/-4.8	14.7/2.4	16.9/1.1	30.1/5.0	29.6/0.8
1 July (183)	12.0/-0.7		14.4/-5.5	15.9/-2.2	30.1/2.8	27.0/1.7
2 July (184)	11.5/-0.6		15.7/0.4	35.1/0.7	33.0/5.3	32.3/0.8
3 July (185)	10.0/0.4		23.5/-0.6	20.8/2.8	34.2/3.4	31.2/-2.4
4 July (186)	8.5/-1.6		14.7/1.4	18.8/-2.2	33.2/3.9	28.0/-2.4
5 July (187)	8.5/-1.6		23.5/1.4	22.1/-0.8	34.2/3.3	33.3/-3.5
6 July (188)	10.0/-1.6		25.0/3.9	28.2/2.2	31.6/2.8	30.7/6.9
7 July (189)	9.5/-1.6		25.5/5.8	24.8/6.1	29.1/5.9	28.0/7.2
8 July (190)	11.5/-2.1		16.7/2.4	17.9/-0.8	28.0/4.8	29.1/
9 July (191)	11.5/-2.1		21.1/4.8	19.4/3.6	28.0/4.5	28.0/3.6
10 July (192)	7.5/-2.1		20.0/0.4	18.9/-1.8		34.9/-3.6
11 July (193)	8.0/-2.1		12.2/-0.1	17.8/-0.8		
12 July (194)	8.5/-2.6				27.0/2.3	33.4/-2.6
13 July (195)	16.1/-0.1	10.3/-3.2				
14 July (196)	11.2/-10.9					

Appendix I. Wind speeds (km per hour) and prevailing wind directions (degrees) at insect sites in the Arctic National Wildlife Refuge, Alaska, in 1984, expressed as mean, standard deviation, sample size and modal direction.

Date	COAST		PLAIN		FOOTHILLS	
(Julian Day)	Insect Relief	Insect	Insect Relief	Insect	Insect Relief	Insect
22 JUNE (174)	10.9, (1) [NE]	10.9, (1) [NE]	4.8, (1) [ENE]			
23 JUNE (175)	5.5,2.2(8) [ENE]		7.6,3.6(7) [VAR]	4.8,3.8(6) [VAR]		1.6, (1)
24 JUNE (176)	4.0,1.4(9) [E]	3.5, (1) [E]	16.1,0.0(6) [ENE]	16.1,0(6) [E]	7.6,4.6(7) [NW]	4.7,2.7(8)[VAR]
25 JUNE (177)	3.5,0.0(8) [NE]		6.6,3.3(8) [N]	5.6,3.5(6) [N]	4.9,3.7(7) [NW]	2.7,1.4(8) [N]
26 JUNE (178)	3.5,0.0(8) [NE]		8.8,8.0(2) [VAR]		6.5,6.7(7) [N]	1.8,0.6(8) [N]
27 JUNE (179)	3.5,0.0(8) [NE]		14.5,2.3(2) [E]			
28 JUNE (180)			16.1,0.0(2) [ENE]	12.1,1.1(2) [ENE]	4.7,3.8(9) [VAR]	4.1,1.6(8) [SE]
29 JUNE (181)	3.5,0.0(8) [NE]		5.2,0.8(4) [NW]	8.0,2.3(4) [WNW]	4.2,2.3(9) [NNW]	4.3,1.8(5) [VAR]
30 JUNE (182)	4.0,1.7(10) [WNW]	5.6,3.4(2) [NE]	7.5,1.7(6) [NNW]	7.8,2.2(6) [VAR]	6.6,4.0(9) [NNW]	3.1,1.3(11)[N]
1 JULY (183)	5.5,2.6(16) [ENE]		20.4,4.8(6) [E]	18.8,4.2(6) [E]	8.3,6.4(9) [NW]	3.5,2.4(8) [N]
2 JULY (184)	16.7,4.9(8) [E]		22.0,5.9(6) [E]	22.1,4.9(7) [E]	4.8,4.3(9) [W]	3.8,3.5(9) [NNW]
3 JULY (185)	14.5,3.7(16) [ENE]		25.0,5.2(6) [ENE]	22.2,3.1(6) [ENE]	10.4,5.1(9)[NNW]	5.3,4.2(8) [NNW]
4 JULY (186)	7.6,2.1(24) [NE]		8.8,1.7(6) [ENE]	16.8,3.4(7) [ENE]	10.9,3.9(10) [NNW]	8.2,4.3(6) [VAR]
5 JULY (187)	8.1,1.0(8) [E]		6.7,0.6(6) [E]	10.5,1.1(2) [ENE]	7.8,5.4(11) [NW]	3.8,1.2(7) [N]
6 JULY (188)	2.0,0.7(8) [WSW]		8.8,3.4(6) [ENE]	9.1,2.8(6) [ENE]	19.5,8.8(11) [SW]	11.2,3.6(7)[SE]
7 JULY (189)	9.9,1.2(8) [W]		12.1,1.1(2) [W]	9.1,1.0(3) [W]	5.2,5.0(11) [VAR]	2.1,0.8(7) [VAR]
8 JULY (190)	4.2,2.5(16) [WNW]		8.6,0.9(6) [NW]	7.5,3.0(6) [WNW]	5.9,4.5(10) [VAR]	2.2,1.5(7) [VAR]
9 JULY (191)	3.9,1.3(9) [WNW]	3.2, (1) [NNE]	11.0,1.9(6) [NNW]	11.0,1.6(6) [W]	11.3,8.5(7) [N]	5.8,3.9(6) [N]
10 JULY (192)	4.1,1.3(8) [WNW]		9.7,1.5(6) [WNW]	8.8,0.9(6) [WNW]	13.3,5.6(4) [NW]	5.6, (1) [NW]
11 JULY (193)	5.3,1.0(8) [NNE]		6.7,1.9(6) [WNW]	7.2,1.3(6) [WNW]		
12 JULY (194)	6.3,2.0(8) [W]				9.3,6.9(11) [VAR]	6.1,4.4(7) [N]
13 JULY (195)	6.3,1.5(9) [W]	4.8, (1) [NNW]				
14 JULY (196)	2.7,1.3(9) [SW]	3.4, (1) [SW]				
COLUMN TOTALS	6.3,4.2(215)	5.3,3.0(7)	11.4,6.6(100)	12.0,6.4(91)	8.3,6.6(150)	4.4,3.4(122)
GRAND TOTALS	6.2,4.2(222)		11.7,6.4(191)		6.5,5.7(272)	

Appendix J. Cloud cover coded as levels 0 to 5 at insect trap sites in the Arctic National Wildlife Refuge, Alaska, in 1984, expressed as median, mean, standard deviation and sample size.

Date	COAST		PLAINS		FOOTHILLS	
(Julian day)	Insect Relief	Insect	Insect Relief	Insect	Insect Relief	Insect
22 JUNE (174)	5,5.0, (1)	5,5.0, (1)	5,5.0, (1)			
23 JUNE (175)	2,2.0,0.0(8)		5,5.0,0.0(7)	5,5.0,0.0(6)		4,4.0, (1)
24 JUNE (176)	1,1.0,0.0(9)	1,1.0, (1)	2,2.0,0.0(6)	2,2.0,0.0(6)	3,3.0,1.2(7)	2,2.4,0.7(8)
25 JUNE (177)	5,5.5,0.0(8)		4,3.8,1.4(8)	4,3.7,1.4(6)	4,3.7,1.4(7)	5,4.1,1.4(8)
26 JUNE (178)	5,5.0,0.0(8)		5,5.0,0.0(2)		5,5.0,0.0(7)	5,5.0,0.0(8)
27 JUNE (179)	5,5.0,0.0(8)		5,5.0,0.0(2)			
28 JUNE (180)			5,5.0,0.0(2)	5,5.0,0.0(2)	5,5.0,0.0(9)	5,4.6,0.5(8)
29 JUNE (181)	5,5.0,0.0(8)		5,5.0,0.0(4)	5,5.0,0.0(4)	5,4.8,0.4(9)	5,5.0,0.0(5)
30 JUNE (182)	5,4.8,0.6(10)	4,3.5,2.1(2)	5,5.0,0.0(6)	5,4.8,0.4(6)	5,5.0,0.0(9)	5,4.8,0.4(11)
1 JULY (183)	5,5.0,0.0(16)		2,2.5,0.8(6)	2,2.0,0.0(6)	3,3.0,1.0(9)	2,2.4,1.1(8)
2 JULY (184)	1,1.0,0.0(8)		2,2.0,0.0(6)	2,2.0,0.0(7)	5,4.3,0.9(9)	4,3.5,1.3(8)
3 JULY (185)	1,1.0,0.0(16)		3,3.0,0.9(6)	4,3.3,1.0(6)	2,2.1,0.3(9)	2,2.1,0.4(8)
4 JULY (186)	1,2.3,1.9(24)		5,5.0,0.0(6)	2,2.4,1.1(7)	2,2.1,0.3(10)	2,2.3,0.5(6)
5 JULY (187)	5,5.0,0.0(8)		4,3.7,0.5(6)	2,2.5,0.7(2)	4,3.8,0.6(10)	3,3.6,0.8(7)
6 JULY (188)	5,5.0,0.0(8)		3,3.7,1.0(6)	4,3.3,1.0(6)	4,3.8,0.6(10)	5,4.3,1.0(7)
7 JULY (189)	5,5.0,0.0(8)		5,5.0,0.0(2)	5,5.0,0.0(3)	5,5.0,0.0(11)	5,5.0,0.0(7)
8 JULY (190)	5,5.0,0.0(16)		5,5.0,0.0(6)	5,4.8,0.4(6)	5,4.8,0.4(10)	3,3.3,1.4(7)
9 JULY (191)	5,5.0,0.0(9)	5,5.0, (1)	5,5.0,0.0(6)	5,5.0,0.0(6)	3,3.3,1.0(7)	4,3.8,0.8(6)
10 JULY (192)	5,5.0,0.0(8)		5,5.0,0.0(6)	5,5.0,0.0(6)	3,3.2,0.5(4)	5,5.0,0.0(1)
11 JULY (193)	2,2.0,0.0(8)		5,5.0,0.0(6)	5,5.0,5.0(6)		
12 JULY (194)	5,5.0,0.0(8)				5,4.7,0.5(11)	5,4.7,0.5(7)
13 JULY (195)	5,5.0,0.0(9)	5,5.0, (1)				
14 JULY (196)		5,5.0, (1)				
COLUMN TOTALS	5,3.9,1.7(215)	5,4.0,1.7(7)	5,4.1,1.2(100)	5,3.8,1.4(91)	4,4.0,1.2(148)	4,3.8,1.3(121)
GRAND TOTALS	5,3.9,1.7(222)		5,4.0,1.3(191)		4,3.9,1.2(269)	

Cloud code 1 = No cloud cover
2 = 1 to 25% cover
3 = 26 to 50% cover
4 = 51 to 75% cover
5 = 76 to 100% cover

Appendix K. Number of warble flies caught per trap day on sticky traps in the Arctic National Wildlife Refuge, Alaska, in 1984, expressed as mean and number of trap days.

Date (Julian day)	COAST	PLAINS	FOOTHILLS
22 JUNE (174)			
23 JUNE (175)			
24 JUNE (176)			
25 JUNE (177)			
26 JUNE (178)			
27 JUNE (179)	0.00,4.3	0.00,23.3	0.00,49.6
28 JUNE (180)		0.00,31.8	0.00,15.3
29 JUNE (181)			
30 JUNE (182)	0.00,79.0		
1 JULY (183)	0.00,51.2		
2 JULY (184)		0.00,54.5	
3 JULY (185)	0.00,24.7		
4 JULY (186)	0.00,28.0		0.01,101.3
5 JULY (187)			0.00,15.0
6 JULY (188)			
7 JULY (189)		0.03,62.4	
8 JULY (190)			
9 JULY (191)			0.00,65.0
10 JULY (192)			0.00,27.8
11 JULY (193)		0.00,45.6	
12 JULY (194)			
13 JULY (195)	0.02,104.8		0.00,61.7
14 JULY (196)	0.01,108.6		0.00,4.4
COLUMN TOTALS	0.01,400.6	0.03,217.6	0.00,340.1

Appendix L. Weather and mosquito catch data for seven 24 hour periods in the Arctic National Wildlife Refuge, Alaska, in 1984, expressed as median, where appropriate, mean and standard deviation. One 24 hour period for coast, three each for plains and foothills.

HOUR (YDST)	AMBIENT AIR TEMP (°C)	WIND SPEED (KPH)	RELATIVE HUMIDITY (%)	SOIL TEMP (°C)	CLOUD COVER[1]	HUMAN HARASSMENT[2]	SWEEP NET COUNT
COAST							
0	2.2	0.0	100	0.0	5	0	0
1	1.7	0.0	100	0.0	5	0	0
2 *	1.9	0.0	100	0.0	5	0	0
3	1.9	0.0	100	0.0	5	0	0
4	1.7	1.6	100	0.0	5	0	0
5	1.7	1.6	100	0.0	5	0	0
6	1.7	4.8	100	0.0	5	0	0
7	2.2	4.0	100	0.0	5	0	0
8	3.9	3.2	100	0.0	5	0	0
9	6.7	4.0	100	0.0	3	1	0
10	5.0	4.0	100	0.0	3	1	2
11	6.7	6.4	100	0.0	2	1	1
12	7.5	7.2	100	0.5	2	1	0
13	7.2	8.0	100	0.5	3	1	0
14 *	5.6	7.2	100	1.0	2	1	1
15	6.5	6.8	100	1.8	4	0	0
16	5.3	6.4	100	2.0	5	0	0
17	4.4	8.0	100	2.0	5	0	0
18	4.4	4.0	100	1.5	5	0	0
19	3.3	8.0	100	1.5	5	0	0
20	2.5	4.8	100	1.5	5	0	0
21	2.5	4.0	100	1.0	5	0	0
22	1.7	3.2	100	1.0	5	0	0
23	1.7	1.6	100	0.5	5	0	0
PLAINS							
0	5.5,0.87	8.8,2.45	69.3,1.15	4.2,0.76	3,3.3,1.53	0,0.0,0.00	0.0,0.00
1	4.5,1.41	5.4,5.37	76.5,9.19	4.0,0.71	5,5.0,0.00	0,0.0,0.00	0,0,0.00
2 *	3.5,0.71	6.8,2.83	87.5,6.36	4.0,0.71	5,5.0,0.00	0,0.0,0.00	0,0,0.00
3	3.2,0.29	6.3,4.06	80.3,4.62	2.7,2.02	2,3.0,1.73	0,0.0,0.00	0,0,0.00
4	3.5,0.50	7.4,2.51	88.7,9.81	1.7,2.47	2,3.0,1.73	0,0.3,0.58	1.3,2.31
5	4.5,0.50	7.4,5.38	86.3,12.66	2.5,1.80	2,3.0,1.73	1,1.0,1.00	64.7,112.01
6	5.0,2.12	10.2,1.98	88.0,4.24	1.8,1.77	4,3.5,2.12	1,1.0,1.41	7.0,9.90
7	8.8,4.54	12.6,1.15	79.0,19.67	2.3,1.61	2,3.0,1.73	1,1.0,1.00	10.0,17.32
8	10.7,4.93	11.7,3.45	73.0,18.52	2.5,1.32	2,3.0,1.73	0,0.7,1.15	15.7,27.14
9	13.5,6.26	11.1,6.94	56.7,25.72	3.0,0.87	4,3.7,1.53	0,0.7,1.15	22.7,39.26
10	14.8,5.53	11.6,4.65	57.3,19.86	3.5,0.50	2,2.7,1.15	1,1.0,1.00	9.3,16.17
11	16.2,5.75	11.5,5.83	53.3,20.21	4.0,0.87	2,2.7,1.15	1,1.3,0.58	10.0,17.32
12	15.0,2.65	13.9,5.66	60.3,11.72	4.7,1.26	2,2.7,1.15	1,1.0,1.00	12.7,21.94
13	16.8,4.01	14.4,8.05	53.0,10.44	5.0,1.32	2,2.7,1.15	1,1.0,1.00	8.0,13.86
14 *	16.2,3.55	14.6,8.99	53.7,9.87	6.2,2.47	2,2.7,1.15	0,0.7,1.15	8.7,15.01
15	16.0,3.60	16.4,4.82	54.7,4.73	6.7,2.93	2,2.3,0.58	0,0.7,1.15	4.0,6.93
16	15.7,3.79	14.3,5.46	57.0,2.65	5.3,4.31	2,2.3,0.58	0,0.7,1.15	15.7,27.14
17	14.5,1.73	18.2,6.47	61.7,7.02	5.5,4.77	2,2.3,0.58	0,0.7,1.15	7.3,12.70
18	14.5,3.50	14.3,2.59	58.3,3.79	5.3,3.75	2,2.0,0.00	1,1.0,1.00	10.7,18.48
19	13.0,2.18	16.6,6.47	63.7,10.07	5.3,3.40	2,2.0,0.00	0,0.7,1.15	11.7,20.21
20	10.2,0.76	11.3,5.04	66.0,10.15	5.3,0.58	2,3.0,1.73	1,1.0,1.00	7.0,10.44
21	9.3,0.58	11.7,3.82	69.0,7.81	5.2,0.76	2,2.3,0.58	1,1.0,1.00	5.7,5.51
22	7.2,0.76	10.1,3.52	71.3,12.42	5.0,0.50	3,3.3,1.53	0,0.0,0.00	0,0.0,0.00
23	6.3,0.76	9.1,2.65	68.3,8.50	4.5,0.50	3,3.3,1.53	0,0.0,0.00	0,0.0,0.00
FOOTHILLS							
0	5.2,0.76	2.2,2.31	94.7,4.62	2.2,2.89	2,2.7,2.08	2,2.0,0.00	47.0,17.69
1	5.2,2.90	1.6,1.60	65.8,37.33	1.4,2.75	2,2.5,1.73	1,1.0,0.82	9.8,6.90
2 *	3.2,2.22	1.0,0.40	93.8,8.10	1.1,2.93	2,2.5,1.73	0,0.5,0.58	5.2,6.65
3	4.2,0.76	2.1,2.31	84.7,10.60	1.2,3.33	2,2.7,2.08	1,0.7,0.58	7.3,8.08
4	4.3,0.76	1.1,0.46	86.7,11.93	1.0,3.46	4,3.3,2.08	1,1.0,0.00	12.7,12.05
5	5.0,1.32	1.1,0.46	95.0,8.66	1.0,3.46	4,3.3,2.08	2,1.3,1.15	65.3,56.65
6	5.2,0.58	2.1,2.31	95.0,8.66	0.8,3.18	3,3.0,2.00	1,1.3,0.58	18.3,16.07
7	6.0,1.41	2.4,2.26	93.0,9.90	1.8,3.89	3,3.0,2.00	2,1.5,0.71	17.0,24.04
8	11.7,4.48	5.6,4.05	69.7,23.24	0.8,3.18	1,2.3,2.31	1,1.3,0.58	9.5,13.44
9	11.0,3.60	7.9,1.28	70.3,19.50	0.8,3.18	2,2.7,2.08	1,1.3,0.58	15.0,13.08
10	12.8,4.25	9.7,1.65	63.0,16.82	1.2,2.93	2,2.3,1.53	1,0.7,0.58	1.3,1.53
11	14.8,3.55	9.7,2.80	55.7,23.59	1.0,3.04	3,2.3,1.15	1,1.0,0.00	6.0,5.00
12	16.7,4.01	12.0,1.50	54.3,20.55	1.0,3.04	2,1.7,0.58	1,1.0,0.00	3.3,2.52
13	18.0,3.97	13.9,3.62	52.7,17.16	1.2,2.89	2,1.7,0.58	1,0.7,0.58	1.7,2.89
14 *	16.0,3.77	11.4,3.62	60.0,19.16	1.5,2.60	2,1.7,0.58	0,0.3,0.58	1.7,2.89
15	18.8,3.18	8.4,2.90	52.5,16.26	0.5,0.00	2,2.5,0.71	2,1.5,0.71	27.0,29.70
16	17.3,5.03	11.4,1.56	61.0,17.35	2.3,1.89	3,3.0,0.00	1,1.3,0.58	3.3,3.06
17	17.8,3.88	11.3,1.60	65.0,25.24	3.2,2.25	2,2.0,0.00	1,1.3,0.58	6.0,4.58
18	14.8,4.37	10.4,1.51	67.3,13.58	3.3,2.25	2,2.0,0.00	1,1.3,0.58	6.7,8.33
19	15.0,4.77	10.7,3.29	65.0,20.22	3.2,2.25	2,2.0,0.00	2,1.7,0.58	11.7,12.01
20	13.7,4.54	10.2,1.28	71.7,15.04	2.8,2.36	2,2.3,0.58	1,1.3,0.58	18.0,31.18
21	13.0,4.33	8.5,5.35	72.3,14.01	2.8,2.75	2,2.3,0.58	2,1.7,0.58	100.0,142.37
22	11.3,2.89	3.2,4.16	74.0,10.82	2.7,2.47	2,2.7,1.15	2,2.0,0.00	251.3,366.53
23	7.7,1.61	1.1,0.46	71.3,15.95	2.7,2.47	2,2.7,2.08	2,2.0,0.00	47.7,44.86

[1] Cloud codes are: 1 = 0% Cover
2 = 1-25% Cover
3 = 26-50% Cover
4 = 51-75% Cover
5 = 76-100% Cover

[2] Harassment levels are: 0 = Mosquitoes not present
1 = Mosquitoes present but not biting
2 = Mosquitoes biting
3 = Mosquitoes so numerous they are easily inhaled

* = Solar midnight or solar noon

OCCURRENCE OF CENTRAL ARCTIC HERD CARIBOU IN THE ARCTIC NATIONAL WILDLIFE REFUGE DURING THE SPRING AND SUMMER

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February 1985

Occurrence of Central Arctic herd caribou in the Arctic National Wildlife Refuge during spring and summer.

With the congressional mandate for a comprehensive inventory and assessment of wildlife resources within the coastal plain of the Arctic National Wildlife Refuge (ANWR), much attention has been focused on the Porcupine Caribou Herd (PH) because of its large size and international status. The majority of the calving grounds and summer range of the PH is on the eastern arctic coastal plain in Alaska and the Yukon Territory. Concerns have been expressed that future petroleum exploration and development in ANWR might have deterimental effects on this herd and/or its habitat. Hence, the need for comprehensive baseline information, both for planning and mitigation purposes, and is a basis for the future assessment of impacts.

It is becoming increasingly apparent that the summer range of the Central Arctic Herd (CAH) (Cameron and Whitten 1979) also includes a portion of the ANWR coastal plain. As early as 1972, Roseneau and Stern (1974) noted heavy trails transecting the Staines and Canning Rivers during the last half of July, and in early July 1973, Roseneau et al. (1974) observed a major eastward crossing of these rivers followed by a westward recrossing later in the month. Numerous other unpublished observations made during various censuses, surveys, and radio-tracking flights over the past decade also indicate that CAH caribou frequently occupy the Staines/Canning River area during June and July.

A principal objective of this study was to determine the timing and extent of range use within ANWR by CAH through long-term monitoring of radio-collared individuals. Data from previous years have not yet been fully analyzed, hover, and we offer the following summary of observations made in June and July 1984 as a brief illustration of the temporal patterns of CAH distribution relative to the westernmost portion of the Refuge.

Methods

During June, July, and early August 1984, 48 CAH caribou, radio-collared on winter range (see Whitten and Cameron 1983) between 1981 and 1984, were relocated periodically using conventional tracking techniques. Of these, 30 (19 adult females, 6 2-year olds, and 5 yearlings) were found east of the Sagavanirktok River on 1-9 June, and an additional 4 were located in the same area on 3 July. On 12 July and 31 July-1 August, 33 of 34 radio-collared caribou believed to be east of the Sagavanirktok River were relocated.

The coastal study area east of Prudhoe Bay was apportioned into three regions of approximately equal size: Region 1, Sagavanirktok River-Shaviovik River; Region 2, Shaviovik River-Staines/Canning River; Region 3, Staines/Canning River-Kakakturuk River. The common boundary of Regions 2 and 3 separates state land from ANWR. Numbers of radio-collared caribou observed within each of these three regions were tallied for each of the four relocation periods.

Results and Discussion

Changes in the distribution of radio-collared CAH caribou among the three coastal regions indicate relatively heavy use of the eastern two-thirds of the study area from late spring through midsummer, with considerable movement across the Staines/Canning River (Table 1). During the calving period in early June, 23 of 30 collared individuals were found in Regions 2 and 3, including 15 of the 19 adults females. All 15 of these females were within 20km of the coast between approximately Bullen Point and the Staines/Canning Delta, corresponding to the eastern CAH calving concentration described previously by Whitten and Cameron (1985). By 3 July, little net change in the distribution of radio-collared caribou was evident, but relocations of 12 July indicate that a eastward movement had occurred. More than half of 33 caribou were found within ANWR; one yearling had moved westward out of area. By the end of July, however, five radio-collared caribou had recrossed the Staines/Canning River and a second yearling had moved across the Sagavanirktok River out of Region 1, implying a generally westward drift. Collectively, the distributional changes noted in July 1984 are consistent with the earlier, somewhat fragmentary observations of CAH movements in the Staines/Canning area (Roseneau and Stern 1974, Roseneau et al. 1974, Cameron and Whitten 1976).

Table 1. Changes in the distribution of radio-collared caribou among three regions of the central arctic coastal plain, Central Arctic herd, late spring-mid-summer 1984.

Date	Region[a] 1	2	3	West[b]	Total relocated
1-9 June	7	18	5	0	30
3 Jul	8	23	3	0	34
12 Jul	3	12	17	1	33
31 Jul-1 Aug	2	17	12	2	33

[a]Region 1 = Sagavanirktok River-Shaviovik River
Region 2 = Shaviovik River-Staines/Canning River
Region 3 = Staines/Canning River-Katakturuk River
[b]Those located west of the Sagavanirktok River.

These and other observations over the past decade suggest that such mid-summer movements occur annually. During routine radio-tracking flights in mid- and/or late July, it is not uncommon to observe aggregations of 2,000 caribou in the Staines/Canning Delta. On 19 July 1983, for example, a mixed group of ca. 3,000, including 12 radio-collared individuals, was sighted just east of the ANWR boundary (unpubl. data, ADF&G and ABR files); subsequent radio-relocations indicated that the majority of the caribou later moved westward across the Canning River and dispersed inland.

Access to the coastal plain portion of ANWR is apparently of some importance to the CAH, both as a calving area and as summer range, particularly during the insect season. Assuming that the 1984 distribution of radio-collared individuals was representative of caribou in the study area, and given that approximately half of the CAH was east of the Sagavanirktok River (based on observations made during the 1983 census: Smith, unpublished data), the limited results presented here demonstrate considerable use of the area in question. During calving (1-9 June), 3 of the 19 adult females relocated (16%) were within ANWR. In July 9%-52% of the radio-collared caribou were found in ANWR. The above calculations, although subject to considerable error, indicate that up to 25% of the entire CAH may occupy the extreme western portion of ANWR for a brief period each summer. If the CAH continues to grow, with an accompanying lateral expansion of summer range, this region may increase in relative importance, both spatially and temporally.

Acknowledgments

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Fairbanks Fishery Resources Progress Report Number FY85-1

FISHERIES INVESTIGATIONS ON THE ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, 1984

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Fisheries investigations on the Arctic National Wildlife Refuge, Alaska, 1984

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Abstract:
Fisheries studies in the Arctic National Wildlife Refuge in 1984 included 1) an investigation of seasonal abundance, age and growth, and food habits of coastal fishes in Beaufort Lagoon; 2) an investigation of Arctic char distribution in the Hulahula River; 3) a study of fall movements of Arctic char in the Aichilik River; 4) an examination of Arctic grayling movements and overwintering sites in three different river systems. The fisheries investigations conducted in June, July, and August 1984 in Beaufort Lagoon resulted in the capture of 1,401 fish of 10 species. Anadromous char and Arctic cisco were more prevalent at the sample sites during June and July, while marine species such as fourhorn sculpin and saffron cod were found to be more abundant in August. Stomach analysis indicate Arctic char fed primarily on amphipods and fish, Arctic cisco fed primarily on mysids and amphipods, and fourhorn sculpin fed primarily on isopods and amphipods. Adult char were found to be nearly stationary in a confined overwintering area from August 1983 through April 1984 on the Hulahula River but migrated to the lagoon system by early June. No adults were found in the river during July sampling. Five char from the Aichilik river were tagged with radio transmitters in early August 1984 near the river mouth and subsequent aerial tracking led to the identification of a spawning and overwintering site approximately 65 km upriver. Arctic grayling were surgically implanted with radio transmitters in August 1984 and aerially tracked periodically throughout the fall. Some fish from Itkilyariak Creek were found to migrate up the Sadlerochit River to, or nearly to, Lake Schrader; grayling from the Tamayariak River were found to move into the lower Canning River; and grayling tagged near the mouth of Akutoktak Creek moved out of the Okpilak River system and into known char overwintering sites on the Hulahula River.

Beaufort Lagoon is located approximately 60 km southeast of Barter Island (Figure 1). The lagoon borders the Arctic coastal plain and is separated from the Beaufort Sea by a long, narrow barrier island. Major rivers flowing into the lagoon are the Aichilik and Egaksrak Rivers. Traditional land-use names for Beaufort Lagoon are Nuvagapak Lagoon and Egaksrak Lagoon on the east side of the Aichilik River delta.

Beaufort Lagoon is described as a limited exchange lagoon (LGL 1983) where the flow of nearshore waters is restricted by a barrier island(s). The entrances to Beaufort Lagoon are near Angun Point and the Aichilik River delta. The nearshore waters are influenced by a northwesterly longshore current and wind patterns (Truett 1981).

Most of Beaufort Lagoon is probably covered with fast ice during the winter months. The open water season usually runs from late June until September or October. In June, snow melt from the rivers enter the lagoon system and accelerates breakup in the lagoon. In late June 1984, open water was restricted to a narrow band along the shoreline where tundra streams entered the lagoon and to the shallow waters off the Aichilik River delta. Waters inside the lagoon are warmer and less saline than offshore waters. Lagoon waters become more saline as summer progresses. Oldsquaw ducks, fish, and epibenthic invertebrates are the major summer inhabitants of Beaufort Lagoon (Spindler 1984).

Access to the Beaufort Lagoon DEW Line Station was provided by charter Cessna 207 aircraft from Kaktovik. A Zodiac Mark III inflatable boat with 15 hp outboard engine and a 15 ft. aluminum sport boat with a 15 hp outboard were used to get to sample locations.

There were three sampling periods: June 20-29, July 23-31, and August 21-28, 1984. Fish sampling was conducted at five stations (Figure 2) and included four habitat types: nearshore mainland, mid-lagoon, inside barrier island and outside barrier island. Three fish sampling methods were used, 1) dual trap, directional fyke nets with 200 ft. lead extended perpendicular from shore (Station 2 and 4), 2) 125 X 6 ft. monofilament experimental gill nets with five panels of 0.5, 1.0, 1.5, 2.0 and 2.5 inch bar mesh (Station 1, 3, and 5), and 3) a dip net.

Fork lengths of fish were measured to the nearest millimeter. Weights of fish were determined by using Pesola spring scales with ranges of 0 to 250 gm, 0 to 500 gm, and 0 to 2500 gm. A coefficient of condition (K) was determined using the following equation:

$$K = \frac{\text{weight} \times 10^5}{\text{length}^3}$$

Ages were determined from otoliths and scales. Otoliths were cleaned in a solution of Kodak Photoflow and if required, ground on 320 grit wet sandpaper and read under a microscope at 40X.

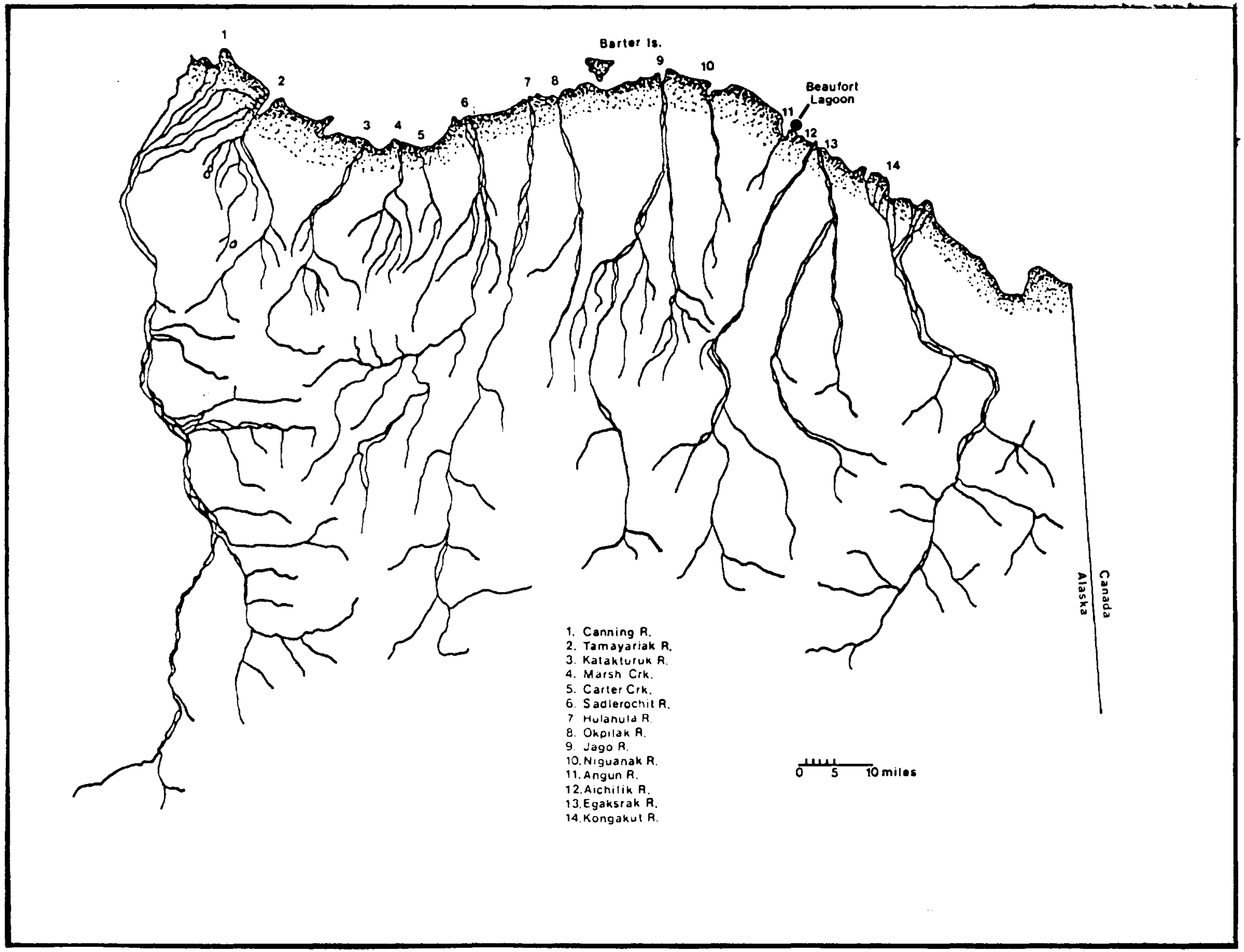

Figure 1. North Slope rivers on the Arctic National Wildlife Refuge, Alaska.

Numbered Floy FD-67 anchor tags were implanted in 108 Arctic char and 70 Arctic cisco to aid in fish movement studies.

Histopathological samples were collected by sacrificing 30 samples each of Arctic char, Arctic cisco, fourhorn sculpin and Arctic flounder. Gill, heart, liver, muscle, gut, spleen, gall bladder, stomach, pyloric caeca, and kidney tissues were excised and preserved together in Bouin's solution. The samples were sent to the National Fisheries Research Center, Seattle, Washington for analysis. Samples were also sent to Analytical Bio-chemistry Laboratories, Columbia, Missouri for heavy metal and hydrocarbon contaminant analysis. The results will not be available until late 1985.

Water chemistry information was collected at ten stations (Figure 2). Temperature, salinity and conductivity were measured with a YSI model 33 salinity meter, turbidity with a Hach Portalab Turbidimeter, and pH with a Hach Mini pH meter.

Fish Movement and Catch Results

Ten species of fish were caught in Beaufort Lagoon, five species were anadromous and five marine (Table 1). The anadromous species were Arctic char, Arctic cisco, least cisco, ninespine stickleback, and boreal smelt. The five marine species were fourhorn sculpin, saffron cod, Arctic cod, Arctic flounder, and a specie of eelpout. A summary of catch at each station by sample period is given in Table 2. Figures 3 through 6 depict individual catch-per-unit-effort (CPUE) values for char, Arctic cisco, sculpin, and flounder respectively.

Arctic Char (Table 2, Figure 3)

Arctic char were the most numerous fish caught (37% of all stations) during all sample periods combined in 1984. The char were most abundant at the inside barrier island station (Station 4) during the July sampling period. This station employed a directional fyke net. Most char were caught in the east side trap during this period indicating a westerly movement. Gill net CPUE values were lowest for the mid-lagoon station (Station 3).

Arctic Cisco (Table 2, Figure 4)

Arctic cisco were the second most numerous anadromous fish caught in Beaufort Lagoon. They were more abundant in the lagoon during July. Their catch rate was highest at the mid-lagoon and inside barrier island stations (Station 3 and 4, respectively).

Fourhorn Sculpin (Table 2, Figure 5)

Fourhorn sculpin were the most frequently caught marine species and ranked second for all species in total numbers caught. They were most abundant in August at the nearshore mainland fyke net station (Station 2).

Arctic Flounder (Table 2, Figure 6)

Arctic flounder accounted for only 3% of the total fish captured in Beaufort Lagoon. They were most numerous in August at the inside barrier island station (Station 4).

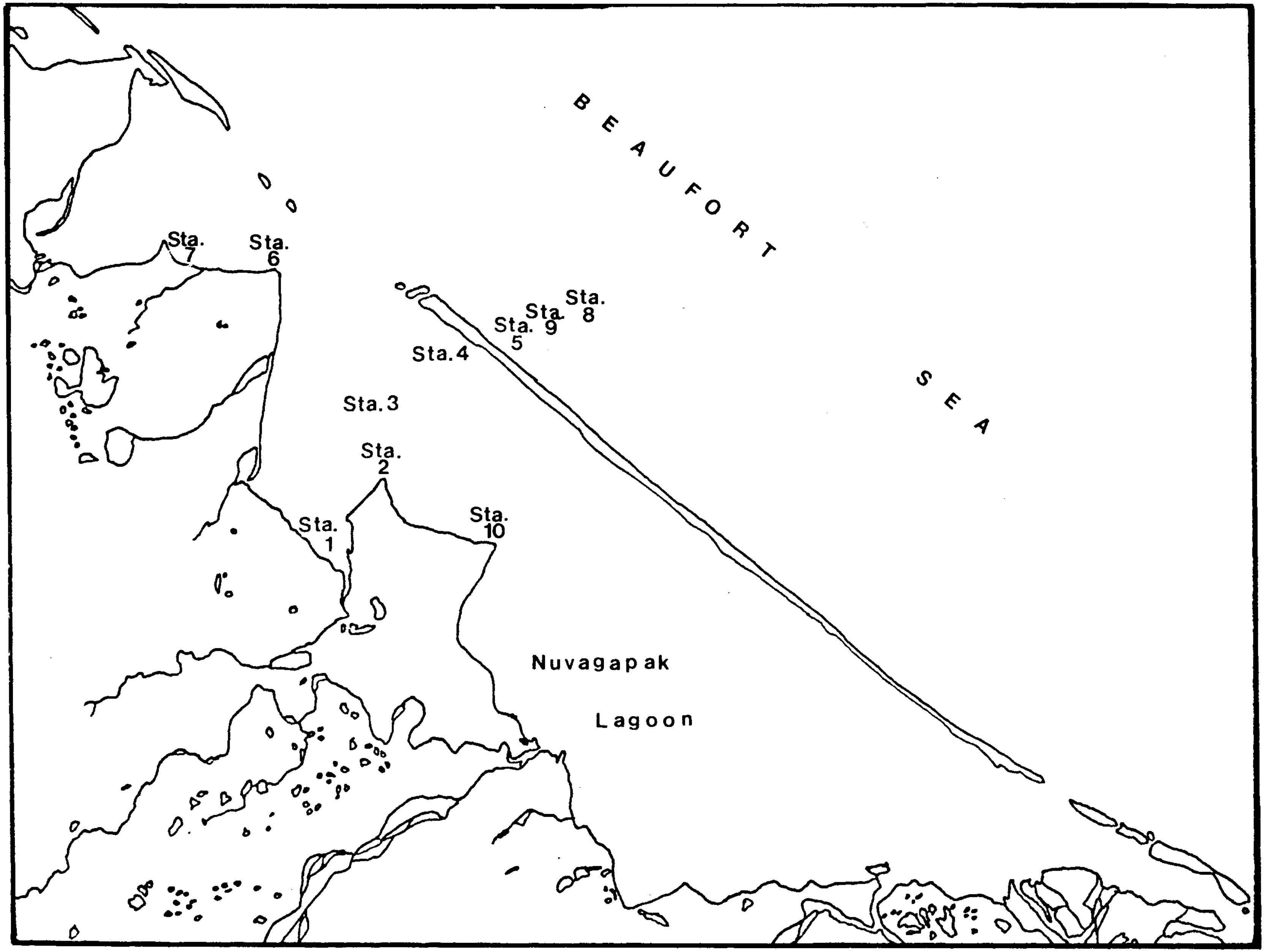

Figure 2. Beaufort Lagoon 1984 sampling stations. Stations 1-5 were fish and water chemistry stations; stations 6-10 were water chemistry stations only.

Table 1. Summary of fish species and numbers caught, Beaufort Lagoon, Alaska, June - August 1984.

Species	Number of Fish Caught Station 1 Gill Net	Station 2 Fyke Net	Station 3 Gill Net	Station 4 Fyke Net	Station 5 Gill Net	Dip Net	Total Caught
1- Arctic char (*Salvelinus alpinus*)	97	48	1	370	1	0	517
2- Arctic cisco (*Coregonus autumnalis*)	68	13	31	74	1	0	187
3- fourhorn sculpin (*Myoxocephalus quadricornis*)	21	187	7	91	0	0	306
4- Arctic flounder (*Liopsetta glacialis*)	3	24	0	14	0	5	46
5- Arctic cod (*Boreogadus saida*)	0	0	0	1	0	0	1
6- saffron cod (*Eleginus gracilis*)	0	103	0	8	0	0	111
7- eelpout (*Lycodes* sp.)	0	0	3	0	0	0	3
8- ninespine stickleback (*Pungitius pungitius*)	0	0	3	0	0	0	3
9- least cisco (*Coregonus sardinella*)	11	120	12	58	0	0	201
10- boreal smelt (*Osmerus eperlanus*)	1	19	0	6	0	0	26
	201	514	57	622	2	5	1401

Table 2. Summary of catch-per-unit effort (CPUE)* by sample station and period for Arctic char, Arctic cisco, fourhorn sculpin, and Arctic flounder, Beaufort Lagoon, Alaska, 1984.

	Station 1	Station 2	Station 3	Station 4	Station 5
Gear Type	E125' gill net	fyke net	E125' gill net	fyke net	E125' gill net
Period Fished (June)	6/22-6/28 136 hours				
No. of Arctic Char Caught	51	-	-	-	-
CPUE	.38	-	-	-	-
No. of Arctic Cisco Caught	11	-	-	-	-
CPUE	.08	-	-	-	-
No. of Fourhorn Sculpin Caught	1	-	-	-	-
CPUE	.01	-	-	-	-
No. of Arctic Flounder Caught	0	-	-	-	-
CPUE	0	-	-	-	-
Period Fished (July)	7/24-7/30 145.5 hours	7/24-7/30 141 hours	7/25-7/27 44.5 hours	7/25-7/27 114 hours	- -
No. of Arctic Char Caught	42	17	0	364	-
CPUE	.29	.12	0	3.19	-
No. of Arctic Cisco Caught	46	9	31	72	-
CPUE	.32	.06	.70	.63	-
No. of Fourhorn Sculpin Caught	12	20	0	32	-
CPUE	.08	.14	0	.28	-
No. of Arctic Flounder Caught	3	2	0	6	-
CPUE	.02	.01	0	.05	-
Period Fished (August)	8/20-8/26 144.5 hours	8/21-8/26 126 hours	8/20-8/24 89.5 hours	8/21-8/26 123 hours	8/24-8/26 48 hours
No. of Arctic Char Caught	4	31	1	6	1
CPUE	.03	.25	.01	.05	.02
No. of Arctic Cisco Caught	11	4	0	2	1
CPUE	.08	.03	0	.02	.02
No. of Fourhorn Sculpin Caught	8	167	7	59	0
CPUE	.06	1.33	.08	.48	0
No. of Arctic Flounder Caught	0	22	0	8	0
CPUE	0	.17	0	.35	0

*CPUE= average number of a single species captured in 1 hour of sampling with a specific gear type.

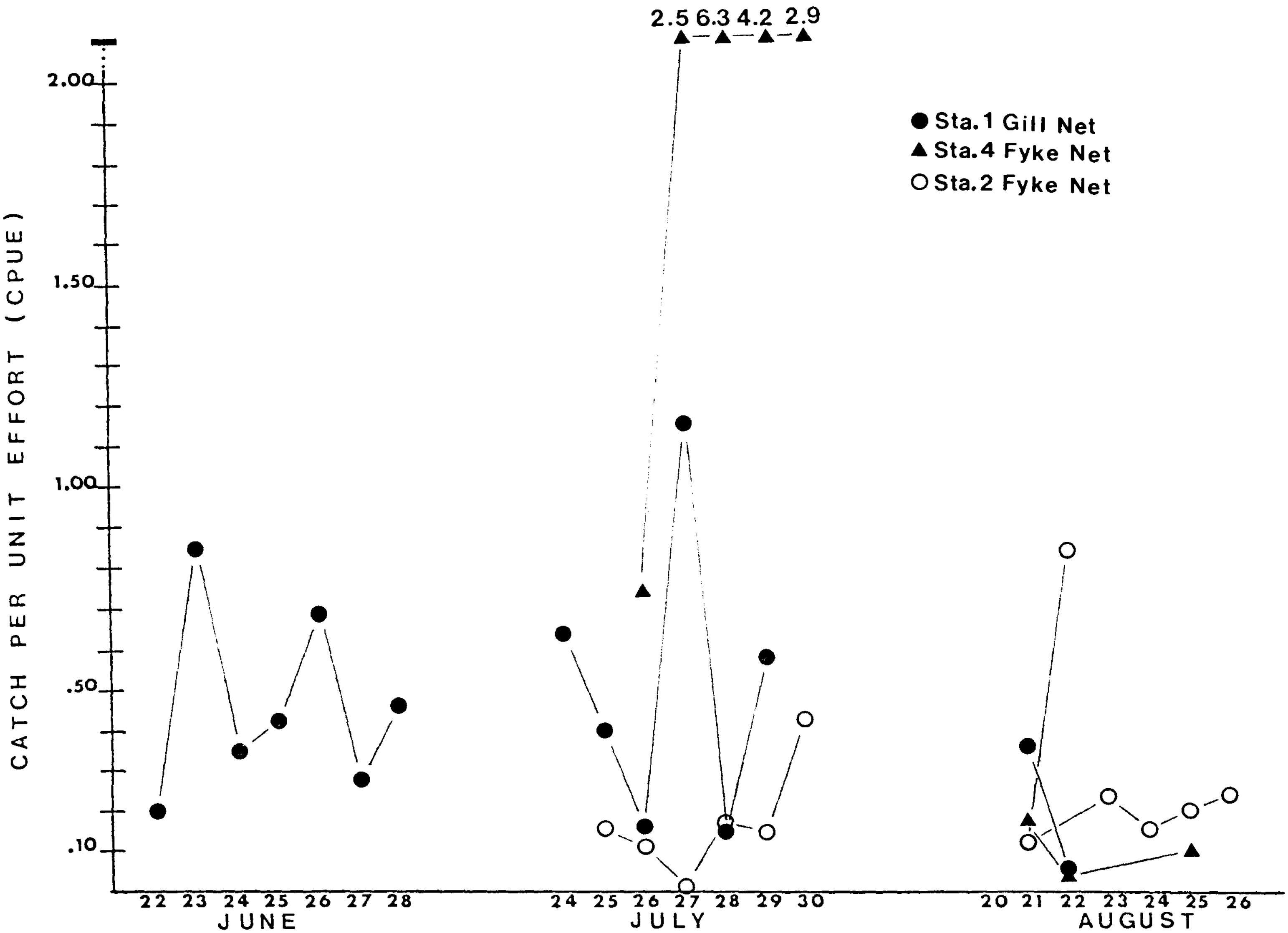

Figure 3. Daily catch rates of Arctic char at 3 sampling stations, Beaufort Lagoon, Alaska, 1984.

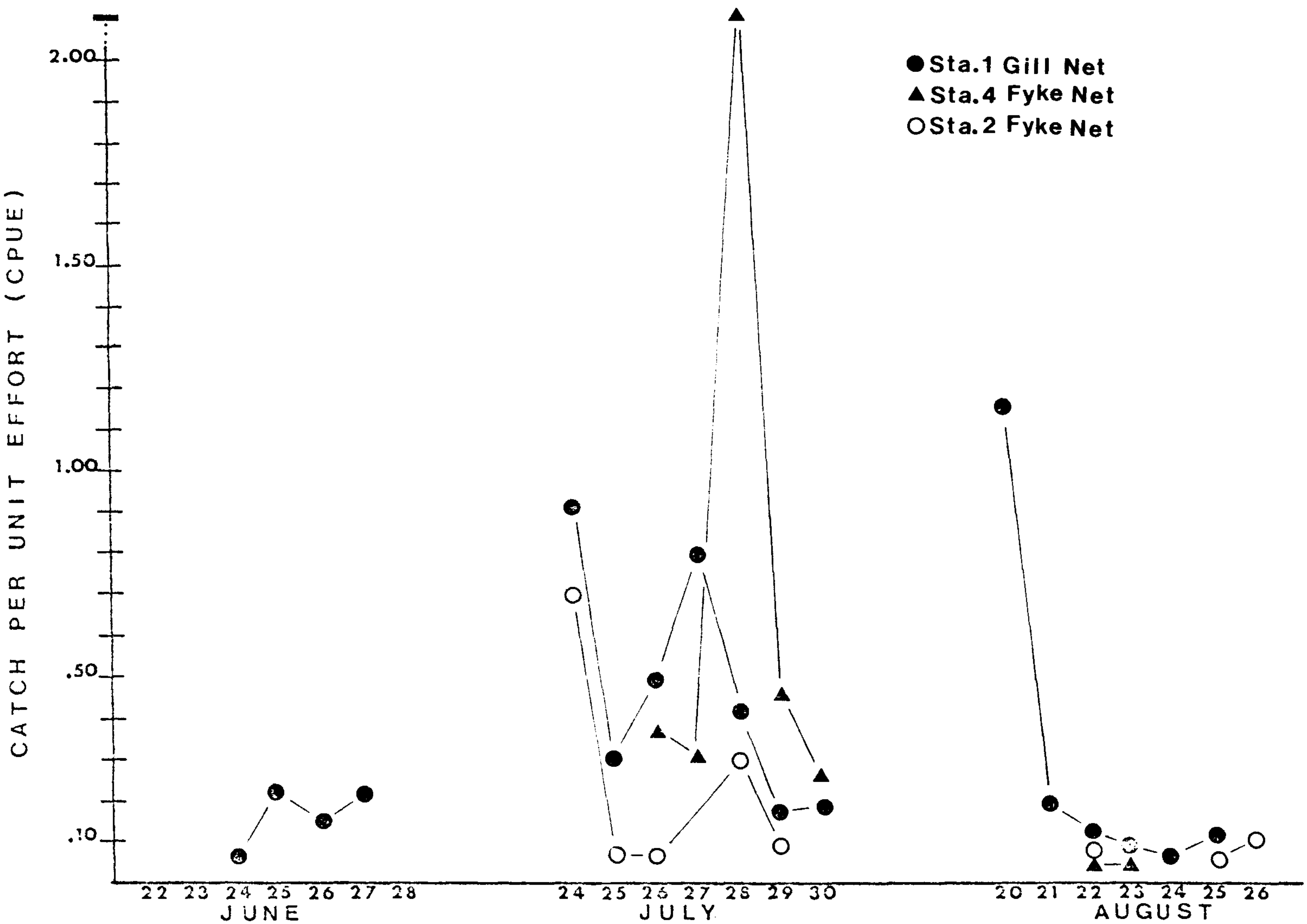

Figure 4. Daily catch rates of Arctic cisco at 3 sampling stations, Beaufort Lagoon, Alaska, 1984.

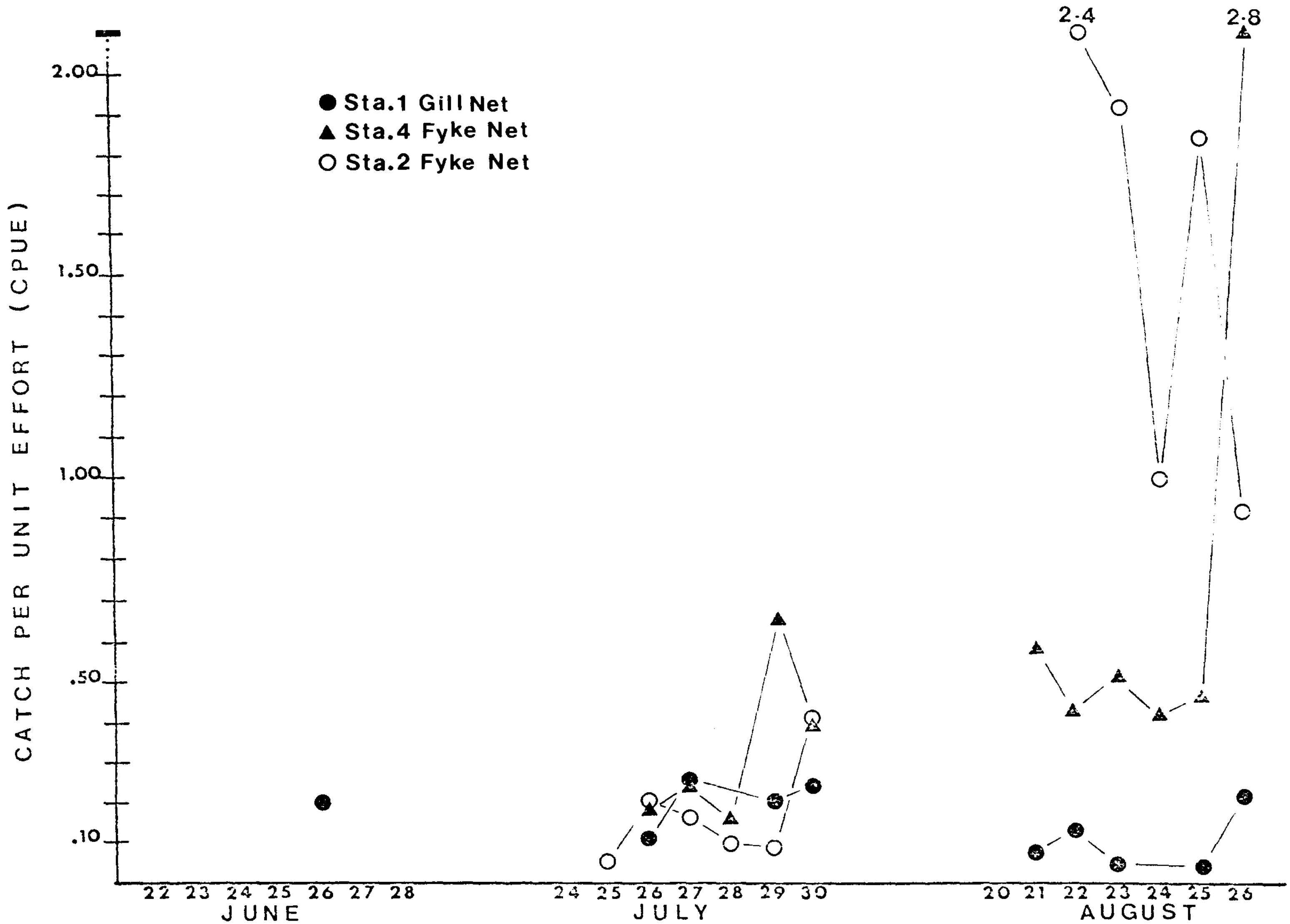

Figure 5. Daily catch rates of fourhorn sculpin at 3 sampling stations, Beaufort Lagoon, Alaska, 1984.

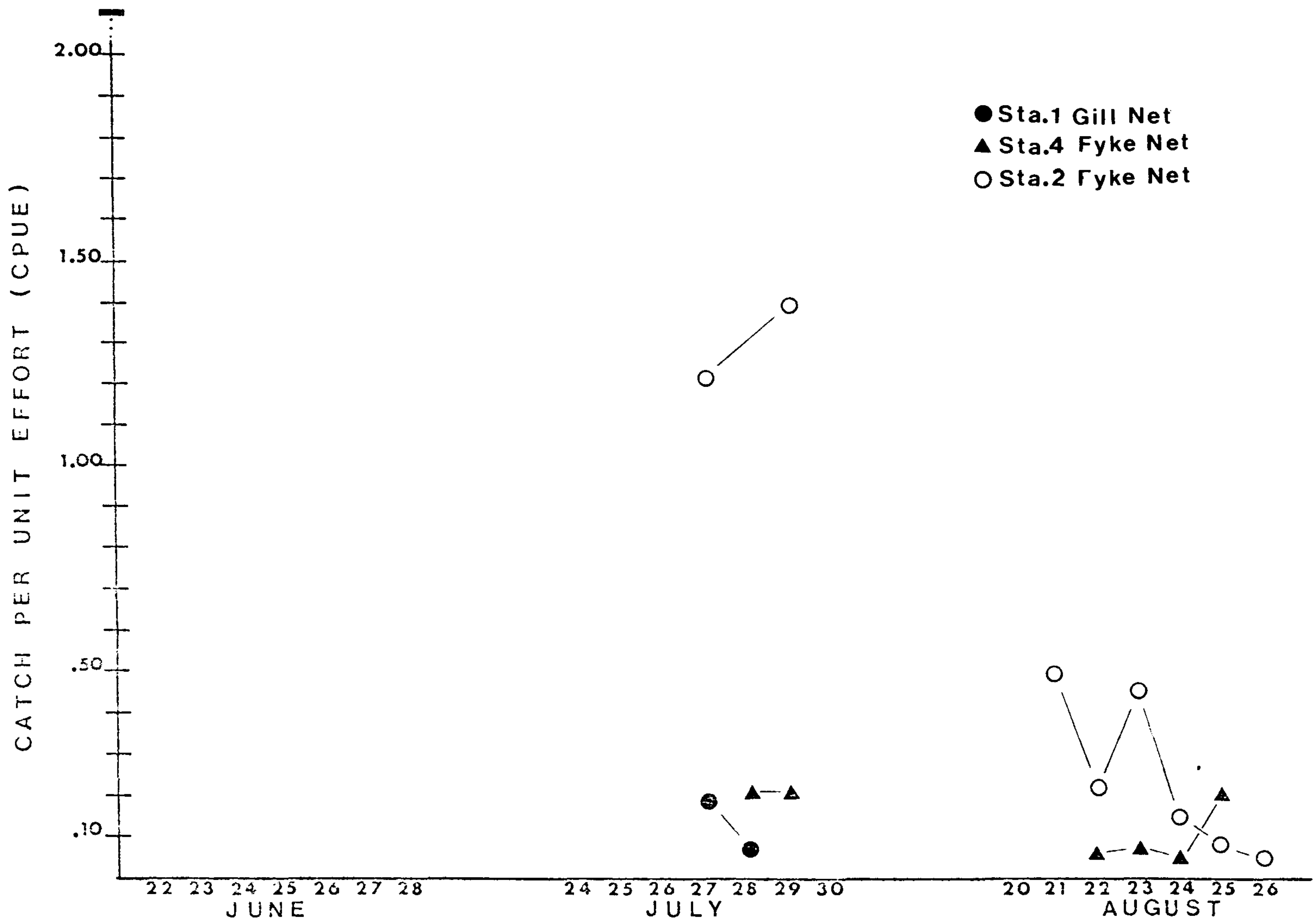

Figure 6. Daily catch rates of Arctic flounder at 3 sampling stations, Beaufort Lagoon, Alaska, 1984.

Other Species

Saffron cod were numerous at the nearshore mainland station in August. Numerically they ranked second behind fourhorn sculpins for marine species.

Least cisco were also numerous in August. Of the fish aged, 97% (n=37) were from age class 2. It is unclear why this anadromous species was more abundant in the lagoon in August when Arctic char and Arctic cisco were apparently moving out or why only one major age class was present. Least cisco have been reported only incidentaly by other investigators in past studies in this portion of the Beaufort Sea coast.

Age and Growth

Arctic char, Arctic cisco, fourhorn sculpin, and Arctic flounder were examined for age and growth relationships. Figures 8 through 11 depict the age/length relationships for these species.

Arctic Char (Table 3, Figure 7)

Arctic char aged from Beaufort Lagoon ranged from 3+ to 13+ years. Age class 7+ comprised about 27% of the samples. Slightly more than 63% of all the char aged were females.

These results are comparable with other investigations conducted along the central and eastern Alaskan Beaufort Sea coast. Bendock (1979) reported age classes of 3 to 12 years with most 7 to 9 years. Females outnumbered males 2:1. In Simpson Lagoon (Craig and Haldorson 1980), the age frequency showed a bimodal distribution. Most of the Arctic char (47%) were from age class 3 to 5 and 25% from age classes 10 and 11; 69% of all the char aged were female.

Arctic Cisco (Table 4, Figure 8)

Arctic cisco aged from Beaufort Lagoon ranged from 4+ to 10+ years. Approximately 50% of these aged were from the 6+ age class. About 55% of the Arctic cisco aged were females.

Arctic cisco aged from the area of Harrison Bay to Flaxman Island (Bendock 1979) were predominantly (72%) from age class 4+. In Simpson Lagoon, Craig and Haldorson (1981) found that most of the Arctic cisco were from age classes 8+ to 10+ and no age 4+ fish were reported. By comparison, age 4+ comprised only 1% (n=85) of the sample from Beaufort Lagoon.

Fourhorn Sculpin (Table 5, Figure 9)

Fourhorn scuplins aged from Beaufort Lagoon ranged from 1+ to 11+ years. Of these 74% were from the age classes 1+ to 4+ years. Approximately 64% of the fourhorn sculpins aged were males.

Fourhorn sculpins aged from Simpson Lagoon ranged from 1+ to 9+ years (Craig and Haldorson 1981). About 44% of those were from age classes 1+ and 2+. Females comprised 70% of the population. Bendock (1979) reports a younger fourhorn sculpin population (ages 1+ to 7+) with age classes 2+ and 3+ comprising the majority of those captured.

Table 3. Age specific length, weight, condition, and sex ratio for Arctic char, Beaufort Lagoon, Alaska, June - August 1984.

	Fork Length (mm)				Weight (grams)				Condition Factor		Sex Ratio	
Age	n	mean	range	S.D.	n	mean	range	S.D.	n	$\bar{K}$	n	% Female
3+	8	198.5	184-217	12.7	8	58.9	39-82	15.3	8	.74	8	87.5
4+	14	280.6	237-328	25.6	14	196.3	112-290	50.4	14	.87	14	28.6
5+	9	343.7	302-377	24.5	9	353.1	245-475	77.3	9	.86	9	66.7
6+	16	425.5	380-505	42.5	16	706.9	435-1200	252.9	16	.89	16	62.5
7+	25	475.1	408-521	28.5	25	1009.4	650-1440	193.2	25	.94	25	68.0
8+	13	503.8	456-533	19.6	13	1170.8	775-1450	175.4	13	.91	13	84.6
9+	2	523.5	523-524	.7	2	1432.5	1285-1580	208.6	2	1.00	2	50.0
10+	2	561.5	544-579	24.7	2	1632.5	1400-1865	328.8	2	.92	2	50.0
11+	2	573.5	541-606	46.0	2	1425.0	1150-1700	388.9	2	.75	2	100.0
12+	1	606.0	-	-	1	2100.0	-	-	1	.94	1	0.0
13+	1	685.0	-	-	1	3000.0	-	-	1	.93	1	0.0
	93				93				93		93	63.4

Table 4. Age specific length, weight, condition, and sex ratio for Arctic cisco, Beaufort Lagoon, Alaska, June - August 1984.

	Fork Length (mm)				Weight (grams)				Condition Factor		Sex Ratio	
Age	n	mean	range	S.D.	n	mean	range	S.D.	n	$\bar{K}$	n	% Female
4+	1	294.0	-	-	1	282.0	-	-	1	1.11	1	0.0
5+	8	350.8	329-366	13.6	8	488.8	425-585	54.5	8	1.14	8	0.0
6+	43	376.8	357-393	8.8	42	631.6	480-820	73.6	42	1.18	43	58.1
7+	19	392.5	364-412	13.8	19	680.2	460-895	115.9	19	1.12	19	57.9
8+	11	420.5	403-449	14.4	11	845.9	600-1120	151.6	11	1.13	11	72.7
9+	2	428.5	428-429	.7	2	932.5	870-995	88.4	2	1.19	2	100.0
10+	1	481.0	-	-	1	655.0	-	-	1	.59	1	100.0
	85				84				84		85	55.3

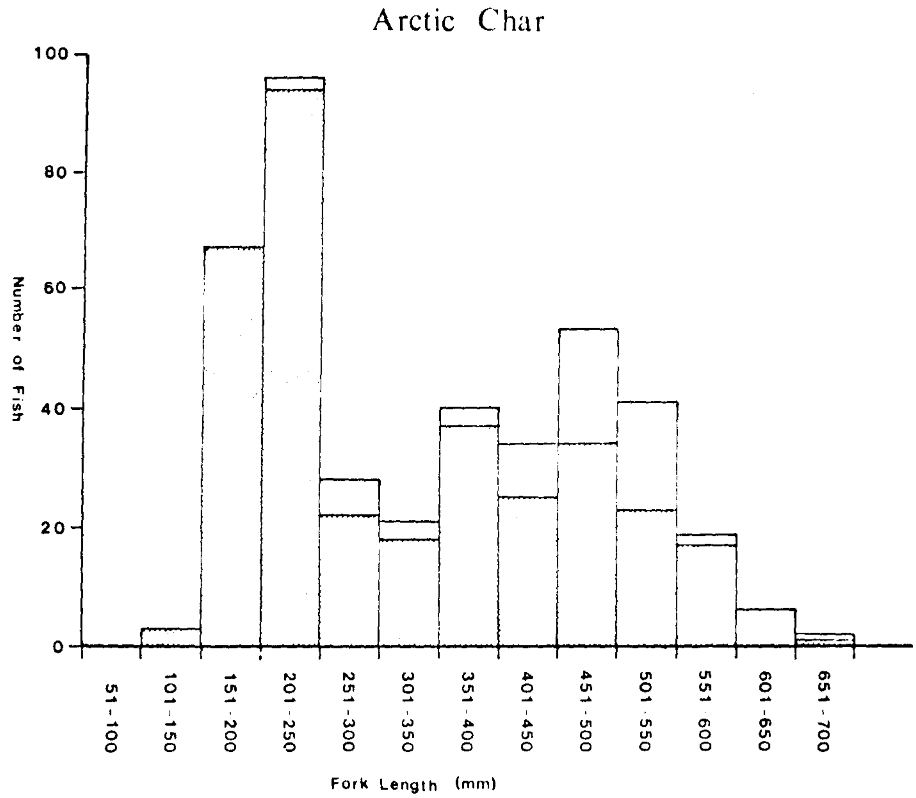

Figure 7. Length frequencies of 410 Arctic char captured with fyke nets (shaded area) and gill nets, Beaufort Lagoon, Alaska, 1984.

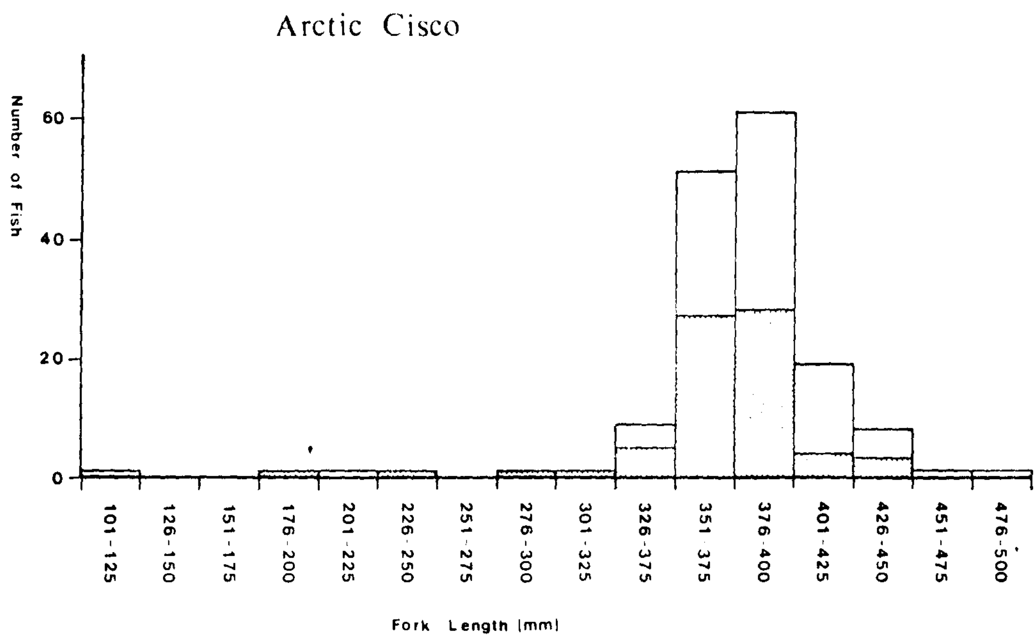

Figure 8. Length frequencies of 156 Arctic cisco captured with fyke nets (shaded area) and gill nets, Beaufort Lagoon, Alaska, 1984.

Table 5. Age specific length, weight, condition, and sex ratio for fourhorn sculpin, Beaufort Lagoon, Alaska, June - August 1984.

	Fork Length (mm)				Weight (grams)				Condition Factor		Sex Ratio	
Age	n	mean	range	S.D.	n	mean	range	S.D.	n	$\bar{K}$	n	% Female
1+	23	64.8	43- 73	10.0	14	3.6	1- 7	1.9	14	1.24	10	20.0
2+	24	99.5	79-120	13.5	22	9.3	3- 19	3.5	22	.96	22	.5
3+	11	135.4	120-159	15.6	11	23.8	12- 38	9.1	11	.92	11	.9
4+	15	181.2	153-219	19.1	15	61.2	40-108	22.2	15	1.00	15	66.7
5+	6	221.3	215-230	6.4	6	109.3	95-120	8.9	6	1.01	6	50.0
6+	3	228.3	220-235	7.6	3	148.0	124-170	23.1	3	1.24	3	66.7
7+	3	249.7	241-259	9.0	3	196.0	180-208	14.4	3	1.27	3	100.0
8+	2	279.5	270-289	13.4	2	269.0	258-280	15.6	2	1.25	2	100.0
9+	2	287.5	279-296	12.0	2	273.0	268-278	7.1	2	1.15	2	100.0
10+	3	312.7	310-315	2.5	3	378.0	279-475	98.0	3	1.23	3	100.0
11+	1	339.0	-	-	1	535.0	-	-	1	1.37	1	100.0
	93				82				82		78	36.2

Table 6. Age specific length, weight, condition, and sex ratio for Arctic flounder, Beaufort Lagoon, Alaska, June - August 1984.

	Fork Length (mm)				Weight (grams)				Condition Factor		Sex Ratio	
Age	n	mean	range	S.D.	n	mean	range	S.D.	n	$\bar{K}$	n	% Female
3+	4	107.8	104-110	2.6	4	17.8	15- 21	3.2	4	1.42	4	0.0
4+	32	127.6	106-151	10.7	32	28.9	9- 48	8.6	32	1.36	32	0.0
5+	6	181.8	148-210	20.4	6	97.2	37-185	48.2	6	1.50	6	0.0
6+	3	203.7	198-211	6.7	3	136.3	113-178	36.2	3	1.60	3	33.3
	45				45				45		45	2.2

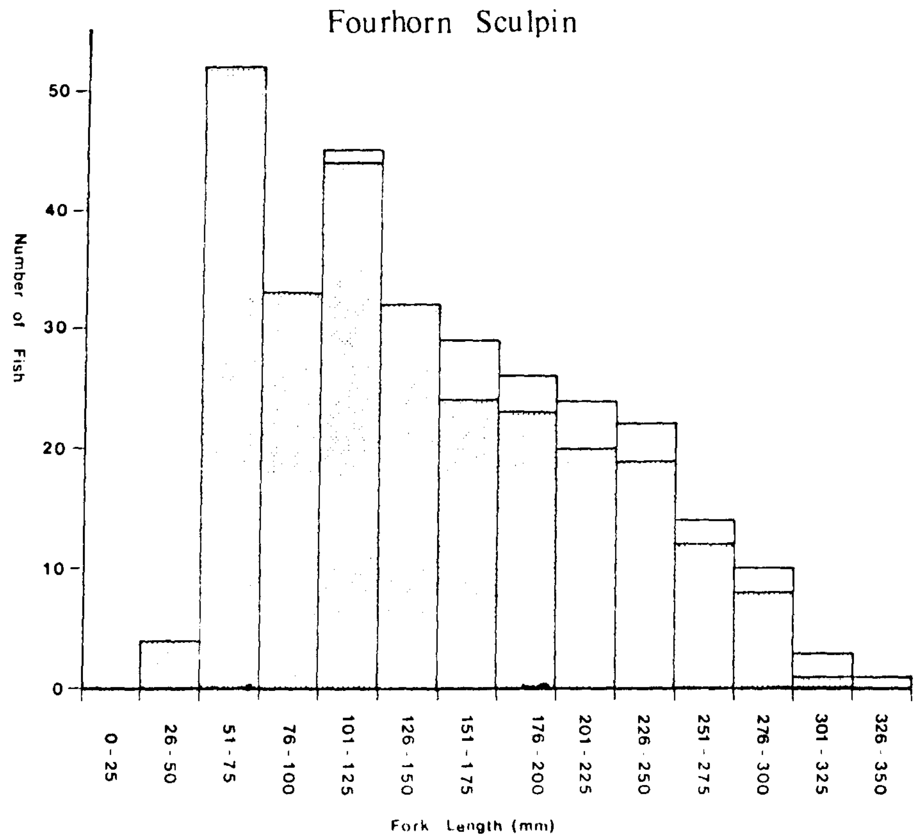

Figure 9. Length frequencies of 295 fourhorn sculpin captured with fyke nets (shaded area) and gill nets, Beaufort Lagoon, Alaska, 1984.

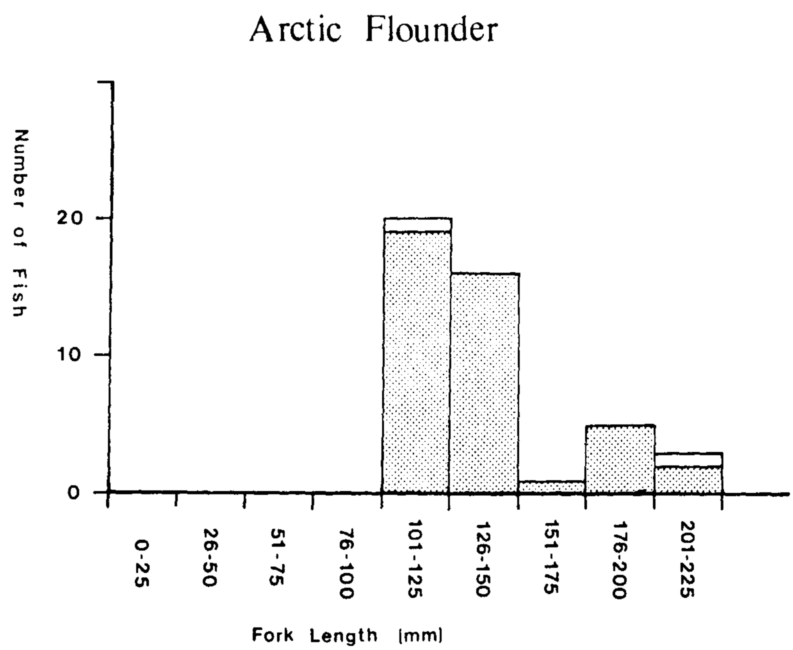

Figure 10. Length frequencies of 45 Arctic flounder captured with fyke nets (shaded area) and gill nets, Beaufort Lagoon, Alaska, 1984.

Arctic Flounder (Table 6, Figure 10)

Arctic flounder aged from Beaufort Lagoon ranged from 3+ to 6+ years. Of those aged, 71% were from age class 4+ years. All the Arctic flounder aged (n=45) were males except one female of 6+ years.

Bendock (1979) reported Arctic flounder from the western Beaufort Sea to be older (range 1+ to 12+, n=37) with age class 10 predominating.

Food Habits

The importance of lagoon and nearshore waters to the feeding ecology of Arctic char, Arctic cisco and fourhorn sculpin has been recorded for several sites along the Beaufort Sea coast. A short food chain reflects the low diversity of Arctic fauna. Amphipods and mysids have been found to be the primary prey items of Arctic char and Arctic cisco, while amphipods and isopods are the major prey items of fourhorn sculpins (Craig and Mann 1974, Griffiths et al. 1975, Griffiths et al. 1976, Bendock 1976, Craig and Haldorson 1981 and Griffiths 1983). The data suggest that these fish species are opportunistic feeders tending to prey on those items most available to them. Most trophic studies have tended to lump prey items to order.

This section provides a preliminary analysis of the more abundant fish species utilizing Beaufort Lagoon and their prey species. Arctic char, Arctic cisco and fourhoun sculpin were collected in Beaufort Lagoon during the ice-free period, June through August. Stomach samples from Arctic char were collected during June and July. Those from Arctic cisco included all three sample periods. Stomach samples from fourhorn sculpin were from July and August. The prey items from the stomachs of each species were analysed by combining all three sample periods (where sample size allowed) and then by grouping them by sample periods to note any change in diet through the summer season.

After the fish were collected and meristic data recorded, the stomach and esophagus were excised and preserved in 10% Formalin and placed in sealed Whirl-Paks. After a period of one to two months the prey items were removed from the stomachs and transfered to 70% isopropol. Prey items from each fish sample were separated and identified to the lowest possible taxon. All prey items were counted except in cases where there were greater than 500 items and then an aliquot sample was taken. The percent volume of each prey taxon from the fish sample was a subjective assessment.

To analyze the data the Index of Relative Importance (IRI) developed by Pikas et al. (1971) was used with a modification to the authors' definition of percent volume (%V). The %V defined by Pinkas et al. (1971) is the aggregate percent volume of prey in total volume of stomach contents of all predators in the sample. As used here, %V is the mean percent volume of prey in the stomach contents for all fish in the sample. The Index of Relative Importance as used for this study is defined as:

$$IRI = \% FO (\%N + \%V), \text{ where}$$

% FO = aggregate percent frequency of occurrence of prey among all fish in the sample

% N = aggregate percent number of prey in total number of prey items in all fish in the sample

% V = percent mean volume of prey in the stomach contents for all fish in the sample.

Those fish specimens which had empty stomachs were not used in calculating %FO and % mean volume.

Figure 11 summarizes the IRI values calculated for Arctic char, Arctic cisco, and fourhorn sculpin.

Arctic Char

Gammarid amphipods were the most important prey item for Arctic char over the summer in Beaufort Lagoon (Table 7). Several species of fish, mostly juveniles, also figured prominantly in the chars' diet.

Gammarus setosus was the most important prey species occurring in approximately 55% of the stomachs. The amphipod also comprised about 60% of the total number of prey items and 25% of the mean prey volume for an IRI value of 4682.97. Fish (IRI = 2406.9) occurred in approximately 57% of the stomachs and comprised about 30% of the mean prey volume. The fish species included ninespine stickleback, sculpin, Arctic cod, and eelpout. Another amphipod, Gammaracanthus loricatus, was third in importance with an IRI of 862.42. It occurred in slightly more than 40% of the stomachs.

Table 7. Prey items of Arctic char, Beaufort Lagoon, summer 1984. Sampling periods are pooled. (n = 62)

	% N	% V	% FO	IRI
Gammarid Amphipods				
Gammarus setosus	60.1	25.2	54.9	4682.97
Gammaracanthus loricatus	15.8	5.6	40.3	862.42
Lysianassidae	3.0	1.7	30.6	143.82
Oedocerotidae	3.1	2.0	24.2	123.42
Other	0.5	3.7	12.9	54.18
Mysid				
Mysis sp.	2.6	1.4	30.6	122.4
Unidentified crustacean	0.2	2.9	11.3	35.03
Isopod	1.4	7.2	25.8	221.88
Fish	13.0	29.6	56.5	2406.9
Miscellaneous	0.3	0.9	17.7	21.24
Unidentified material	-	19.8	21.0	415.8

% N = aggregate percent number of prey
% V = percent mean volume
% FO = percent frequency of occurrence
IRI = Index of Relative Importance

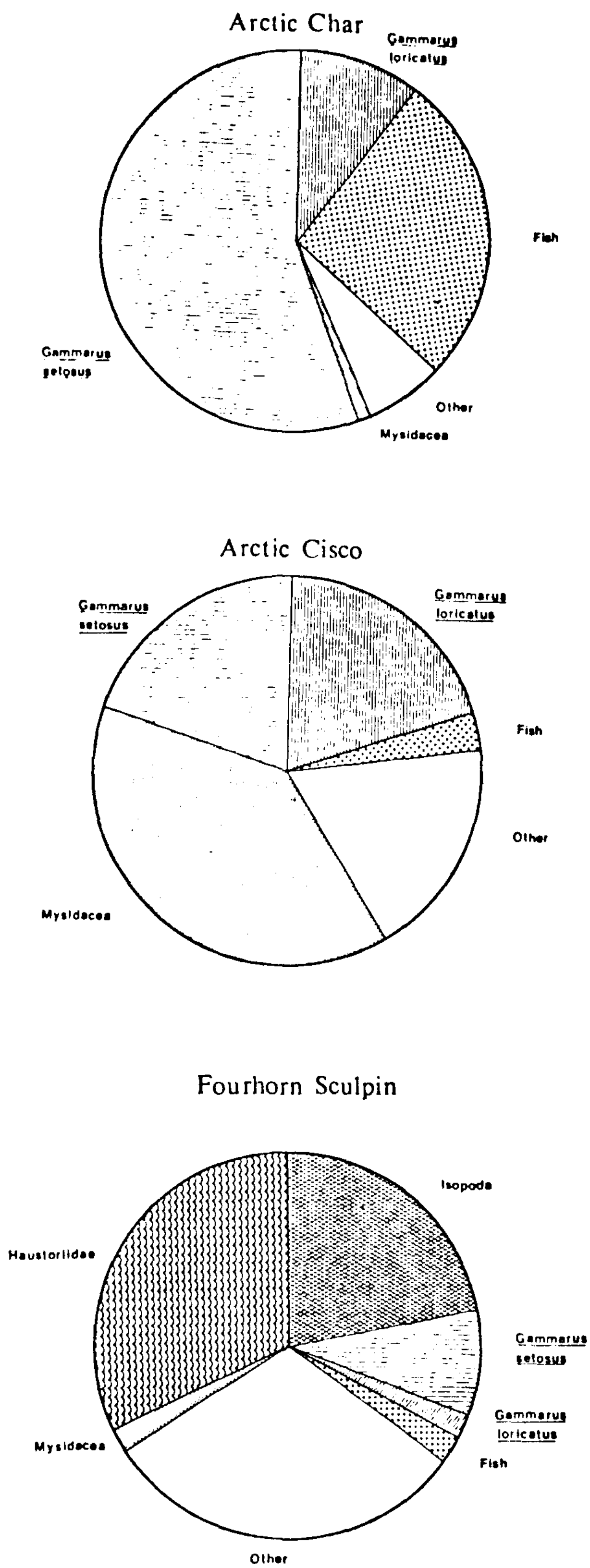

Figure 11. Comparison of IRI values of major prey items for Arctic char, Arctic cisco, and fourhorn sculpin, Beaufort Lagoon, Alaska, June, July, and August 1984.

The diet of Arctic char was heavily dependent on Gammarus setosus (IRI = 11495.4) during June (Table 8). The amphipods occurred in 83.3% of the stomachs. It comprised 91.5% of the total prey number and 46.5% of the mean prey volume. Fish (IRI = 3040.45) also had a high frequency of occurrence (83.3%) and high mean volume (35%); however, the percent total number was low (1.5%).

Table 8. Prey items of Arctic char, Beaufort Lagoon, June 1984. (n = 12)

	% N	% V	% FO	IRI
Gammarid Amphipods				
Gammarus setosus	91.5	46.5	83.3	11495.4
Gammaracanthus loricatus	1.2	1.4	33.3	86.58
Lysianassidae	2.2	0.5	16.7	45.09
Oedocerotidae	0.2	3.7	33.3	129.87
Other	0.8	1.1	25.0	47.5
Mysid				
Mysis sp.	1.7	1.8	58.3	204.05
Isopod	0.3	7.9	25.0	205.
Unidentified crustacean	0.5	1.3	16.7	30.06
Fish	1.5	35.0	83.3	3040.45
Miscellaneous	0.1	0.8	33.3	29.97

% N = aggregate percent number of prey
% V = percent mean volume
% FO = percent frequency of occurrence
IRI = Index of Relative Importance

The IRI values for the prey items were more evenly distributed in July than in June (Table 9). Gammarus setosus figured highest again with an IRI of 3177.6. It occurred in 48% of the stomachs and accounted for 46.1% of the total prey numbers and 20.1% of the mean prey volume. Fish (IRI = 2330.0) occurred in 50% of the stomachs and comprised 28.4% of the mean prey volume. Gammaracanthus loricatus occured in 42% of the stomachs.

Table 9. Prey items of Arctic char, Beaufort Lagoon, July 1984. (n = 50)

	% N	% V	% FO	IRI
Gammarid Amphipods				
Gammarus setosus	46.1	20.1	48.0	3177.6
Gammaracanthus loricatus	22.4	6.6	42.0	1218.
Lysianassidae	3.3	1.9	34.0	176.8
Oedocerotidae	4.3	1.6	22.0	129.8
Other	0.3	4.3	10.0	46.
Mysid				
Mysis sp.	3.0	1.3	38.0	163.4
Isopod	1.9	7.1	26.0	234.
Unidentified crustacean	0.1	3.2	10.0	33.
Fish	18.2	28.4	50.0	2330.
Miscellaneous	0.4	0.9	14.0	18.2
Unidentified material	-	24.6	26.0	639.6

% N = aggregate percent number of prey
% V = percent mean volume
% FO = percent frequency of occurrence
IRI = Index of Relative Importance

Arctic Cisco

Mysids and two species of gammarid amphipods were the predominant prey items of Arctic cisco for the summer in Beaufort Lagoon (Table 10). Mysids occurred in about 62% of the stomachs and comprised approximately 40% of the total prey number and 25% of the mean prey volume for an IRI value of 3998.46. The amphipods Gammarus setosus and Gammaracanthus loricatus ranked second and third, respectively. Gammarus setosus occurred in 58.8% of the stomachs while Gammaracanthus loricatus was 38.2%. Several species of fish, isopods, cumaceans, and gammarid amphipods from the families Oedocerotidae and Haustoriidae had a frequency of occurence ranging from 23-38%; however, their percent prey number and volumes were low.

Table 10. Prey items of Arctic cisco, Beaufort Lagoon, summer 1984. Sampling periods are pooled. (n = 34)

	% N	% V	% FO	IRI
Gammarid Amphipods				
Gammarus setosus	13.3	22.5	58.8	2105.04
Gammaracanthus loricatus	35.9	8.4	38.2	1692.26
Lysianassidae	2.7	5.3	38.2	305.6
Oedocerotidae	0.4	6.0	23.5	150.4
Other	1.2	7.6	47.1	414.48
Mysid				
Mysis sp.	40.2	24.5	61.8	3998.46
Isopod	0.1	3.7	32.4	123.12
Unidentified crustacean	0.8	9.8	35.3	374.18
Fish	2.0	7.8	35.3	345.94
Miscellaneous	3.4	4.4	47.1	367.38

% N = aggregate percent number of prey
% V = percent mean volume
% FO = percent frequency of occurence
IRI = Index of Relative Importance

Gammarus setosus was the most important prey item (IRI = 10910) during the late June sampling period (Table 11). It occurred in all the stomachs and comprised 59.8% of the total prey number and 49.3% of the mean prey volume. Gammaracanthus loricatus and fish ranked second and third with IRI values of 1919.68 and 1620.78, respectively.

Mysids (IRI = 3943.7) replaced Gammarus setosus as the dominant prey item during July (Table 12). They occurred in 56.5 % of the stomachs analysed and comprised 42.3% of the total prey number and 27.5% of the mean prey volume. Gammaracanthus loricatus remained second (IRI = 1228.22) and Gammarus setosus was third (IRI = 997.02).

Table 11. Prey items of Arctic cisco, Beaufort Lagoon, June 1984. (n = 7)

	% N	% V	% FO	IRI
Gammarid Amphipods				
Gammarus setosus	59.8	49.3	100	10910.0
Gammaracanthus loricatus	7.7	14.7	85.7	1919.68
Lysianassidae	11.8	6.7	71.4	1320.9
Oedocerotidae	1.5	1.1	42.9	111.54
Other	4.0	3.2	71.4	514.08
Mysid				
Mysis sp.	4.3	8.7	71.4	928.2
Isopod	0.2	0.9	42.9	47.19
Unidentified crustacean	0.2	1.4	42.9	68.64
Fish	9.7	13.0	71.4	1620.78
Mollusk	0.4	0.3	14 3	10.01
Terrestrial vegetation	0.4	0.6	28.6	28.6

% N = aggregate percent number of prey
% V = percent mean volume
% FO = percent frequency of occurence
IRI = Index of Relative Importance

Table 12. Prey items of Arctic cisco, Beaufort Lagoon, July 1984. (n = 23)

	% N	% V	% FO	IRI
Gammarid Amphipods				
Gammarus setosus	2.1	17.0	52.2	997.02
Gammaracanthus loricatus	48.6	8.0	21.7	1228.22
Lysianassidae	0.4	3.2	30.4	109.44
Oedocerotidae	0.2	4.6	21.7	104.16
Other	0.2	10.3	34.8	365.4
Mysid				
Mysis sp.	42.3	27.5	56.5	3943.7
Isopod	0.1	5.2	34.8	184.44
Cumacea	1.1	14.0	39.1	590.41
Copopod	0.4	5.3	17.4	161.82
Fish	0.1	4.1	21.7	91.14
Mollusk	0.4	0.4	21 7	17.36
Terrestrial vegetation	0.4	0.4	17.4	13.92

% N = aggregate percent number of prey
% V = percent mean volume
% FO = percent frequency of occurrence
IRI = Index of Relative Importance

Fourhorn Sculpin

Gammarid amphipods representing the family Haustoriidae were found in slightly more than 30% of the stomachs of fourhorn sculpin from the July and August sampling periods (Table 13). The amphipods comprised 12% of the mean prey volume and about 38% of the prey numbers for an IRI value of 1517.76. Isopods, ranking second (IRI = 1050.51), were found in approximately 36% of the stomachs. They comprised only about 8% of the prey numbers; however, they made up more than 20% of the prey volume. Gammarid amphipods from the family Lysianassidae ranked third with an IRI of 562.5 and Gammarus setosus was fourth (IRI = 420.0).

Table 13. Prey items of fourhorn sculpin, Beaufort Lagoon, summer 1984. Data from sampling periods are pooled. (n = 36)

	% N	% V	% FO	IRI
Gammarid Amphipods				
Gammarus setosus	11.2	5.6	25.0	420.
Gammaracanthus loricatus	1.9	5.1	13.9	97.3
Lysianassidae	9.9	12.6	25.0	562.5
Haustoriidae	37.6	12.0	30.6	1517.76
Oedocerotidae	0.8	4.3	8.3	42.33
Unidentified	2.7	14.5	22.2	381.84
Mysid				
Mysis sp.	1.3	6.3	11.1	84.36
Isopod	8.5	20.6	36.1	1050.51
Cumacea	20.8	0.9	5.6	121.52
Unidentified crustacean	1.1	5.3	11.1	71.04
Fish	1.3	8.2	11.1	105.45
Eggs	1.1	0.2	5 6	7.28
Terrestrial vegetation	1.9	1.5	8.3	28.22
Unidentified material	-	3.1	8.3	25.73

% N = aggregate percent number of prey
% V = percent mean volume
% FO = percent frequency of occurrence
IRI = Index of Relative Importance

Isopods ranked as the most important prey item in July (Table 14). They were found in one-third of the stomachs, and comprised 7.4% of the total prey number and 23.8% of the mean prey volume for an IRI value of 1038.96. The IRI value for Gammarus setosus (IRI = 1018.98) was only slightly less than that for isopods. This amphipod was found in one-third of the samples. Gammarid amphipods from the families Lysianassidae and Haustoriidae were also important prey items found in the July samples.

Haustoriid amphipods (IRI = 1928.07) were the most important prey item in the August samples (Table 15). They were in one-third of the stomachs and comprised 42% of the prey numbers and 15.9% of the mean prey volume. Isopods were ranked second (IRI = 1058.75). They occurred in about 38% of the stomachs and comprised 19% of the mean prey volume. Lysianassidae amphipods were ranked third with an IRI of 528.52.

Table 14. Prey items of fourhorn sculpin, Beaufort Lagoon, July 1984. (n = 12)

	% N	% V	% FO	IRI
Gammarid Amphipods				
Gammarus setosus	18.5	12.1	33.3	1018.98
Gammaracanthus loricatus	9.3	14.6	25.0	597.5
Lysianassidae	37.0	12.1	16.7	819.97
Haustoriidaee	11.1	4.1	25.0	380.0
Unidentified	3.7	5.4	8.3	75.53
Mysid				
Mysis sp.	-	-	-	-
Isopod	7.4	23.8	33.3	1038.96
Fish	3.7	15.4	16.7	318.97
Eggs	5.6	0.1	8 3	47.31
Terrestrial vegetation	3.7	4.2	8.3	65.57
Unidentified material	-	8.3	8.3	68.89

% N = aggregate percent number of prey
% V = percent mean volume
% FO = percent frequency of occurrence
IRI = Index of Relative Importance

Table 15. Prey items of fourhorn sculpin, Beaufort Lagoon, August 1984. (n = 24)

	% N	% V	% FO	IRI
Gammarid Amphipods				
Gammarus setosus	10.0	2.4	20.8	257.92
Gammaracanthus loricatus	0.6	0.4	8.3	8.3
Lysianassidae	5.3	12.8	29.2	528.52
Haustoriidae	42.0	15.9	33.3	1928.07
Oedocerotidae	0.9	6.5	12.5	92.5
Unidentified	2.5	19.0	29.2	627.8
Mysid				
Mysis sp.	1.6	9.4	16.7	183.7
Isopod	8.7	19.0	37.5	1038.75
Cumacea	24.3	1.3	8.3	212.48
Unidentified crustacean	1.2	8.0	16.7	153.64
Fish	0.9	4.6	8.3	45.65
Eggs	0.3	0.2	4 2	2.1
Terrestrial vegetation	1.6	0.2	8.3	14.94
Unidentified material	-	0.5	8.3	4.15

% N = aggregate percent number of prey
% V = percent mean volume
% FO = percent frequency of occurrence
IRI = Index of Relative Importance

The apparent high overlap of prey species in Beaufort Lagoon (Figure 7), more notably exhibited in the diets of Arctic char and Arctic cisco, reflect the low diversity and yet seasonally abundant invertebrate communities. Little is understood about their movements in and out of the lagoons, identification of and recruitment from nursery areas, and their abundance and distribution.

Different methods of analysis presented by other investigators have shown similar results in identifying principal prey items (Craig and Mann, 1974, Griffiths et al. 1975, Griffiths et al. 1976, Bendock 1976, Craig and Haldorson 1981 and Griffiths 1983). Taxon presented as percent volume, percent total number of prey items, or percent frequency of occurrence are most commonly used. Bias is inherent in each of these methods. For example, one predator in the sample may have preyed heavily on a large number of smaller prey while most of the sample population was utilizing a lower number of larger prey of a different taxon. In this way, the importance of the former would be biased in its favor. The Index of Relative Importance (IRI) overcomes some of these biases. Percent mean volume was one of the values used in this section to calculate the IRI. It should be pointed out that this method as opposed to percent volume (%V) derived from the percent aggregate volume of prey taxon may tend to overestimate the importance of a small prey specie.

Gammarid amphipods, mysids, isopods and to a lesser degree several fish species were the major prey items to Arctic char, Arctic cisco and fourhorn sculpin in Beaufort Lagoon. The amphipod, Gammarus setosus, was an important prey item to all three predators. This was reported to be one of the more abundant amphipods in terms of numbers and biomass in Angun Lagoon (Jewett and Feder 1983), a lagoon adjacent to Beaufort Lagoon. Arctic char preyed on Gammarus setosus more extensively throughout the season than did either Arctic cisco or fourhorn sculpin. Another amphipod, tentatively identified as Gammaracanthus loricatus, was also important in the diets' of Arctic char and Arctic cisco. Isopods and Haustoriid amphipods were important prey items of fourhorn sculpins.

Although sample sizes were small and results may be inconclusive it appears Arctic cisco changed their diet from relying substantially on Gammarus setosus in late June to mysids and amphipods in July, with mysids the more important prey item. Fourhorn sculpins also showed a slight shift in diet from isopods in July to amphipods in August. Arctic char became less dependent on Gammarus setosus from June to July. Whether these changes are because of changing prey abundance, sample station differences, or some combination of these factors is not known.

Water Chemistry

A summary of the water chemistry data collected from Beaufort Lagoon is presented in Tables 16 and 17 and Figure 2. Salinity and conductivity increased through the season. Water temperature was highest in July and decreased in August. Water temperature in nearshore waters outside the lagoon were colder by several degrees when compared with lagoon stations. Salinity and conductivity outside the lagoon were usually greater than lagoon stations.

Water temperatures and salinities were within the range reported by other investigators along the Beaufort Sea coast. Griffiths (1983) reported higher salinities in Beaufort Lagoon (24 o/oo) in late July to early August 1982.

Table 16. Summary of water chemistry data at sample stations 1, 2, 4, and 5, Beaufort Lagoon, Alaska, 1984.

Sampling Period	Total Days Sampled	Average Air Temp.(°C)	Average Water Temp.(°C)	pH Range	Average Salinity o/oo	Average Conductivity (uohms/cm)	Average Turbidity (NTU)	Ave. Water Depth (cm)
STATION 1								
June 22-28, 1984	7	3.4	2.3	7.80-8.30	2.9	3,470	3.7	59
July 24-29, 1984	6	9.1	9.3	7.20-7.60	8.0	10,230	2.4	80
August 20-26, 1984	7	1.9	5.4	7.60-8.01	12.3	14,340	4.7	74
STATION 2								
July 25-29, 1984	5	6.9	9.2	7.20-7.95	7.6	9,760	3.1	76
August 20-26, 1984	4	1.8	5.4	7.85-8.10	12.2	13,850	5.2	70
STATION 4								
July 25-29, 1984	5	7.0	8.6	7.00-7.75	7.9	10,240	3.3	90
August 20-26, 1984	4	2.5	4.5	7.70-7.90	13.4	15,610	2.9	83
STATION 5								
July 25-29,1984	4	5.4	7.5	7.30-8.05	6.9	8,610	4.1	85
August 20-26, 1984	4	2.3	3.5	7.90-7.95	14.6	16,390	2.6	78

Table 17. Water temperature, salinity, and conductivity, Beaufort Lagoon, July and August 1984.

Sample Station	Sample Date	Water Temp. (°C)	Salinity (o/oo)	Conductivity (uohm/cm)
1	7/30/84	8.0	7.8	9,000
1	8/24/84	5.5	12.5	14,650
2	7/30/84	8.0	7.9	9,100
2	8/24/84	5.5	12.6	13,800
3	7/30/84	8.2	7.9	9,100
3	8/24/84	5.0	12.3	12,900
4	7/30/84	8.5	7.8	9,000
4	8/24/84	5.0	12.8	14,850
5	7/30/84	5.0	7.5	8,050
5	8/24/84	3.0	14.9	15,800
6	7/30/84	9.0	7.5	8,900
6	8/24/84	4.5	12.0	12,400
7	7/30/84	7.5	8.0	9,150
7	8/24/84	4.0	14.5	14,500
8	7/30/84	4.8	8.0	8,700
8	8/24/84	2.2	15.0	15,000
9	7/30/84	5.0	8.0	8,550
9	8/24/84	2.0	16.2	15,200
10	7/30/84	8.5	7.0	8,300
10	8/24/84	4.1	13.3	13,500

DISTRIBUTION OF ARCTIC CHAR IN THE HULAHULA RIVER

Several investigations were undertaken in 1983 and 1984 to determine distribution of Arctic char in the Hulahula River.

Telonics radio transmitters were implanted in 29 Arctic char in September 1983 in the area of Fish Hole 2, a traditional subsistence fishing site on the Hulahula River in the northern foothills of the Brooks Range. Methods, catch results, and age structure of Arctic char were discussed previously by Smith and Glesne (1983) and Daum et al. (1984). Subsequent aerial tracking efforts throughout the winter and spring resulted in the identification of no substantial movement from the area except by one fish which moved upstream above Katak Creek to the vicinity of Fish Hole 3 (See Table 18 and Figure 12 and 12a).

On the ground investigations of the Fish Hole 2 area in April 1984 revealed ample flow and deep holes to maintain overwintering fish populations (See winter water chemistry results, Table 19). Subsistence fishermen present at the site during the April sampling were catching Arctic char.

Thirty-foot experimental gill nets were set underneath the ice at Site A and G (Figure 12a), a short distance downstream from the subsistance fish hole (Site B). The nets were set with the aid of a ice auger and Murphy stick (Bendock, 1980). Ice depth was 1 to 1.5 meters thick.

The CPUE values for the gill nets ranged from 0.13 to 1.39 fish per hour. Female char comprised about 52% of the catch (n=21) and ranged in length from 282 to 550 mm. Males comprised 38% of the catch and they ranged from 290 to 625 mm. The remainder of the catch were immature char. Using the age length relationship for Arctic char in the Hulahula River (Daum et al. 1984), all the char captured in gill nets in April 1984 were in the four year age class and greater. No juveniles were captured in the gill nets; however, juvenile char were observed to be widely distributed throughout the spring. A large congregation of juveniles ($n > 50$) was observed in a shallow, quiescent pool of the spring.

Investigations were undertaken in July 1984 to determine summer distribution of char in the Hulahula River. A two man crew floated from Grasser's Bar in the headwaters to a takeout point on the coastal plain approximately three miles from the river mouth. A summary of catch results for all sampling is presented in Table 20.

Ninety-two hours of gillnetting resulted in the capture of no adult char, indicating the probable near absence of adults during the July period of peak flows. Since the Hulahula River is a glacial-fed system as well as spring-fed, during high summer temperatures the river is extremely high and turbid. The amount of adequate resting habitat and available food resources for fish appeared to be extremely limited during the July sampling. As the weather cools in August, the flow is drastically reduced and the river clears. During late August the majority of anadromous adult char re-enter the river from the lagoon system (Daum, et al. 1984).

Juvenile char were captured throughout the system, especially near the spring areas which provide good food sources, overwintering habitat, and spawning

Table 18. Summary of winter movements of 29 radio-tagged Arctic char, Hulahula River, Alaska, 1983-1984.

Floy Tag No.	Wing Band No.	Fork Length (mm)	Weight (grams)	Sex & Spawning Condition*	Date Tagged	Location Tagged**	Tracked Location 10/19/83	12/14/83	3/22/84	4/27/84
5808	5	523	1300	NS-?	9/9/83	A	A	F	E	F
5809	9	524	1460	NS-?	9/9/83	A	A	F	E	F
5810	10	631	2375	NS-?	9/9/83	A	A	F	E	D
5892	13	555	1525	NS-?	9/10/83	A	A	A	A	D
5898	15	565	2075	NS-?	9/10/83	D	Z	-	Z	-
5766	17	513	1500	NS-?	9/10/83	D	A	F	E	F
5761	20	539	1520	S-F	9/10/83	D	A	F	-	E
5323	21	576	1990	S-F	9/10/83	D	A	F	E	F
5913	22	523	1480	S-F	9/10/83	D	A	A	F	F
4443	23	592	1990	S-F	9/10/83	D	A	F	E	B
5939	24	604	2325	S-F	9/11/83	A	A	F	B	B
5940	25	539	1475	NS-?	9/11/83	A	A	F	E	D
3207	26	556	1700	NS-?	9/11/83	D	A	F	B	F
3208	27	582	1570	NS-?	9/11/83	D	A	F	E	D
4009	29	558	1700	S-M	9/11/83	D	A	F	E	F
5054	30	664	2900	S-M	9/11/83	D	A	F	-	F
5990	31	530	1450	S-M	9/11/83	D	A	F	E	F
3231	34	550	1620	NS-?	9/12/83	A	A	F	B	F
4007	32	573	1720	S-M	9/12/83	A	A	F	E	D
3371	35	609	2125	NS-?	9/14/83	A	A	F	E	D
3328	36	561	1600	S-M	9/14/83	A	A	F	E	F
3329	37	589	2075	NS-?	9/14/83	A	A	F	E	B
5996	38	55	2150	NS-?	9/13/83	D	A	F	E	D
3425	39	640	2250	S-M	9/17/83	D	A	F	E	F
3426	45	635	2200	S-M	9/17/83	D	A	F	B	F
3430	48	617	2025	S-M	9/18/83	C	A	F	E	F
3431	52&53	604	1800	S-F	9/19/83	D	A	F	E	F
3363	55	540	1800	NS-?	9/14/83	A	A	F	E	B
3417	54	561	2100	NS-?	9/14/83	A	A	F	B	F

*S = Spawner F = Female
NS = Non-spawner ? = Sex undetermined
M = Male
**See Figures 12 and 12a.

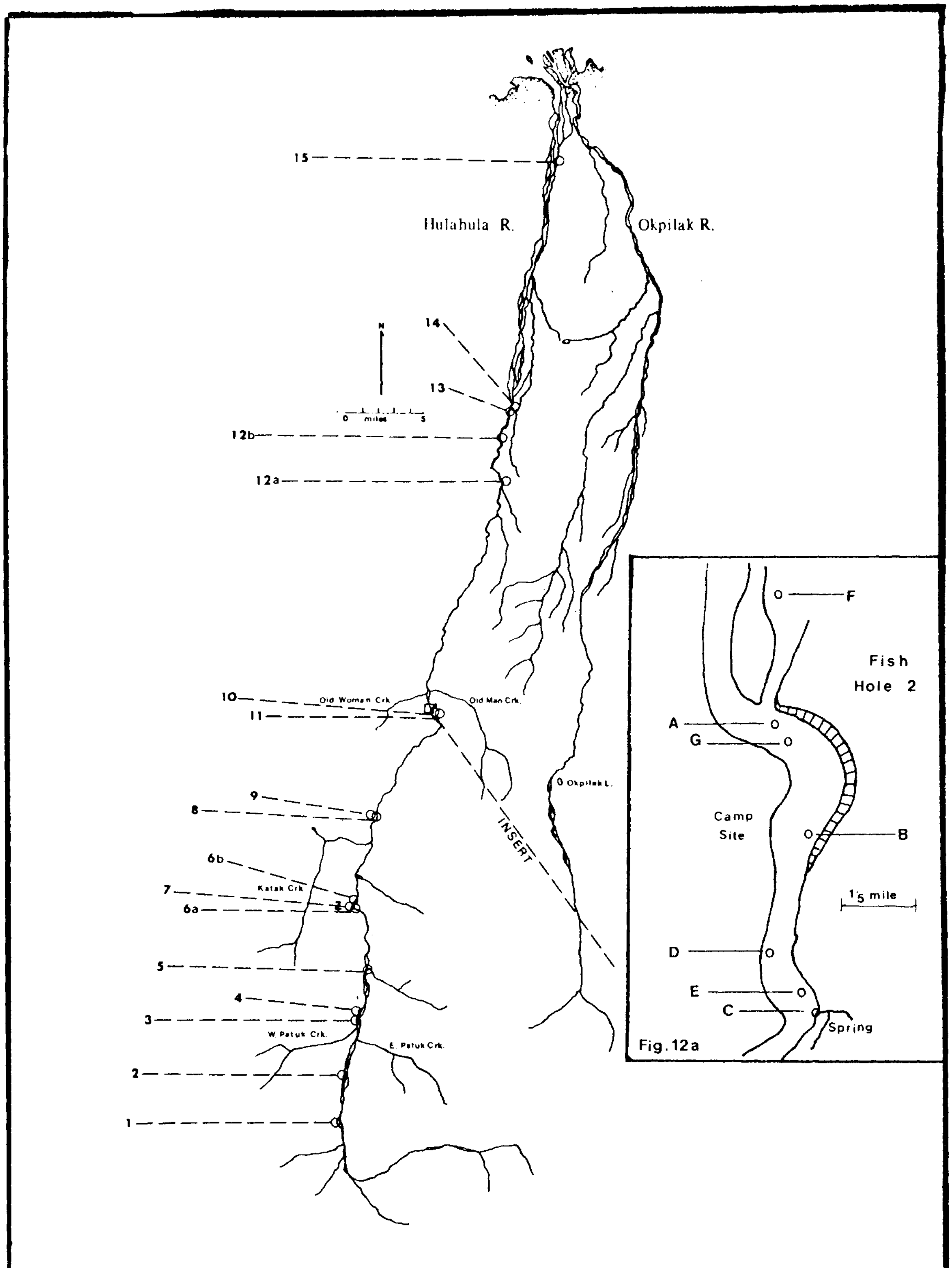

Figure 12. Sampling stations for fish, water chemistry, and telemetry, Hulahula River, Alaska, 1983-1984. See Tables 18, 19 and 20.

Table 19. Summary of water chemistry data at Fish Hole 2, Hulahula River, Alaska, April 1984.

Sample Site	Date	Air Temp. (°C)	Water Temp. (°C)	Water Depth (feet)	Ice Depth (feet)	Dissolved Oxygen (mg/1)	pH	Conductivity (uohms/cm)	Alkalinity (mg/1)	Discharge (cfs)	Comments
A	4/25/84	-14	-2	6.4	1.3	10.5 mg/1	7.8	460	171.2	-	-
B	4/25/84	-14	0	7.0	5.0	9.0 mg/1	8.0	430	137.0	-	-
C	4/25/84	-14	-1*	1.1	0	9.0 mg/1	7.8	-	154.1	2.3	Spring
D	-	-	-	-	-	-	-	-	-	-	-
E	4/27/84	-	-	1.3	-	-	-	-	-	5.1	Open Water
F	4/27/84	-	-	.5	3.1	-	-	-	-	-	-

*Spring water temperature near source was +8°C.

habitat for adults. Age specific length relationships for 30 juvenile char are given in Table 21. Their growth appear to be close to those of char in other Arctic rivers as reported by McCart (1980). Arctic grayling were observed in the spring areas at Fish Hole 2 and Fish Hole 3 (Sites 7 and 11, respectively, on Table 22 and Figure 12). Eight of these fish were captured, measured, aged, and their stomach contents examined. The range of ages determined by scale analysis was 3 to 6 years; fork length varied from 224 mm to 294 mm; weight from 78 grams to 239 grams; and 7 of the 8 fish were males. The food items were primarily terrestrial insects and juvenile char and grayling. One grayling at site 7 had 38 juvenile fish in its stomach.

Table 20. Summary of catch-per-unit-effort (CPUE) for Arctic char, Hulahula River, Alaska, July 1984

Sample Site	Angling			E 30' Gill Net			Baited Minnow Trap		
	Hours Fished	Char Caught	CPUE	Hours Fished	Char Caught	CPUE	Hours Fished	Char Caught	CPUE
2	.5	0	0	-	-	-	-	-	-
4	-	-	-	3	0	0	6	1	.17
6a	.75	0	0	13	0	0	39	4	.10
6b	.25	0	0	2.5	0	0	5	2	.40
8	-	-	-	12	0	0	36	0	0
10	.5	0	0	35	0	0	30	2	.07
11	2	0	0	-	-	-	15	1	.07
12a	-	-	-	13	0	0	13	0	0
12b	-	-	-	2.5	0	0	-	-	-
13	.5	0	0	12.5	0	0	48	3	.06
14	-	-	-	-	-	-	11	0	0
15	-	-	-	11	0	0	22	1	.05
Total Hours Fished	4.5			104.5			225		
Total Char Caught		0			0			14	
Mean CPUE			0			0			.06

NOTE: All char captured or observed during sampling periods were juveniles.

Table 21. Age specific length of juvenile Arctic char, Hulahula River, Alaska, July 1984.

Age	Sample Size	Mean Fork Length (mm)	Standard Deviation	Range (mm)
0+	10	30	3.29	24- 35
1+	10	85	5.18	73- 98
2+	10	124	6.16	105-142

NOTE: All juvenile char were captured using baited minnow traps or a dip net.

During the July investigations water chemistry characteristics were measured throughout the Hulahula River system (Table 22). Sample site 9 was not associated with any known fish holes (areas which have open water and support overwintering fish populations) yet over 300 young of the year char were observed at the site indicating use of the area for spawning and overwintering.

During August and September 1983, 2,228 Arctic char were tagged with numbered floy tags on the Hulahula River at two locations (see Table 23 and Figure 13). In the course of 10 months, 24 of these tagged fish were recovered (1.08 %). The char recovered at the greatest distances from its tagging site was caught at Beaufort Lagoon in July 1984, approximately 130 km from where it was tagged.

Studies of Arctic char distribution on the Hulahula River in 1984 revealed that many adult char are concentrated in restricted overwintering areas at or close to spawning sites from between August and September until late May or early June. By July it appears at least most adults have left the system and entered the coastal lagoons. Juvenile char of the first three year classes were found throughout the river system but were primarily associated with spring areas.

FALL MOVEMENTS OF ARCTIC CHAR IN THE AICHILIK RIVER

A field camp was established near the mouth of the Aichilik River on August 8, 1984. The location of the camp was approximately two miles up from the coast on the west bank near the mouth of a slough (See Figure 14). This site is directly across the river from a USGS bench mark (VABM 14).

Sampling was undertaken using two each 40-foot and 125-foot experimental mesh gill nets near the camp site. A Mark II Zodiac with a 35 hp jet outboard provided access to the nets for periodic checks.

Fishing success was hampered by extremely high water conditions during most of the 11 day sampling period. Catch per unit effort is depicted in Figure 15. Overall, 110 Arctic char and 8 Arctic grayling were captured in 11 days of sampling. The age-specific size, condition, and sex ratio relationships for 37 char is presented in Table 24. Thirty-two of the fish were tagged with numbered floy tags and released immediately upstream of their respective capture sites. Five large adult char, which were believed to be migrating spawners, were fitted with radio transmitters. The Telonics transmitters were esophagelly implanted in the char which were then held for observation for at least 24 hours before their release.

Tracking of the five radio-tagged char was completed from a Cessna 185 aircraft fitted with tuned dual H antennas, one on each wing strut. Table 25 gives the results of the tracking to date. Tracking will continue periodically until spring of 1985.

The one upriver char use area identified in Figure 14 (Site E), approximately 65 km from the river mouth, is a major spawning and overwintering site (Smith and Glesne 1982).

Table 22. Water chemistry data, Hulahula River, July, 1984.

	Sample Site	Date	Air Temp. (°C)	Water Temp. (°C)	Conductivity (uohms/cm)	pH	Alkalinity (mg/l)	Hardness (mg/l)	Discharge (cfs)	Comments
1	Grasser's Bar	6/30/84	14.0	9.0	205	8.0	77	144	-	Upper most sample site
2	3.5 mi. downstream from Grasser's Bar	7/1/84	17.0	11.0	205	7.8	72	116	-	-
3	West Patuk Cr. near mouth	7/2/84	15.5	6.0	95	7.7	36	126	-	-
4	.5 mi. below mouth of West Patuk	7/2/84	14.0	12.0	190	7.9	63	106	667.0	-
5	Unnamed Creek 4.5 mi. below East Patuk Creek	7/2/84	14.5	10.0	140	7.6	37	79	-	Clear tributary
6a	3 mi. upstream of Kolotuk Creek	7/3/84	20.0	9.0	180	7.9	68	91	-	0.5 mi. above Fish Hole No. 3
7	Spring at No.6	7/3/84	18.0	6.5	235	7.8	71	161	7.7	Juvenile grayling and char and adult grayling
8	3.2 mi. downstream of Katak Creek	7/4/84	14.0	11.0	150	7.9	41	97	-	River high and turbid
9	Spring at No.8	7/4/84	16.5	11.0	195	8.0	98	118	1.2	Juvenile char
10	Fish Hole 2	7/5/84	17.0	10.0	300	7.6	72	63	-	River high and turbid
11	Spring at No. 10	7/5/84	18.0	9.0	560	7.8	146	218	-	Juvenile char and adult grayling
12a	16 mi. below Fish Hole 2	7/6/84	17.5	11.5	175	8.1	52	71	-	River high and turbid
13	1 mi. above Fish Hole 1	7/7/84	9.5	9.0	160	7.8	51	73	-	River high and turbid
14	Spring at Fish Hole 1	7/7/84	12.0	2.0	305	7.6	85	181	-	No fish observed
15	3 mi. upstream of Hulahula River Mouth	7/8/84	7.5	8.0	195	7.9	63	110	-	River high and turbid

Table 23. Recovery information for 24 floy-tagged Arctic char, Hulahula River, Alaska, 1983-1984.

Floy Tag Number	Date Tagged	Location Tagged(1)	Tagged Length (mm)	Tagged weight (grams)	Recapture Date	Recapture Location(1)	Recapture Length (mm)	Recapture Weight (grams)	Recaptured by
3620	8/22/83	C	331	-	10/83	B	-	-	Subsistence Fishermen
5632	9/7/83	A	367	440	10/83	A	-	-	Subsistence Fishermen
5361	9/3/83	A	354	415	10/83	A	-	-	Subsistence Fishermen
2580	8/13/83	C	260	-	10/83	B	-	-	Subsistence Fishermen
5373	9/4/83	A	418	650	6/25/84	D	-	-	Sport Fishermen
5767	9/10/83	A	459	825	6/25/84	D	-	-	Sport Fishermen
3409	9/16/83	A	539	1600	6/20/84	D	550	-	Sport Fishermen
3579	8/20/83	C	450	-	7/11/84	E	-	-	Subsistence Fishermen
2804	8/20/83	C	390	-	7/15/84	E	-	-	Subsistence Fishermen
4436	8/24/83	A	414	580	7/15/84	E	-	-	Subsistence Fishermen
4170	8/17/83	A	435	825	7/12/84	E	-	-	Subsistence Fishermen
4277	8/22/83	A	520	1400	7/11/84	E	-	-	Subsistence Fishermen
2511	8/17/83	C	374	-	7/16/84	E	-	-	Subsistence Fishermen
4491	8/24/83	A	468	950	7/26/84	E	-	-	Subsistence Fishermen
2823	8/20/83	C	325	-	7/28/84	F	365	-	U.S. Fish & Wildlife
3322	9/13/83	A	422	625	7/84	E	-	-	Subsistence Fishermen
5503	9/5/83	A	365	475	4/24/84	A	385	420	U.S. Fish & Wildlife
3607	8/21/83	C	303	-	4/25/84	A	-	-	Subsistence Fishermen
5903	9/10/83	A	319	320	4/25/83	A	-	-	Subsistence Fishermen
5193	8/3/83	A	395	560	4/25/84	A	403	525	U.S. Fish & Wildlife
5641	9/7/83	A	375	460	4/25/84	A	377	460	U.S. Fish & Wildlife
2522	8/17/83	C	286	-	4/27/84	A	-	-	Subsistence Fishermen
5291	9/2/83	A	494	1350	4/28/84	A	520	1200	U.S. Fish & Wildlife
4043	8/27/83	A	484	1230	4/25/84	A	488	1125	U.S. Fish & Wildlife

(1) See Figures 12 and 12a.

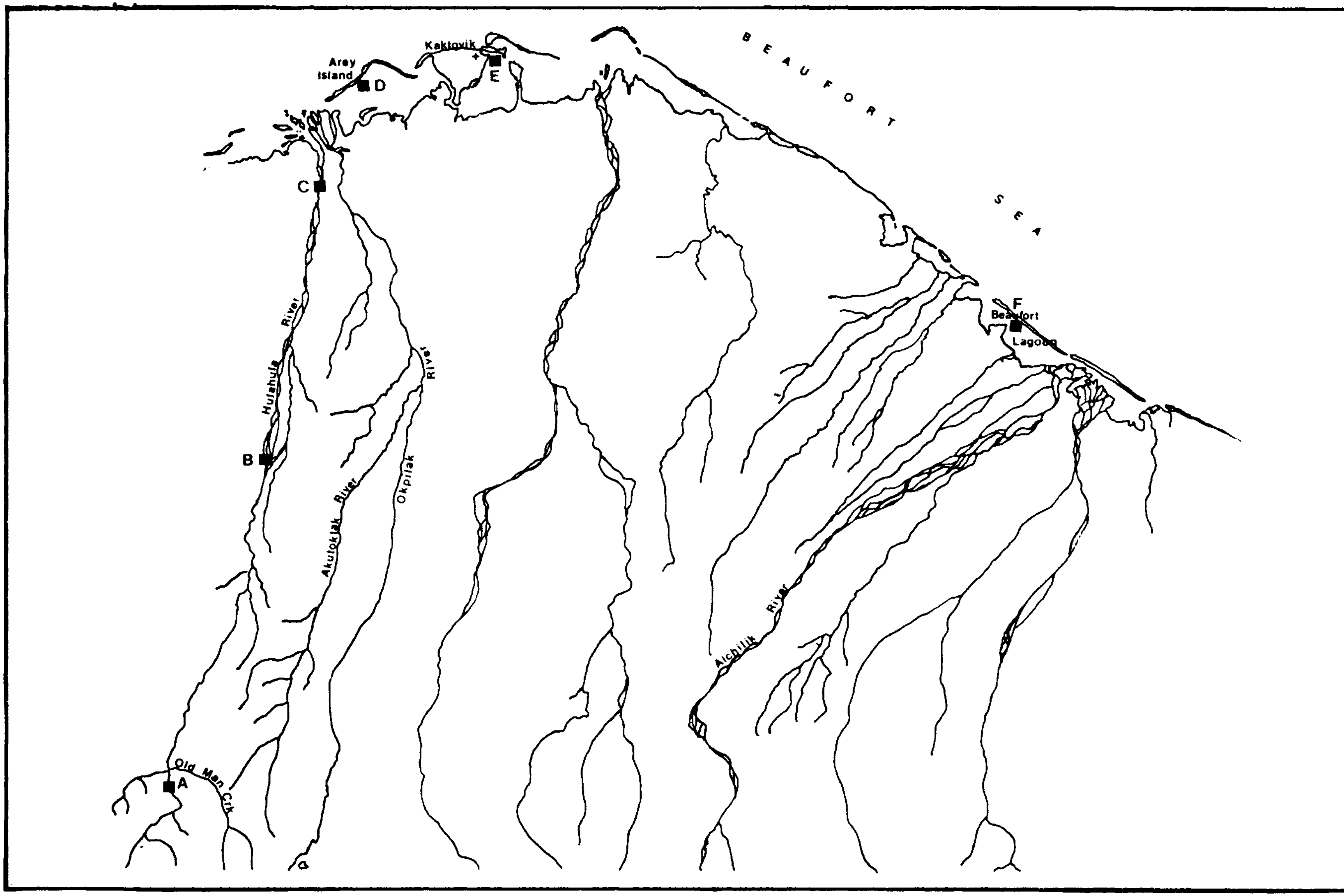

Figure 13. Tagging and recapture locations for radio-tagged Arctic char, Hulahula River, Alaska, 1983-1984. See Table 23.

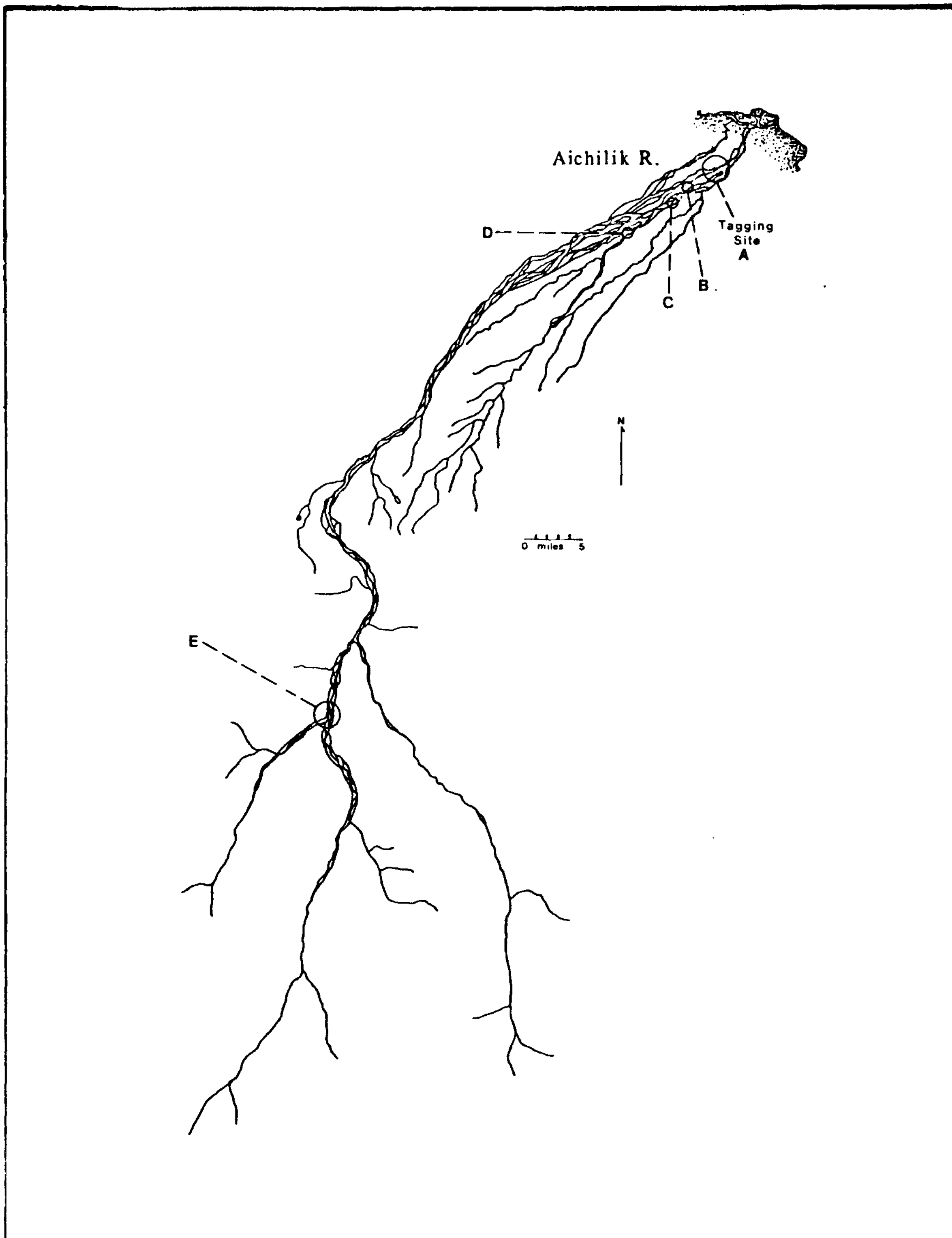

Figure 14. Tagging site and relocation areas of radio-tagged Arctic char, Aichilik River, Alaska, 1984.

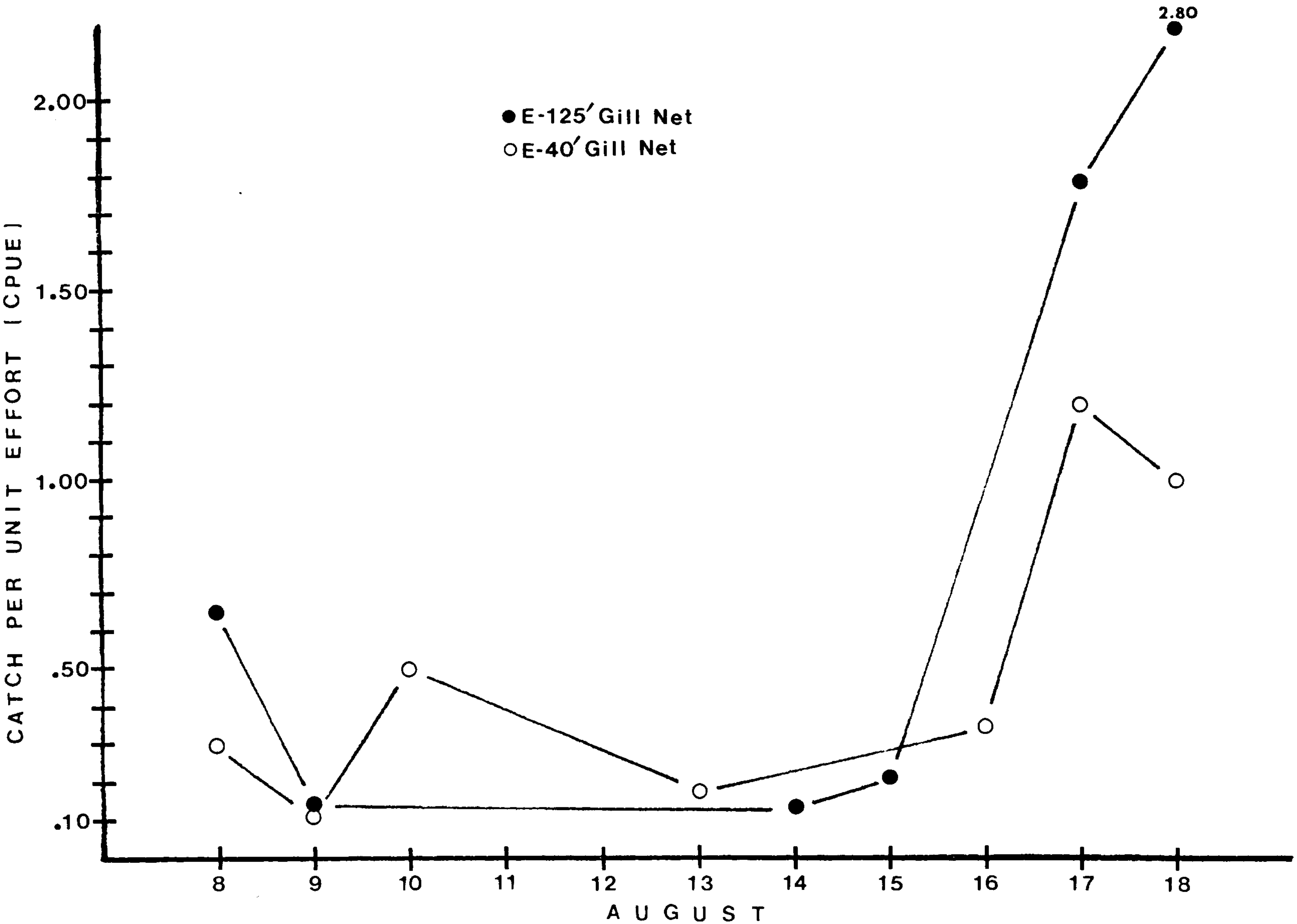

Figure 15. Daily catch rates of Arctic char, Aichilik River, Alaska, 1984.

Table 24. Age specific length, weight, condition, and sex ratio for Arctic char, Aichilik River, Alaska, August 1984.

	Fork Length (mm)				Weight (grams)				Condition Factor		Sex Ratio	
Age	n	mean	range	S.D.	n	mean	range	S.D.	n	$\bar{K}$	n	% Female
2+	1	146.0	-	-	1	28.0	-	-	1	.90	0	-
3+	11	219.5	187-250	19.8	11	104.9	59-145	28.6	11	.97	11	63.6
4+	7	268.6	233-299	25.7	7	175.1	115-245	53.9	7	.88	7	42.9
5+	5	348.6	306-375	25.5	5	369.0	255-450	85.1	5	.86	5	80.0
6+	6	390.2	358-432	29.0	6	516.7	420-705	110.8	6	.86	6	66.7
7+	5	458.0	443-469	11.0	5	929.0	810-1100	113.3	5	.96	5	80.0
8+	1	521.0	-	-	1	1460.0	-	-	1	1.03	1	100.0
9+	1	559.0	-	-	1	1650.0	-	-	1	.94	1	100.0
	37				37				37		36	66.7

Table 25. Fall movement of five radio-tagged Arctic char, Aichilik River, Alaska, 1984.

Floy Tag Number	Fork Length (mm)	Weight (grams)	Date Tagged	Location Tagged	Tracked Location 8/12/84	8/18/84	9/19/84	10/16/84
3432	573	1620	8/ 8/84	A	B	D	E	-
3435	526	1550	8/15/84	A	-	-	E	E
3451	535	1500	8/17/84	A	-	C	-	-
3462	565	1750	8/17/84	A	-	-	E	E
3463	545	1750	8/18/84	A	-	-	-	-

Overwintering habitat of Arctic grayling is severely limited on the north slope during winter. Water becomes scarce by late November in most rivers with ice formation of two meters or more restricting available habitat to deeper pools and springs. Oil and gas development can directly impact the fishery if water withdrawals are allowed in these limited overwintering areas.

Until freeze-up, grayling are well distributed in several rivers in the 1002c study area. Most of these rivers are shallow and contain few marginal pools suitable for overwintering fish (Smith and Glesne, 1982). Movements in late fall and overwintering locations of grayling in these rivers is not well known.

A radio telemetry project was initiated in 1984 to determine fall movements and overwintering locations of grayling in three rivers in the 1002c study area. Four types of telemetry transmitters were used (Table 26). Transmitter size and life expectancy were primary considerations used in selection of transmitter type. Size was limited to 2-3% of fish body weight. Minimum size fish used for tagging was 340 mm fork length. Three months was the minimum requirement for transmitter life necessary to follow fish to overwintering locations. Grayling were captured by angling and were anesthesized in tricaine methanesulfonate (MS-222). Transmitters were implanted surgically through a small incision anterior to the pelvic girdle. The antenna was allowed to trail externally through a small hole posterior to the pelvic girdle.

Table 26. Transmitter characteristics and grayling size range.

	Transmitters				Grayling	
Transmitter Brand	Mean Weight (g)	Mean Pulse (ppm)	Life Expectancy (days)	No. Implanted	Fork Length Range (mm)	Weight Range (g)
Wildife Materials (WM)	9.3	69.0	90	9	341-371	375-525
Telonics (TEL)	14.8	34.1	90	7	351-374	422-560
Advanced Telemetry Systems (ATS)	18.8	52.0	187	7	375-424	480-855
AVM	15.7	59.6	-	6	368-379	510-610

Fifteen transmitters were implanted in grayling on Itkilyariak Creek at its confluence with the Sadlerochit River from August 1-7; three on the Akutoktak River near its confluence with the Okpilak River from August 8-13 ; and eleven on the Lower Tamayariak River from August 17-19. These rivers have been described by Smith and Glesne (1982) and Daum et al. (1984). Aerial tracking was conducted periodically through the fall at altitudes between 500 and 1000 feet above ground level.

Relocations were depicted on USGS 1:250,000 topographical maps and movements from tagging sites computed. Four reference transmitters, one of each model, were placed at the Sadlerochit River site. These transmitters were used to verify receiver operation and to check transmitter life.

Movements of the 15 fish from Itkilyariak Creek were aerially tracked six times from August 8 to October 30 (Table 27). There was a general downstream movement into the main Sadlerochit River during the first two weeks following release. Of the eleven fish relocated on August 18, ten were in the Sadlerochit River within 8 km of the confluence of the Itkilyariak. Major upstream movement was observed on October 30 when one fish was located in Lake Schrader and two were in the Kekiktuk River 5 to 6 km below the lake outlet. This movement, 64 to 71 km, occurred between August 18 and October 30.

Table 27. Movements of 15 radio tagged grayling in the Sadlerochit River drainage, August-October 1984.

	Locations and Movements (km)*					
Tag Brand	Aug. 11	Aug. 12	Aug. 16	Aug. 18	Sept. 18	Oct. 30
WM	-	-	-	-	-	-
WM	F(+ .3)		F(+1.1)	G(+3.0)		
WM	E(-7.0)	D(-5.9)	D(-5.9)	D(-5.9)	C(-4.5)	C(- 4.5)
WM	H(+4.9)	H(+3.8)	H(+3.8)	H(+4.9)		
WM						
WM			E(-7.8)	E(-7.8)	E(-7.8)	
TEL	F(+ .9)			G(+2.4)		
TEL	A(-1.3)	A(-1.3)		A(- .3)		K(+71.0)
TEL	D(-5.8)		D(-5.8)	D(-5.8)	G(+2.0)	
TEL	A(-1.3)	A(-1.3)		A(-1.3)		
TEL	A(-1.3)	A(-1.3)				J(+65.0)
AVM	A(- .7)	A(- .7)	A(-1.0)	A(-1.0)	B(-2.7)	A(- 1.7)
ATS	A(- .8	A(- .8)	A(-1.0)	A(- .8)	H(+3.8)	G(+ 2.6)
ATS	0	0	0	0		I(+61.6)
ATS	F(-7.8)	E(-7.8)			D(-6.3)	

*Distances are from tagging site; (+) indicates upstream movement; (-) indicates downstream. General locations are depicted on Figure 16.

Only two of the three grayling implanted from the Akutoktak River were relocated. These grayling were located only once on November 1 and had left the Okpilak River drainage and entered the Hulahula River (Figure 17). Both fish had traveled downstream approximately 30 km to the coast, entered the brackish water of the delta and then moved up the Hulahula River. One fish had traveled upstream 34 km to Fish Hole 1; the other 68 km to Fish Hole 2. These two sites are fed by springs and support a popular winter subsistence char fishery for Kaktovik residents.

The 11 fish implanted in August on the Tamayariak River were not tracked until September 18 due to weather. Only five fish were relocated and all were in the Canning River (Table 28 and Figure 18). The longest movement was 44 km from the release site on the Tamayariak River. This movement consisted of 6.4 km downstream to the confluence with the Canning River and 37.0 km upstream through the Canning River delta. One fish from the Tamayariak River had been tagged with a numbered floy tag two years before. This fish, a female, measured 371 mm fork length and weighed 525 grams on August 17, 1984. It was originally tagged by Smith and Glesne (1982) in the same area on July 20, 1982 and was 328 mm fork length and 360 grams.

Table 28. Movement of 11 radio tagged grayling in the Tamayariak and Canning Rivers, August-October 1984.

Tag Brand	Locations and Movements (km) Sept. 18	Oct. 31
WM		C(40.9)
WM		
WM	A(24.8)	
AVM		
AVM	B(13.4)	
AVM		
AVM		D(42.1)
ATS		
ATS		
ATS		E(43.4)

*Distances are total movement from tagging site and include 6.4 km downstream in the Tamayariak River. Locations are depicted on Figure 18.

Although grayling are well distributed in the lower sections of some rivers in the 1002c study area during the summer (Smith and Glesne 1982, Daum et al. 1984) these areas may not provide the majority of overwintering habitat. Some fish displayed major movement during fall away from the lower sections and into spring and lake areas in the foothills. Three Sadlerochit River fish moved over 60 km upstream during September and October. One fish from the Okpilak River drainage moved over 98 km during a 74 day period and into a different river system. These movements, while indicative of the mobility of grayling in this area, further show that winter and summer habitat is limited in the 1002c area. Grayling may have to move considerable distances to spawning and/or feeding areas in the spring and return this distance in the fall to overwinter. Although inconclusive, the results of this study reflect the scarcity of grayling overwintering habitat and emphasize the necessity of documenting grayling movements and habitat requirements in this area before oil and gas development proceeds.

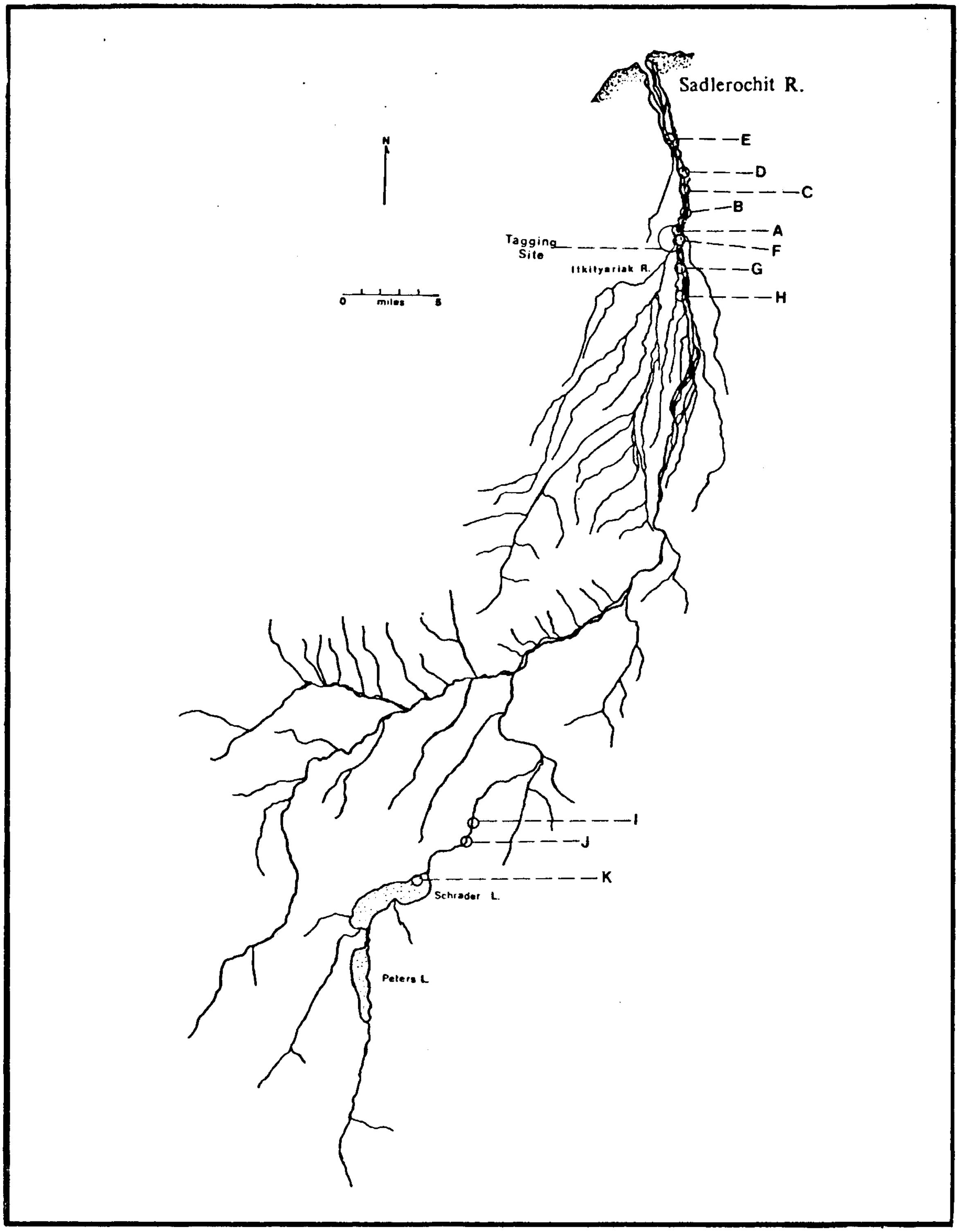

Figure 16. Tagging site and relocation areas of radio-tagged Arctic grayling, Sadlerochit River, Alaska, 1984.

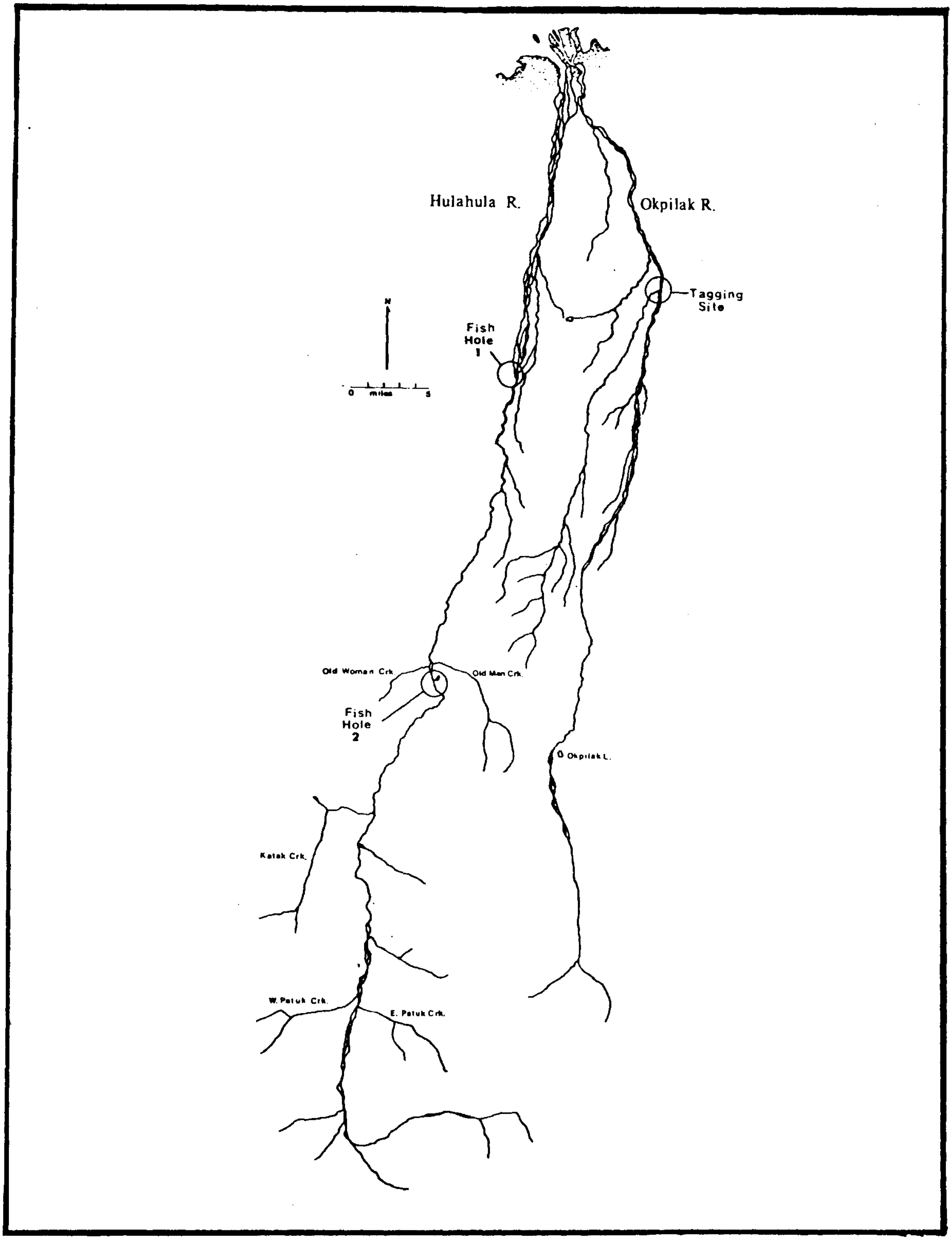

Figure 17. Tagging site and relocation areas of radio-tagged Arctic grayling, Okpilak and Hulahula Rivers, Alaska, 1984.

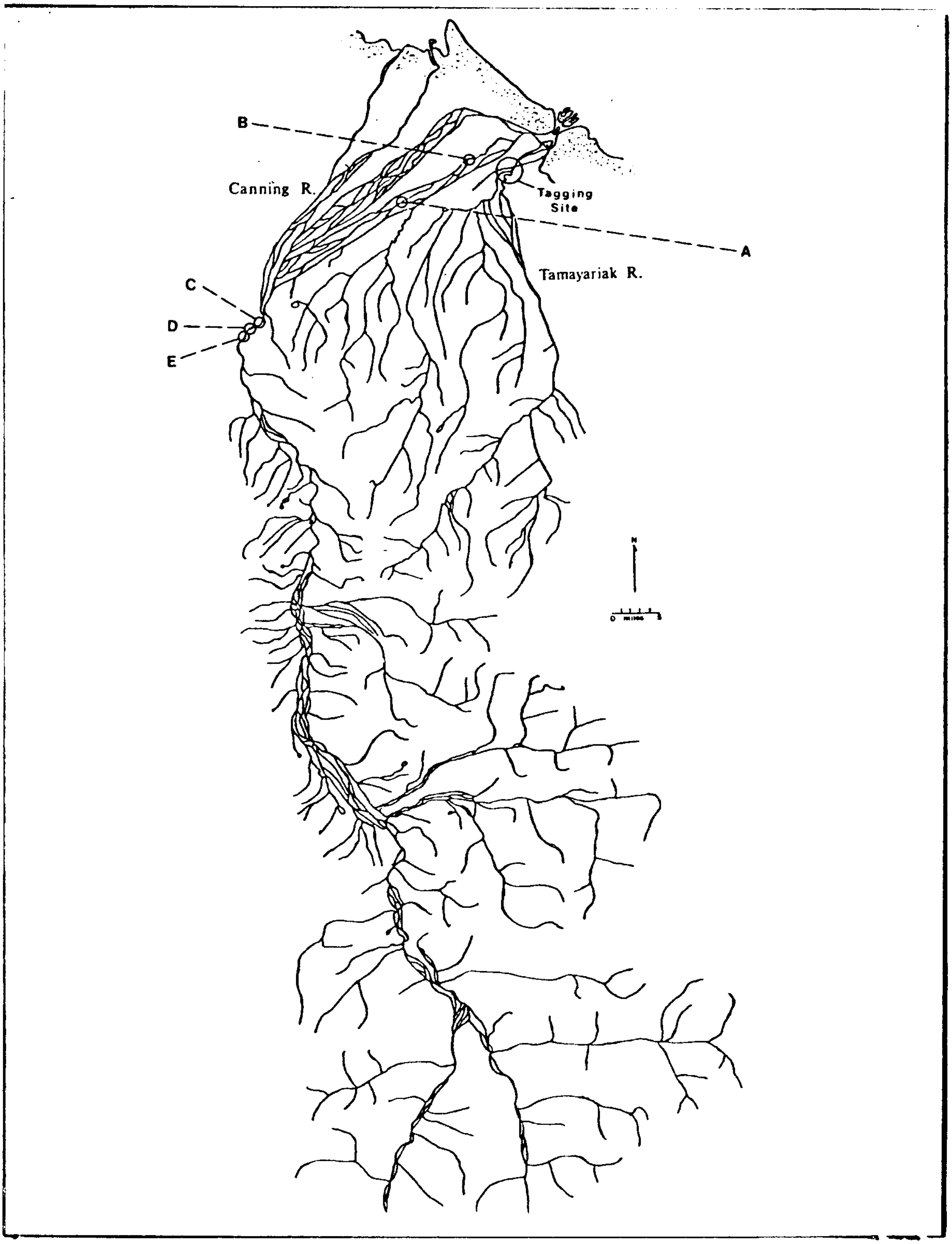

Figure 18. Tagging site and relocation areas of radio-tagged Arctic grayling, Tamayariak and Canning Rivers, Alaska, 1984.

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