Work subunit Ic: Differential impacts of predators (brown bears, wolves, golden eagles) on caribou calving in the 1002 area and potential displacement areas: an assessment of predation risks.

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INTRODUCTION

Predators can be an important factor affecting caribou (*Rangifer tarandus granti*) populations (Bergerud 1983). To reduce predation risk, caribou have evolved two strategies: predator swamping and predator avoidance. Predator swamping may occur, for example, when low densities of predators encounter relatively high densities of prey through aggregation at a calving ground. Such effects are augmented when calving occurs with a high degree of synchrony. Predator avoidance may occur when caribou select areas with either fewer predators or high visibility to aid in detection and avoidance of predators. Use of traditional calving areas may be influenced by either or both strategies.

Potential impacts of petroleum exploration and development within the 1002 area of the Arctic National Wildlife Refuge (ANWR) may result in displacement of the Porcupine Caribou Herd (PCH) from areas traditionally used during the calving and post calving periods (Clough et al. 1987). The primary concern is that calf survival may decline if caribou are displaced during the calving and post-calving periods to areas east and south of the traditional high density calving and post-calving areas. Increased calf mortality may occur due to displacement into areas which have a higher density of predators, higher rates of predation, or where a higher proportion of the predators regularly use caribou as a food source.

Caribou predators that occur within the calving grounds of the PCH are brown bears (*Ursus arctos*), wolves (*Canis lupus*), and golden eagles (*Aquila chrysaetos*). This study was designed to assess predation risks to caribou calving in the 1002 area and potential displacement areas. Original study objectives were as follows:

1. Compare relative abundance of predators within calving concentration areas to that in adjacent potential displacement areas to the east and south of the 1002 boundaries.
2. Identify relationships between movements and distribution patterns of caribou and predators.
3. Quantify the seasonal use of caribou as a food source and its relation to productivity of the predator populations utilizing the coastal plain of ANWR.

Funding reductions constrained this study and study objectives were therefore modified. We were unable to conduct surveys to estimate predators densities in the traditional high density calving and potential displacement areas. Rather, we employed indirect measures (e.g., distributions of radio-collared animals, den locations, nest sites) to estimate relative abundance of predators in these areas. We were also unable to quantify the use of caribou as a food source and determine how the availability of caribou as prey relates to productivity of predator populations. We focused our research efforts on brown bears because they were believed to be one of the most important predators on caribou calves. Because wolves were thought to be a less important predator on caribou calves and because golden eagles were the most difficult and expensive to study, they received secondary consideration. As a result, our findings relate primarily to the potential impacts of brown bear predation on calving caribou.

METHODS

The study area (1002 study area) was located in northeastern Alaska between the Canning River and the Canadian border north of the Brooks Range Divide (Fig. 1). For purposes of spatial distribution analyses, study area boundaries were delineated to include the common distributions of calving Porcupine herd caribou and radio-collared brown bears and wolves, 1988-1990 (Fig. 1). The study area was divided into 3 broad physiographic categories (zones): the coastal plain, generally flat with elevations < 300 m; the foothills, characterized by buttes and ridges, with elevations between 300-900 m; and mountains, ranging in elevation between 900-2000 m with river valleys of 500-1000 m (Reynolds and Garner 1987) (Fig. 1). These zones comprised 38.5%, 18.9%, and 42.6% of the 16,000 km^2 study area, respectively.

Brown Bears

Immobilization, handling, instrumentation and aging procedures followed those described by Reynolds (1976) and Garner et al. (1984, 1985) for brown bears in northern Alaska, except Telazol (*tilelamine hydrochloride* and *zolzepam hydrochloride*) was the immobilizing agent used between 1988 and 1990. Brown bears monitored in this study were initially captured and instrumented between the years 1982 and 1990. Between 1982 and 1985, bears were instrumented as they were encountered, regardless of sex, age or reproductive condition. During those years, capture efforts were focused on the coastal plain, in the foothills, and the northern mountains bordering the foothills. No bears were captured in 1986. In 1987, capture efforts focused on adult females, so that reproductive parameters could be studied. In that year, capture efforts were distributed across all physiographic zones. Between 1988 and 1990, capture efforts focused on recollaring bears with failing radio-transmitters, instrumenting subadult offspring of marked females, and instrumenting bears of specific sex and age cohorts to replace bears lost from our sample.

Our sample of radio-collared brown bears represented 61% (n = 66) of the brown bear population on the study area, based on a 1983 estimate of 108 bears (includes all age classes) on the north slope of ANWR from the Canning River to the Canadian boundary (Garner et al. 1984), an area roughly 25% larger than that of our study area. Preliminary analysis indicate that the ANWR bear population has been stable between 1982 and 1990 (Reynolds et al. in prep.). Based on the distribution of our capture efforts and the large number of bears in our sample, we assumed our sample was geographically representative of the ANWR bear population, with the exception that deep mountain bears were probably underrepresented. The age composition of instrumented bears in our sample was assumed representative of the population. The sex composition of our sample was slightly biased towards females (Table 1).

Radio-collared brown bears and caribou were radio-relocated (relocated) from Cessna-185 or PA18 Supercub aircraft from late May through late June at approximately 3-5 day and 1-3 day intervals, respectively. Based on the length of this time interval, movement rates of brown bears (Linderman 1974, Craighead 1976) and caribou (Fancy and Whitten 1991), we assumed

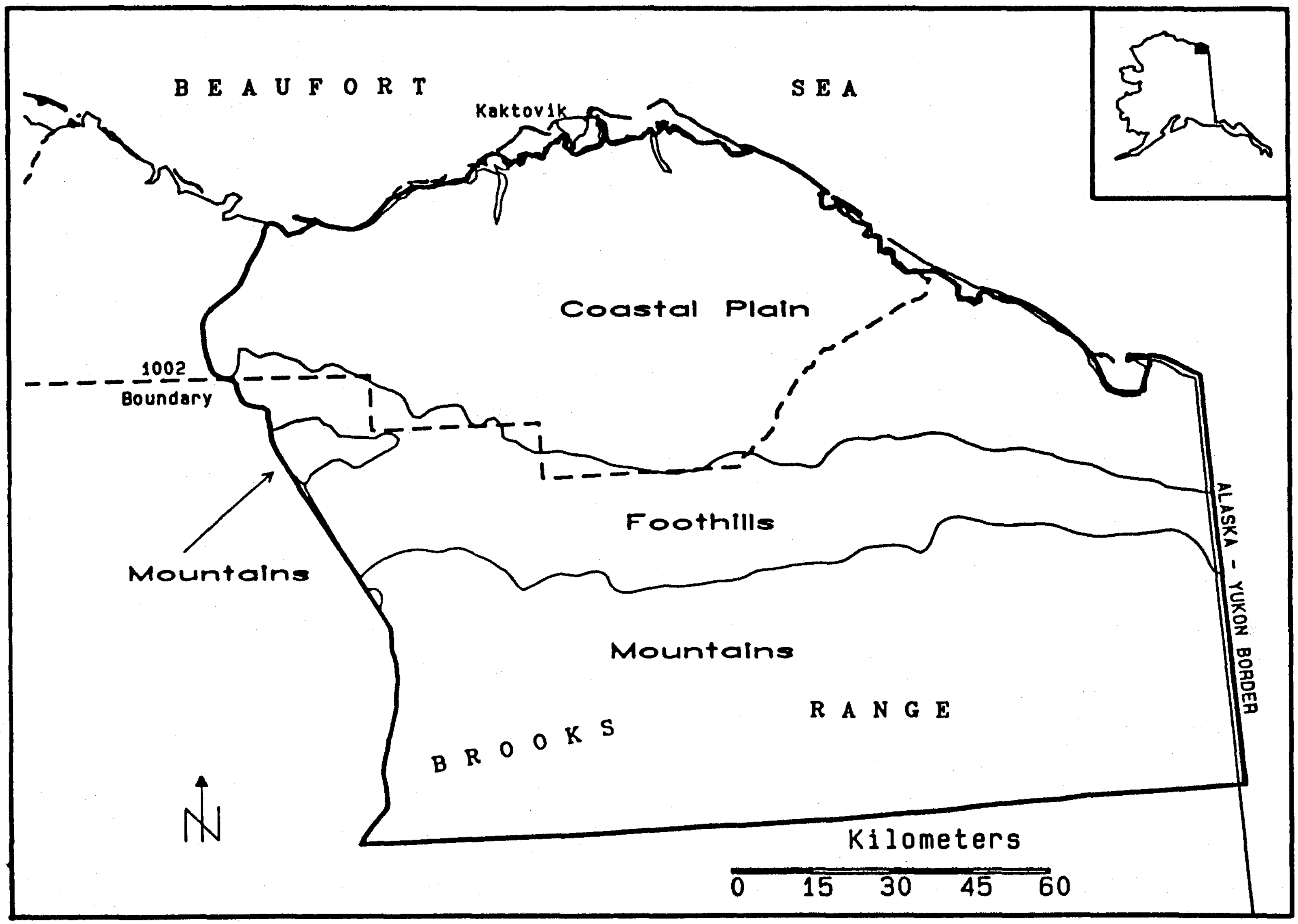

Figure 1. Location of the 1002 area, principal study area (1002 study area) and physiographic zones in the Arctic National Wildlife Refuge, Alaska.

Table 1. Age and sex composition of radio-collared brown bears monitored in the 1002 study area located on and near the coastal plain of the Arctic National Wildlife Refuge, Alaska, 1988-1990.

	1988		1989		1990	
Age/Sex	No.[a]	Perc.[b]	No.[a]	Perc.[b]	No.[a]	Perc.[b]
Adult:						
Male	11	23.4	14	26.4	14	30.4
Female	28	59.6	30	56.6	24	52.2
Subadult[c]:						
Male	3	6.4	4	7.5	3	6.5
Female	5	10.6	5	9.4	5	10.9
Total groups	47	100.0	53	100.0	46	100.0

[a] number
[b] percentage
[c] <6 years of age and independent (2 and 3 year-old radio-collared cubs accompanying sows are not represented)

assumed consecutive relocations of individuals were independent observations. Radio-tracking flights prior and subsequent to this period were conducted opportunistically. Attempts were made to visually locate instrumented bears during each relocation to ascertain attribute information including number of young with females, intraspecific and interspecific interaction, and physical and vegetative characteristics of sites. Bear and caribou relocations were plotted on U.S.G.S 1:63,360 scale topographic maps, then computer digitized in Universal Trans Mercator (UTM) coordinates.

Analyses presented in this report, unless otherwise specified, only include relocations obtained from instrumented brown bears and caribou from 29 May - 22 June (calving period), 1988-1990. The sampling unit for brown bears was a single bear, a family group, or a male bear with a consort(s) and was termed 'bear'. The sampling unit for caribou was a female caribou accompanied by a calf and was termed 'caribou'. Because spatial distributions of parturient and barren cows differed ($\underline{P} \leq 0.05$, unpubl. data), in the event a caribou lost her calf, then that individual was excluded from all further analyses for that year. To control variation in radio-location sample size among individual bears and caribou, only one relocation/animal/5 day time interval was used in the analyses. In instances where multiple radio-locations were obtained for an individual animal within a single time interval, relocations were averaged to produce a single arithmetic mean location. Based on the time caribou generally arrive on the 1002 study area, the time of peak calving, the period of greatest calf vulnerability to predation by brown bears, and the time of post calving aggregation (Garner and Reynolds 1986:213-241), the calving period was divided into 5, 5 day time intervals as follows: 29 May - 2 June (early calving); 3 June - 7 June (peak calving); 8 June - 12 June (late calving); 13 June - 17 June (post calving); 18 June - 22 June (pre-aggregation).

We tested the hypothesis that brown bears used the coastal plain, foothill, and mountain zones in proportion to availability during the years 1988, 1989, and 1990. To eliminate biases resulting from unequal sample sizes among radio-collared bears, only bears (n = 15, 16, 19, 1988-1990, respectively) relocated in each of the 5 time intervals within respective years were used in the analyses. The number of bear relocations in each physiographic zone by year and the relative availability (i.e., area) of coastal plain, foothill, and mountain zones on the study area were determined using a Geographic Information System (GIS). Significant differences in use versus availability were determined using the Chi-square goodness-of-fit and Bonferroni multiple comparison statistics (Neu et al. 1974).

The hypothesis that spatial distribution patterns of brown bears were similar in 1988, 1989, and 1990 was tested using Multi-Response Permutation Procedures (MRPP). Multi-Response Permutation Procedure is a non-parametric method for testing whether two or more sets of data come from the same probability density distribution and makes no assumption about the shape of the underlying distribution, homogeneity of variance, or equality of sample sizes (Mielke and Berry 1982, Mielke 1984). We used a randomized block design (Mielke and Iyer 1982) to reduce variation among individual bears and only locations of bears (n = 28) relocated during corresponding time intervals in each of the 3 years were compared (e.g., for a bear relocated during time intervals 1, 3, and 5 in 1988, 1 and 3 in 1989, and 1 and 5 in 1990, only those relocations for time interval 1, 1988-1990, were used in the analysis).

We tested the hypothesis that spatial distribution patterns of brown bears did not change over the course of the calving period by comparing the distributions of brown bear relocations among time intervals within respective years using MRPP procedures. Relocations were blocked by individual bear with only those bears (n = 11, 16, 19, 1988-1990, respectively) having been relocated in all 5 time intervals within a given year used in the analysis.

The hypothesis that populations of radio-collared bears (n = 47, 53, 46, 1988-1990, respectively), and caribou with calves (n = 55, 47, 53, 1988-1990, respectively) were distributed independently during concurrent time periods we tested using a distance-based test of independence (paired point-to-animal distances analysis) (Diggle and Cox 1983). The alternate hypotheses were that bear and caribou distributions were positively ('attracted') or negatively ('avoided') associated. This analysis compared distances from systematically distributed sample points to the nearest bear and caribou relocations (events) using Kendall's coefficient of rank correlation (Sokal and Rohlf 1969). Distances were measured using a "nearest neighbor" software program (J. Greslin, Alaska Fish and Wildlife Research Center, 101 12th Ave, Fairbanks, AK) run on a 386 personal computer. The number of sample points was approximately 25% of the total number of bear and caribou relocations per time interval. This procedure was based on suggested sampling intensities for systematic spatial sampling and guarded against oversampling (Diggle and Cox 1983). To minimize edge effect (Diggle and Cox 1983), the sample point was discarded when the distance from a sample point to the study area boundary was less than the distance from the nearest event, either bear or caribou.

We tested the hypothesis that distances between radio-collared caribou with calves (n = 55, 47, 53, 1988-1990, respectively), and brown bears (n = 47, 53, 46, 1988-1990, respectively) were similar within and among years. Distances between each caribou location and the nearest bear location within respective time intervals were calculated. We compared mean distances between caribou and bears among years and among time intervals within years using General Linear Model and Bonferroni multiple comparison procedures (SAS 1985). Time interval 4 was not included in among year or 1988 within year analyses because of a partial brown bear survey conducted between 13 -17 June, 1988 (i.e., all of the 21 relocations for that particular time interval were distributed in the eastern portion of the study area).

Wolves

The study area was the same as for brown bears (Fig. 1). Immobilization, handling, radio-collaring and aging procedures followed those described by Weiler and Garner (1987) for wolves in northeastern Alaska. Wolves monitored in this study were initially captured and instrumented between 1984 and 1990. Wolves were captured as they were encountered, although emphasis was placed on instrumenting breeding adults. In 1988 and 1989, we attempted to instrument all members of several packs so that the movements of all pack members, regardless of sex, age, or reproductive condition could be monitored. These efforts were mostly unsuccessful. In 1990, emphasis was placed on recollaring adult breeding females whose transmitters were about to fail. Our sample of wolves was not representative of the population with regard to sex and age composition or social status (i.e., residents versus dispersers).

Radio-tracking of wolves followed the methods described for brown bears and was mostly incidental to that for brown bears. Relocations were plotted on U.S.G.S 1:63,360 scale topographic maps, then computer digitized in Universal Transverse Mercator (UTM) coordinates. Wolf den sites were monitored by stationary ground-based observers for 2-4 day periods in late July and early August to ascertain pup production.

Analyses presented in this report, unless otherwise specified, include only locations obtained from instrumented wolves relocated during the 1988, 1989, and 1990 calving periods. The sampling unit for wolves was a single wolf or a pack of 2 or more wolves and was termed 'wolf'. Delineation of calving periods follow that described for brown bears. Because we did not have all members of individual wolf packs instrumented, and because wolf packs are loosely structured throughout the summer months with wolves hunting and traveling independently or in small groups, our analysis focused on the spatial distribution and movement patterns of radio-collared wolves associated with packs, as opposed to the juxtaposition of wolf pack territories in relation to the spatial distributions of calving caribou. Due to small annual sample sizes, we pooled radio-locations across years after ocular evaluations of wolf spatial distribution patterns for the years 1988, 1989, and 1990 showed no apparent differences. This conclusion precluded comparing wolf distributions and movements among years and small sample sizes precluded similar comparisons among time periods within years. We compared the number of wolf relocations in the coastal plain, foothill, and mountain zones from 1988-1990 to estimate use of these habitats during the calving period. The number of wolf den sites in each of the 3 physiographic zones was also determined and supplemented relocation data in assessing use of physiographic zones by wolves during the calving period.

We investigated the relationship between wolf productivity and availability of calving caribou by comparing litter sizes of wolf packs having access to calving caribou to those without access to calving caribou. Only one wolf pack without access to calving caribou during the calving period was monitored (i.e., the Drain Creek pack), although this pack normally had access to migrating adult caribou and calves later in the summer. Access to calving caribou was defined as those wolf packs whose previously defined territories (Garner and Reynolds 1986:324-

326) overlapped the traditional high density calving grounds of the PCH (i.e., the Aichilik, Egaksrak, and Sadlerochit packs). We used Scheffe's multiple contrasts for the one-way ANOVA procedure (Zar 1984:196-198) to compare litter sizes between the Drain Creek pack and the above packs with access to calving caribou. Litter sizes were logarithmic transformed to meet the assumption of normality (Zar 1984:238-239).

Golden Eagles

The study area included the coastal plain within the 1002 area and those areas to the east, south and west within approximately 30 km of the 1002 boundary. The 30 km buffer around the 1002 area was a liberal estimate of the distance golden eagles might travel from their nest sites to utilize calving caribou on the 1002 area. This was based on Newton's (1979) observations in South Dakota indicating that golden eagles ranged out 10-12 km from their nests on a regular basis.

The focus of the 1988-1990 golden eagle study was to identify breeding territories. We attempted to conduct 2 surveys per year, the first during the incubation stage to locate occupied nest territories, and the second during the fledgling stage to determine productivity, band young and collect prey remains. Survey intensity varied during the three years of the study, therefore comparisons among years were not possible.

In 1988, golden eagles were surveyed opportunistically resulting in 2 partial surveys. The first, conducted in early June from a Bell 206 helicopter, included the foothills region south of the 1002 boundary. The second, conducted in late July and early August from a PA18 Supercub, included the northern edge of the mountains and the foothills behind the Front Range, between the east end of the Sadlerochit Mountains and Egaksrak River. Nest visits to band young and collect prey remains were also conducted during this survey. In 1989, the study area was surveyed more intensively. In late May, previously known nest sites ($n = 45$) were checked for occupancy and additional areas in the Sadlerochit Mountains, Shublik Mountains, Third Range, and Front Range (Kikiktat Mountain to the Kongakut River) were also surveyed. Ground fog prevented complete surveys of the Front Range that year. In late July, all occupied golden eagle nest sites were surveyed to determine productivity, band nestlings, and collect prey remains. In 1990, a single survey was conducted in late July to determine occupancy of known nest territories, determine productivity, band young, and collect prey remains. Surveys in 1989 and 1990 were conducted from Bell 206 helicopters.

In 1988, we attempted to capture and radio-tag (instrument) golden eagles on the coastal plain and at nest sites in the foothills. Capture efforts employed techniques described by O'Gara and Getz (1986) and Ellis (1975) using a helicopter to pursue and fatigue the eagle and a net shot from the helicopter to entangle the eagle once it landed. Capture efforts at nest sites were made using harnessed pigeons and bow nets with rabbits or pigeons as bait.

RESULTS

Brown Bears

Sixty-six brown bears were radio-tracked between 1988 and 1990. Three instrumented bears died in 1988, 1 died in 1989, and 4 died in 1990. Of those deaths, none were known to be study-induced. In addition, one bear shed its collar in 1989. Forty-seven, 53, and 46 brown bears were radio-tracked, 1988-1990, respectively (Table 1), resulting in 170, 195, and 180 radio-relocations, respectively (Figs. 2-4). Not all bears were included in all analyses.

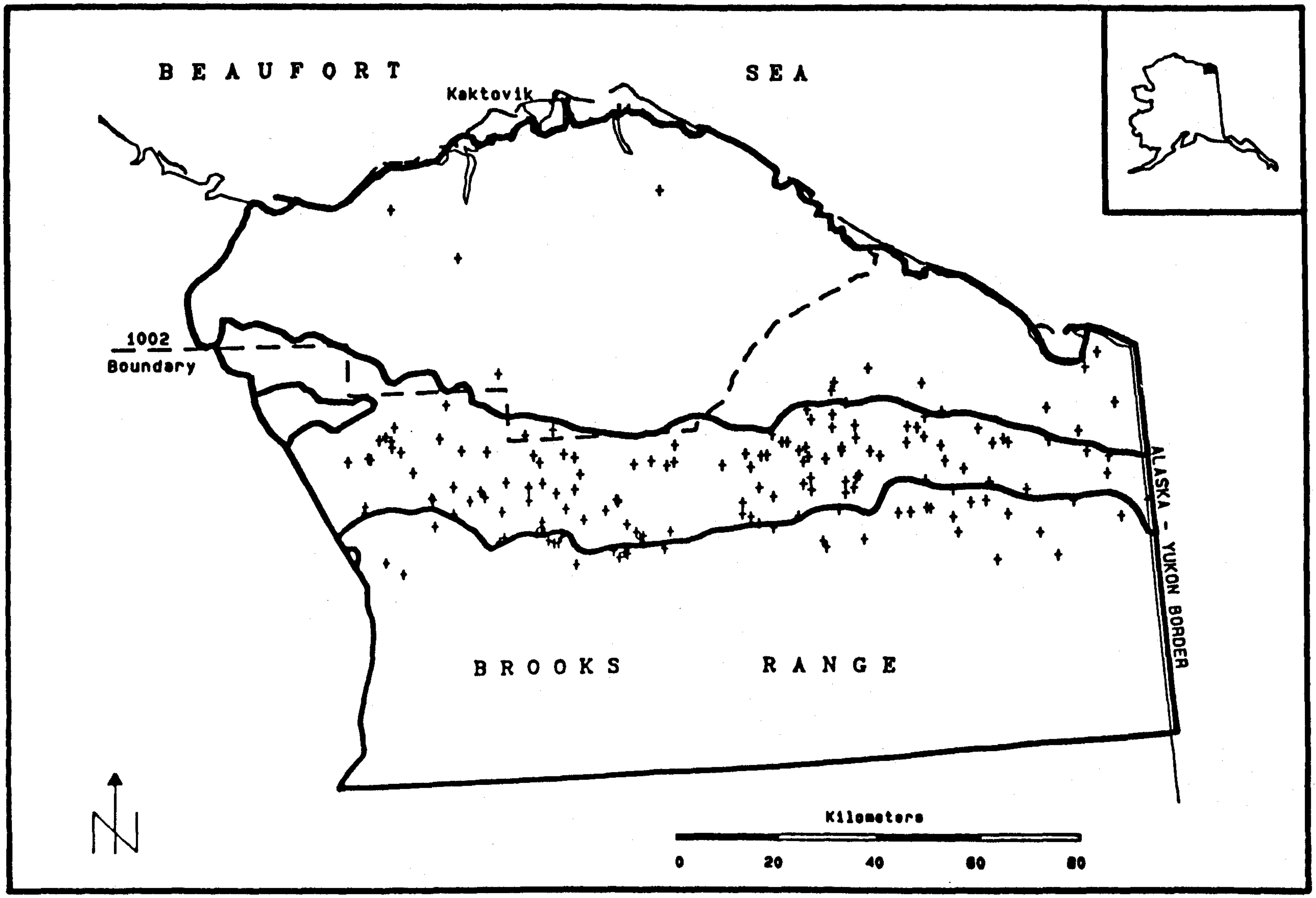

Figure 2. Radio-relocations of brown bears in the 1002 study area located on and near the coastal plain of the Arctic National Wildlife Refuge, Alaska, 29 May - 22 June, 1988.

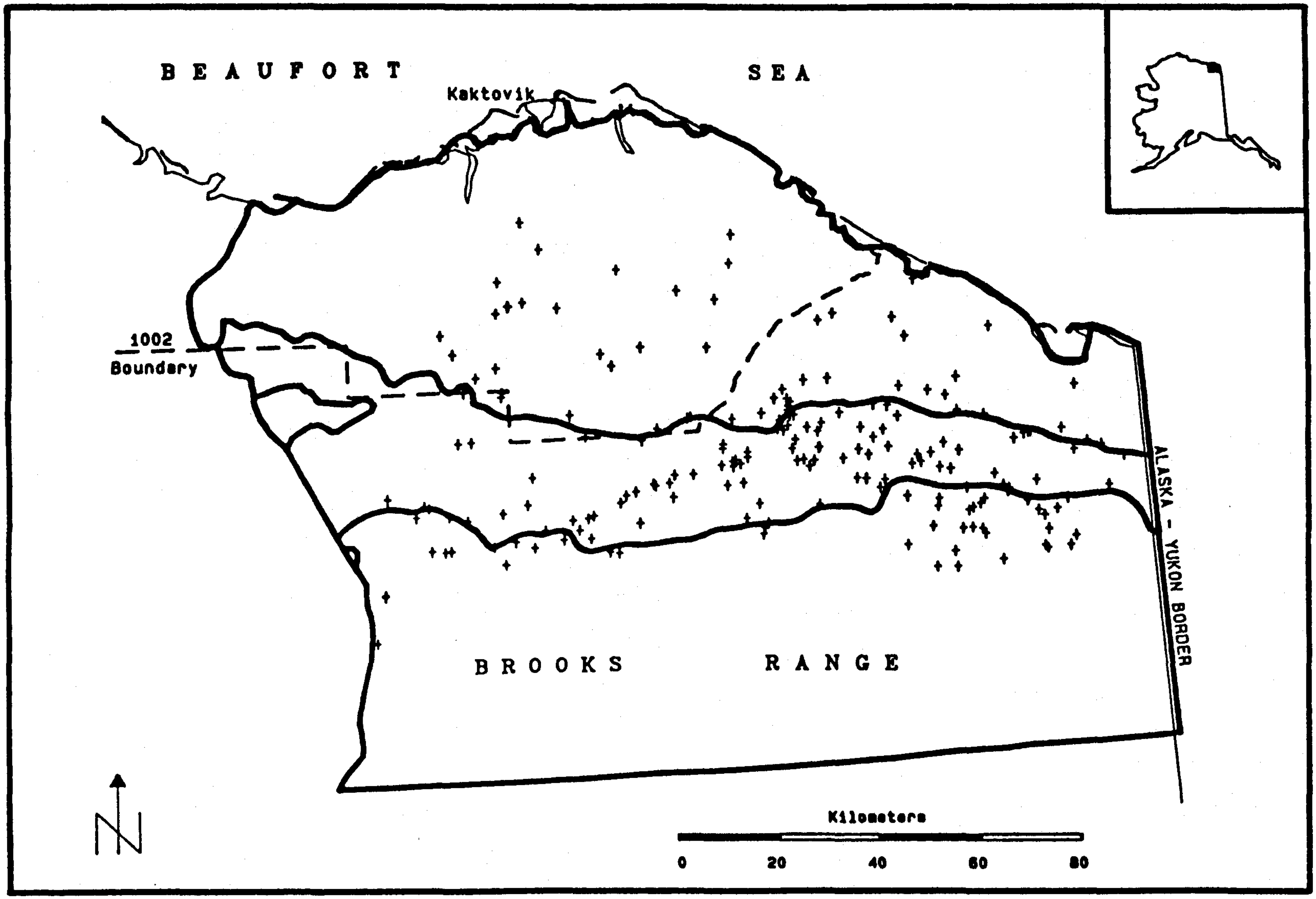

Figure 3. Radio-relocations of brown bears in the 1002 study area located on and near the coastal plain of the Arctic National Wildlife Refuge, Alaska, 29 May - 22 June, 1989.

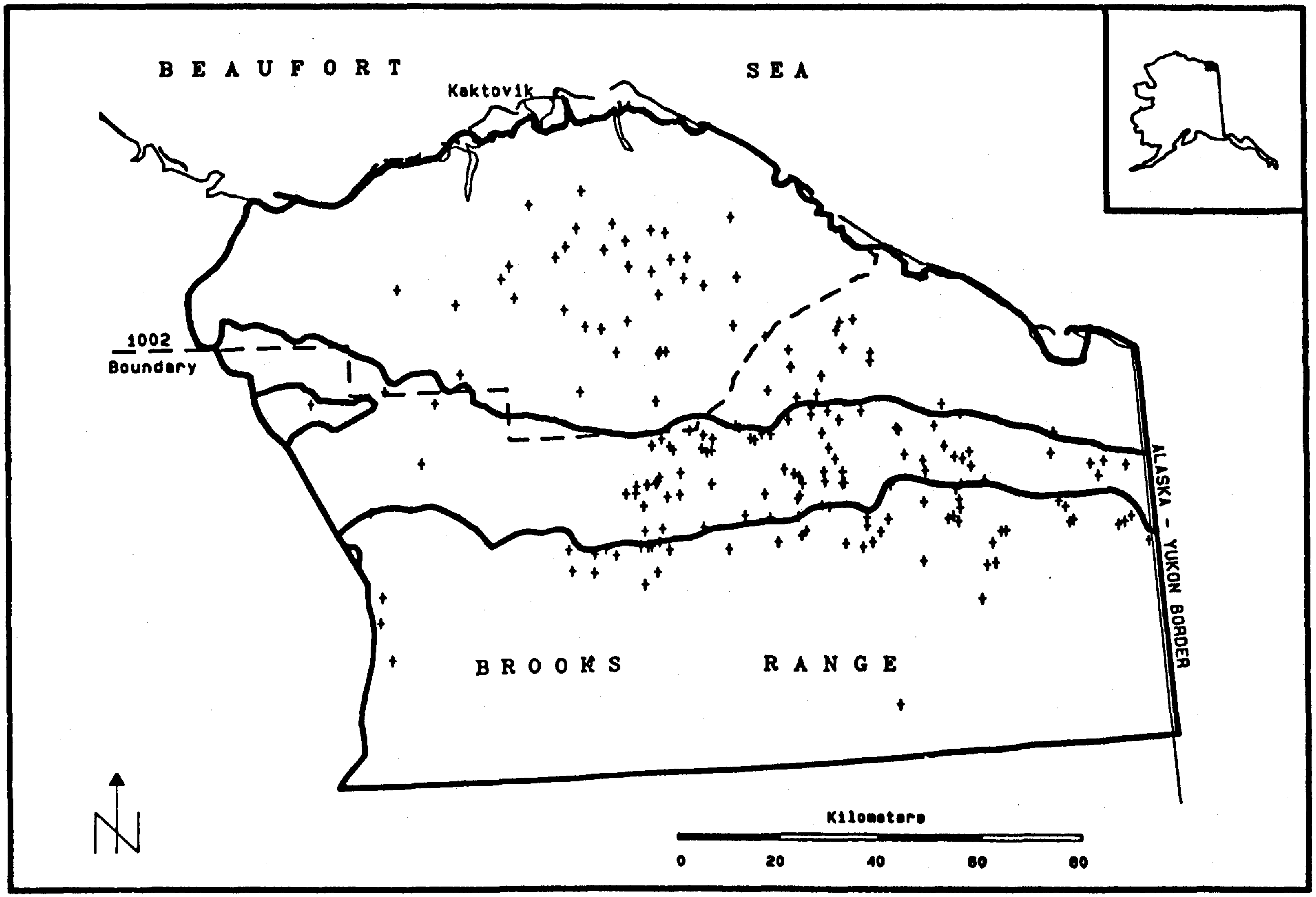

Figure 4. Radio-relocations of brown bears in the 1002 study area located on and near the coastal plain of the Arctic National Wildlife Refuge, Alaska, 29 May - 22 June, 1990.

The distribution of brown bear radio-locations relative to the coastal plain, foothill, and

The distribution of brown bear radio-locations relative to the coastal plain, foothill, and mountain zones was non-random for the years 1988 (χ^2 = 51.6; df = 2; P < 0.0001), 1989 (χ^2 = 46.6; df = 2; P < 0.0001), and 1990 (χ^2 = 50.8; df = 2; P < 0.0001)(Table 2). In all years, the foothills received greater use than expected whereas the mountains received less use than expected (P < 0.05). The coastal plain received less use than expected in 1988 and 1989 (P < 0.05), but was used in proportion to availability in 1990 (P > 0.05).

The spatial distribution patterns of brown bears differed among years (*n* = 213; MRPP: P = 0.0326). Considering only radio-locations of bears relocated in each time interval within a given year, the proportions of relocations in the coastal plain and foothills zones differed substantially between 1988 (60.0% and 12.7%, respectively; *n* = 55), 1989 (48.8 and 23.8%, respectively; *n* = 80), and 1990 (45.3% and 38.9%, respectively; *n* = 95) (Table 3).

The spatial distribution patterns of brown bears did not differ among time intervals within years, 1988-1990 (*n* = 55, 80, 95; MRPP: P = 0.56, 0.22, 0.60, respectively) (Table 3).

Distributions of brown bears and caribou with calves were positively correlated (P < 0.05) during time interval 1988 (Table 4). During all other time intervals, bear and caribou distributions were statistically independent (P > 0.05); although, distributions tended to be positively correlated in 1988 and 1989, and negatively correlated in 1990.

Mean distances between radio-collared caribou with calves and brown bears differed among years (F = 9.41; df = 2; P < 0.0001). Distances in 1988 (mean = 6.4 km) and 1989 (mean = 6.7) were less (P < 0.05) than in 1990 (mean = 11.5). Means in 1988 and 1989 were not different (P > 0.05). Mean distances also differed among time intervals in 1988 (F = 2.91; df = 3; P = 0.0364), and 1990 (F = 3.44; df = 4; P = 0.0097) (Table 5). In 1989, no differences were observed among time intervals (F = 1.92; df = 4; P = 0.1086). In 1988, the mean distance between caribou and bears during time interval 3 was less (P < 0.05) than that during time interval 5. In 1990, the mean distance for time interval 1 was less than that for time interval 5 (P < 0.05).

Wolves

Seventeen wolves in 4 packs were relocated on 58 occasions during the calving periods of the PCH, 1988-1990 (Table 6). Radio-collared wolves were relocated on the coastal plain on 5 occasions, in the foothills on 32 occasions, and in the mountains on 21 occasions (Fig. 5). Five unmarked wolves (i.e., uncollared wolves not traveling with known radio-collared wolves) were sighted, of which, 3 were in the mountains, and 2 were in the foothills. All den sites of wolf packs monitored from 1988-1990 were located in the mountains with one exception: the Sadlerochit pack denned in the foothills in 1990. None of the radio-collared wolf packs denned on the coastal plain during the course of this study.

During the calving periods 1988-1990, radio-collared wolves were relocated in the vicinity of caribou on 20 (34%) occasions and were seen on caribou carcasses on 5 (9%) occasions. In 1989, on 2 June, wolf #47 of the Sadlerochit pack and an unmarked gray wolf were observed on the coastal plain in the vicinity (<800m) of approximately 50 caribou. On 6

Table 2. Distribution of radio-locations of brown bears by physiographic zone, 29 May - 22 June, 1988 (n = 55), 1989 (n = 80), and 1990 (n = 95), in the 1002 study area located on and near the coastal plain of the Arctic National Wildlife Refuge, Alaska. Includes only brown bears relocated at least one time during each of the 5 time intervals within a year (1988: n = 11; 1989: n = 16; 1990: n = 19).

Year	Physiographic Zone	Percent of Area	R_L Obs[a]	%[b]	Ratio Obs/Exp[c]
1988	Coastal plain	38.5	7	12.7	0.33[d]
	Foothills	18.9	33	60.0	3.17[d]
	Mountains	42.6	15	27.3	0.64[d]
1989	Coastal plain	38.5	19	23.8	0.62[d]
	Foothills	18.9	39	48.8	2.58[d]
	Mountains	42.6	22	27.5	0.65[d]
1990	Coastal plain	38.5	37	38.9	1.01
	Foothills	18.9	43	45.3	2.40[d]
	Mountains	42.6	15	15.8	0.37[d]

[a] radio-locations observed
[b] percentage
[c] radio-locations observed divided by radio-locations expected
[d] significantly different from expected at the P < 0.05 level (Bonferroni multiple comparisons test)

Table 3. Percentage frequency of radio-relocations of brown bears by physiographic zone and time interval in 1988 (n = 55), 1989 (n = 80), and 1990 (n = 95), in the 1002 study area located on and near the coastal plain of the Arctic National Wildlife Refuge, Alaska. Includes only brown bears relocated at least one time during each of the 5 time intervals within a year (1988: n=11; 1989: n = 16; 1990: n = 19).

		Percentage				
	Physiographic	Time Interval[a]				
Year	Zone	1	2	3	4	5
1988	Coastal plain	0.0	1.8	3.6	3.6	3.6
	Foothills	16.4	9.1	14.5	12.7	7.3
	Mountains	3.6	9.1	1.8	3.6	9.1
1989	Coastal plain	2.5	3.8	5.0	6.3	6.3
	Foothills	11.3	8.8	11.3	10.0	7.5
	Mountains	6.3	7.5	3.8	3.8	6.3
1990	Coastal plain	8.4	6.3	9.5	8.4	6.3
	Foothills	7.4	9.5	8.4	8.4	11.6
	Mountains	4.2	4.2	2.1	3.2	2.1

[a] 1 = 29 May - 2 June; 2 = 3-7 June; 3 = 8-12 June; 4 = 13-17 June; 5 = 18-22 June

Table 4. Sample sizes, Kendall's coefficients of rank correlation (KCRC) and probability values by time interval for paired point-to-animal distances of radio-collared female caribou accompanied by calves and radio-collared brown bears between 29 May - 22 June, 1988-1990, in the 1002 study area located on and near the coastal plain of the Arctic National Wildlife Refuge, Alaska.

Time Interval[a]	Number Bear Relocations	Number Caribou Relocations	Number Sample Points	KCRC	P Value[b]
1988_1	36	48	22	0.4026	$P > 0.05$
2	35	39	20	0.2421	$P > 0.2$
3	43	40	21	0.4571	$P < 0.05$
4	21	41	14	0.2308	$P > 0.2$
5	35	34	17	0.1618	$P > 0.5$
1989_1	34	44	15	0.5048	$P > 0.05$
2	40	43	20	-0.0316	$P > 0.5$
3	40	40	22	0.3420	$P > 0.1$
4	40	40	18	0.2941	$P > 0.2$
5	41	40	17	0.1176	$P > 0.5$
1990_1	36	41	16	-0.3167	$P > 0.2$
2	33	45	22	-0.1342	$P > 0.5$
3	41	38	19	-0.0877	$P > 0.5$
4	40	24	16	-0.1167	$P > 0.5$
5	37	35	18	-0.2288	$P > 0.2$

[a] time interval: 1 = 29 May - 2 June; 2 = 3-7 June; 3 = 8-12 June; 4 = 13-17 June; 5 = 18-22 June.
[b] two-tailed test.

Table 5. **Mean distances between radio-collared female caribou accompanied by calves and radio-collared brown bears by time interval in the 1002 study area located on and near the coastal plain of the Arctic National Wildlife Refuge, Alaska, 1988-1990.**

Year	Time Interval[a]	Number of Measurements	Mean Distance[b]	Standard Error
1988	1	48	6.4	0.8
	2	39	7.0	1.2
	3	40	4.0[c]	0.9
	4	41	10.8[de]	2.1
	5	34	8.3[c]	1.1
1989	1	44	6.2	0.5
	2	43	7.0	0.7
	3	40	5.9	0.7
	4	40	6.1[d]	0.7
	5	40	8.4	0.9
1990	1	41	9.3[f]	0.7
	2	45	11.2	0.8
	3	38	10.6	0.9
	4	24	13.2[d]	1.9
	5	35	14.1[f]	1.1

[a] 1 = 29 May - 2 June; 2 = 3-7 June; 3 = 8-12 June; 4 = 13-17 June; 5 = 18-22 June

[b] in kilometers

[c] means of time intervals 3 and 5 differ at the $\underline{P} < 0.05$ level (Bonferroni multiple comparisons test)

[d] not included in among year comparisons due to an incomplete survey conducted during time interval 4 in 1988

[e] not included in within year comparisons due to an incomplete survey conducted during time interval 4 in 1988

[f] means of time intervals 1 and 5 differ at the $\underline{P} < 0.05$ level (Bonferroni multiple comparisons test)

Table 6. Number of radio-collared wolves, pack size, and number of pups of wolf packs radio-tracked in the 1002 study area located in and near the coastal plain of the Arctic National Wildlife Refuge, Alaska, 1988-1990.

		Number		
Year	Pack	Radio-collared	Individuals	Pups[a]
1988	Aichilik[b]	4	5	5
	Egaksrak[b]	2	2	1
	Sadlerochit[b]	6	8	4
	Drain Creek[c]	3	4	3
1989	Aichilik[b]	4	5	8
	Egaksrak[b]	2	3	3
	Sadlerochit[b]	4	4	0[d]
	Drain Creek[c]	3	5	6
1990	Aichilik[b]	3	8	7
	Egaksrak[b]	1	4	–
	Sadlerochit[b]	2	3	2
	Drain Creek[c]	2	9	3

[a] minimum number of pups counted during the denning period
[b] had access to the traditional calving grounds of the Porcupine caribou herd
[c] did not have access to the traditional calving grounds of the Porcupine caribou herd
[d] the Sadlerochit pack did not den in 1989 because both the male and female breeders were killed during late winter of that year. Thus, we did not include the 1989 data for the Sadlerochit pack in litter size comparisons between packs with and without access to calving caribou

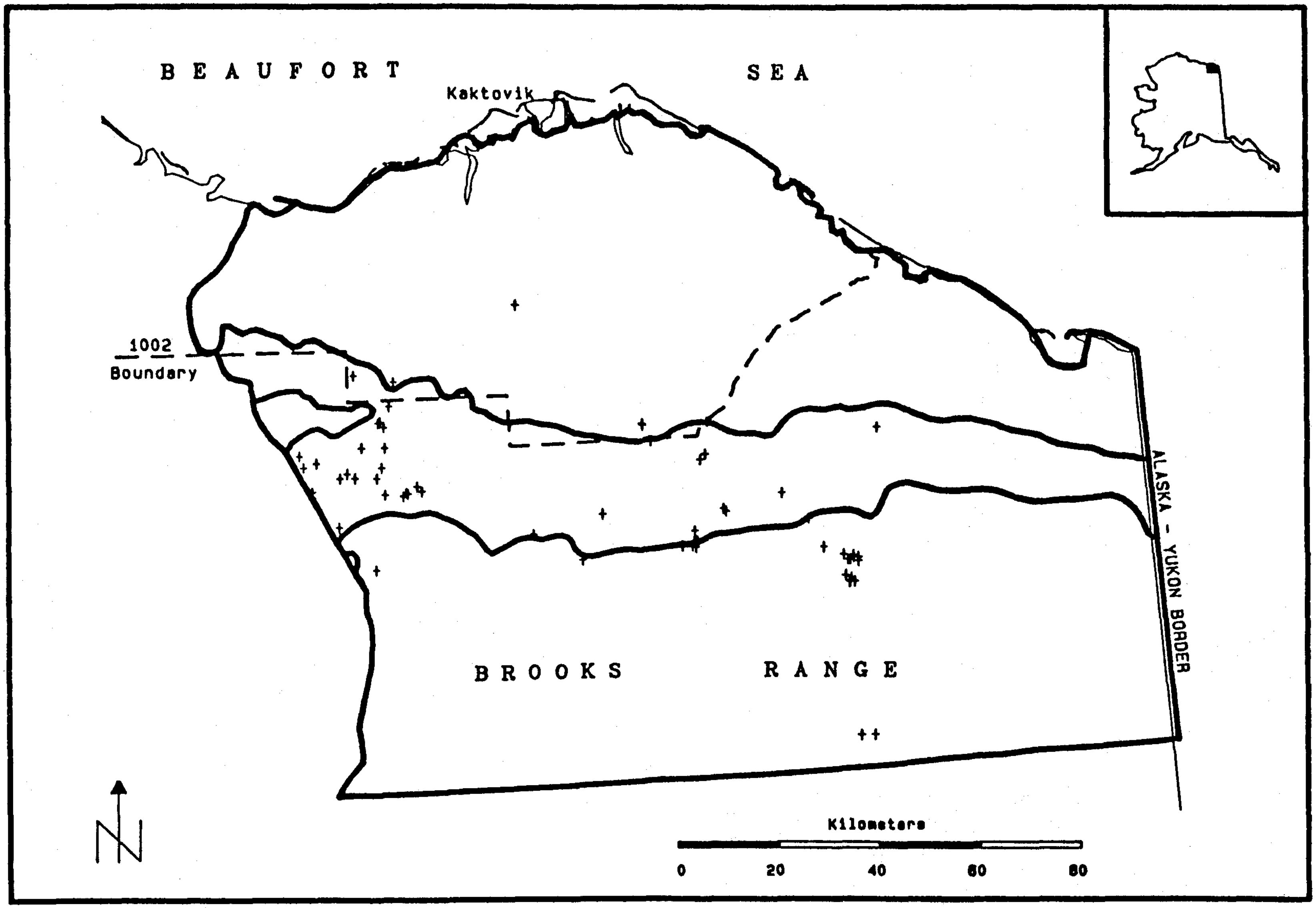

Figure 5. Radio-relocations of wolves in the 1002 study area located on and near the coastal plain of the Arctic National Wildlife Refuge, Alaska, 29 May - 22 June, 1988-1990.

June, wolves #40 and #42 were relocated on the coastal plain in the vicinity of about 100 caribou. On 8 June, wolf #49 of the Aichilik pack was relocated on the coastal plain in the vicinity of 20 caribou. Also, on 1 July, both the Aichilik (6 adults) and Egaksrak (2 adults) packs were relocated 33 km and 57 km, respectively, from their dens in the direction of large aggregations of caribou approximately 30 km away. In 1990, on 13 June, wolves #31, #45 and #46 of the Aichilik pack were relocated on the high coastal plain/low foothill region with a dead caribou calf. On 19 June, wolves #45 and #46 were relocated on the coastal plain about 400 m from the carcass of an adult bull caribou. In the above cases, the Aichilik wolves were approximately 16 and 23 km north, respectively, of their den site.

Litter size for 10 known litters ranged from 1 to 8 pups with a mean of 4.2 pups/litter (Table 6). Mean litter size of 4.3 pups for 7 litters of the 3 wolf packs with access to calving caribou was not different ($S = 0.0377$; $F_{.05(1), 3, 6}$; $\underline{P} > 0.25$) from that of 4.0 pups for 3 litters of the 1 wolf pack without access to calving caribou.

Golden Eagles

Since survey effort varied between years, survey results for each year are presented separately. Locations of golden eagle nest structures in northern ANWR are shown in Figure 6.

1988 Surveys: During the early June survey, 5 golden eagle nest territories were identified, 4 of which were occupied. During the late July survey, 9 new nests were located, all of which were unoccupied. In addition, 6 known (previous to 1988) nest sites were checked, 4 of which were occupied. The cliff complex on the east fork of the Okerokovik had 2 unoccupied nests, and an adult persistently soared above the cliffs. These cliffs were such that it was very difficult to search them from the air, and there could have been an occupied nest there also. At the 8 occupied nest sites, a total of 10 young were produced for an average of 1.25 young per pair (Table 7).

1989 Surveys: In late May 1989, golden eagles were found nesting at 8 of 45 previously known nest sites. In addition, 6 new nest sites were located. Three eagles were seen at cliffs and 18 eagles (4 adults, 10 subadults and 4 unknown age) were observed in non-nest cliff areas. In late July, 11 of the 14 breeding pairs previously observed in May produced 14 young (Table 7), 8 of which were banded.

1990 Survey: Nine occupied golden eagle nests and 10 golden eagle nestlings were observed (Table 7). Three nests were visited and 3 nestlings were banded. Several adult eagles not associated with nest territories were observed, and these eagles could have been from pairs that attempted to breed but failed. Since only one survey was conducted, the number of pairs that attempted to breed but failed is unknown. Of the 10 golden eagle nestlings observed during the survey, 3 had fledged previous to the survey, 1 was dead in the nest, 2 were nearly fledged (> 10 weeks old), 3 were between 7 and 9 weeks old, and one was approximately 6 weeks old.

Radio-tagging: Two subadult eagles were captured and instrumented on the coastal plain between 29 May and 5 June, 1988. In late July and early August, 10 nests were visited, and 7 nestlings were radio-tagged. Although attempts were made to catch adult golden eagles at most of these nest sites, none were captured. No golden eagles were instrumented in 1989 or 1990.

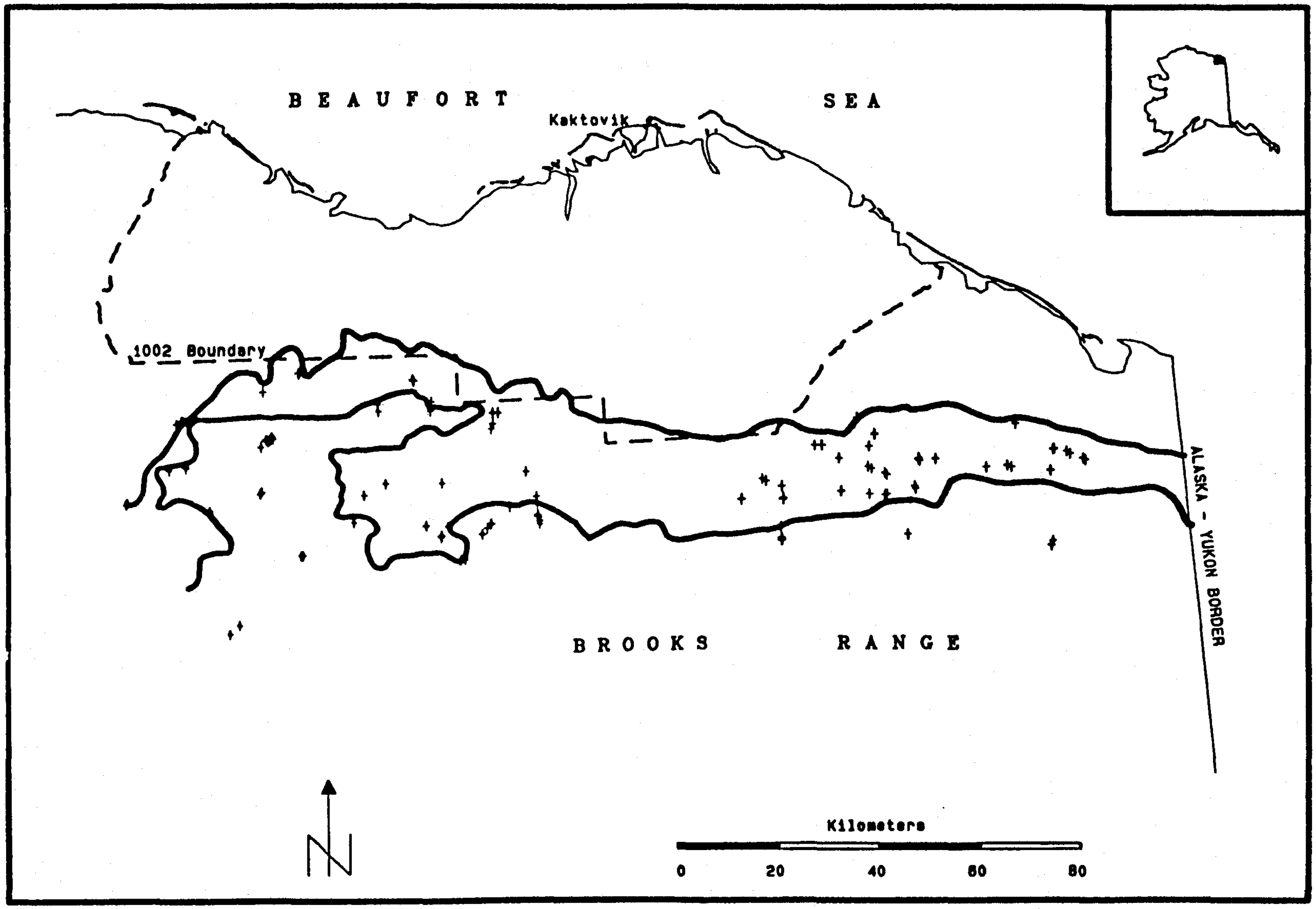

Figure 6. Golden eagle nest structures located within 30 km of the 1002 area in the Arctic National Wildlife Refuge, Alaska, 1988-1990.

Table 7. Productivity of golden eagle nest territories checked within 30 km of the 1002 area located on the Arctic National Wildlife Refuge, Alaska, 1988-1990.

	Year		
	1988	1989	1990
Number of pairs	9	14	9
Pairs with young	8	11	8
Number of young	10	14	10
Young per successful pair	1.25	1.27	1.25

Both of the subadults instrumented on the coastal plain remained in the immediate area of their capture for several weeks and then were not seen or heard again. Both birds were observed several days after capture and both flew well with the radio package. The 7 young instrumented eagles were observed at or near the nest sites throughout the remainder of the summer. During the last radio-tracking survey of 29 September to 4 October, no instrumented eagles were detected. This may have been function of the solar cells on the transmitters being covered by feathers resulting in transmitter failure after about 2 weeks.

Prey: Prey remains seen at golden eagle nests included caribou, Dall sheep (*Ovis dalli),* ptarmigan (*Lagopus* spp.), arctic ground squirrel (*Spermophilus parryii*), short-eared owl (*Asio flammeus*), common raven (*Corvus corax*), and a water pipit (*Anthus spinoletta*). Arctic ground squirrel appeared to be the most commonly taken prey.

DISCUSSION

Brown Bears

Andrewartha and Birch (1954) stated that animal distribution is the spatial expression of animal abundance. In this study, the foothills received greater use by bears than either the coastal plain or the mountains, therefore, spatial distribution data study suggest that, during the calving period, brown bears were more abundant in the foothills than on the coastal plain or in the mountains.

Several hypotheses may explain our observations regarding brown bear distributions in ANWR. The foothills provide a varied physiographic environment which ultimately increases habitat diversity. Pearson (1977) reported that in the southwestern Yukon, the greatest bear densities and smallest home ranges were found in areas with the most rugged terrain and the highest habitat diversity. Thus, our first hypothesis is that the foothills provide greater habitat diversity than either the coastal plain or mountains, because the coastal plain is extremely flat and much of the mountains lack sufficient soils to support the growth of vegetation.

Pearson (1977) hypothesized that social intolerance regulated grizzly bear numbers, and in diverse, rugged areas there was less chance for 2 bears to confront one another. This second hypothesis may be applicable to our study area where open tundra provides little protective cover. The foothills and mountains may be important to adult females with young, especially those with newborn cubs, in avoiding confrontations with other bears, particularly adult males.

Our third hypothesis involves Arctic ground squirrels, an important brown bear food item in ANWR (Phillips 1984), which are found in colonies restricted to well-drained, permafrost-free soils (Mayer and Roche 1954, Melchior 1964). Such areas are found along ridges, river sand banks, hillocks, and other raised areas in sandy soils. Thus, one would expect a greater abundance of ground squirrels in the foothills than on the coastal plain or in the mountains. Banfield (1958) hypothesized that the central Canadian Arctic population of grizzly bears could not survive in areas devoid of ground squirrels.

The fourth hypothesis to account for observed bear distributions is that the foothills and mountains also provide den sites for brown bears during late fall, winter, and early spring. On ANWR, from 1982 through 1985, 189 of 199 brown bear dens were located in the foothills and mountains (Garner and Reynolds 1986). They noted that all bears captured on the coastal plain and foothills moved south of their capture locations to den. Of the brown bears monitored during the winters of 1988-1989 (n = 53) and 1989-1990 (n = 46) in this study, only one bear denned on the coastal plain. These data demonstrate that there is not a discrete subpopulation of brown bears inhabiting the coastal plain throughout the year, but that some bears' home ranges include the coastal plain. Those bears apparently use the coastal plain to varying degrees within and among years depending, most likely, on a variety of biotic and abiotic factors.

The spatial distribution patterns of radio-collared brown bears during calving differed among years. One hypothesis for these annual differences is that brown bear distributions change in response to calving caribou distributions (Figs. 7-9). Garner et al. (1985) reported that brown bears shifted their use onto the coastal plain in years when caribou calved there. In 1988, when snow melt on the coastal plain was latest in 20 years and caribou calved primarily in the foothills, 12.7% of the brown bear relocations were on the coastal plain and 60.0% were in the foothills. In contrast, in 1989 when calving occurred on the southern portion of the coastal plain, 23.8% and 48.8% of the brown bear relocations were found in the coastal plain and foothill zones, respectively. In 1990, when caribou calved primarily on the coastal plain as a result of the earliest breakup ever recorded; by 28 May the entire coastal plain was >95% snow free (Fancy and Whitten 1991), 38.9% of the brown bear relocations were on the coastal plain and 45.3% were in the foothills.

Within years, we detected no changes in the spatial distribution patterns of radio-collared brown bears with respect to the chronology of calving. This suggests that brown bear distribution patterns may have been established prior to and possibly independent of the distributions of calving caribou and remained relatively constant throughout the calving period. One hypothesis for these results may be that some bears follow the melting snowline north onto the coastal plain in spring. In 1988, when breakup was unusually late, no brown bears were relocated on the coastal plain during the early calving period (time interval 1); whereas, in 1990, when breakup was unusually early, 8.4% of the brown bear relocations were on the coastal plain during the early calving period. In addition, brown bear use of the coastal plain tended to increase progressively through the calving period in 1988 and 1989, years when breakup occurred during the calving period, whereas, this trend was not apparent in 1990, a year when the coastal plain

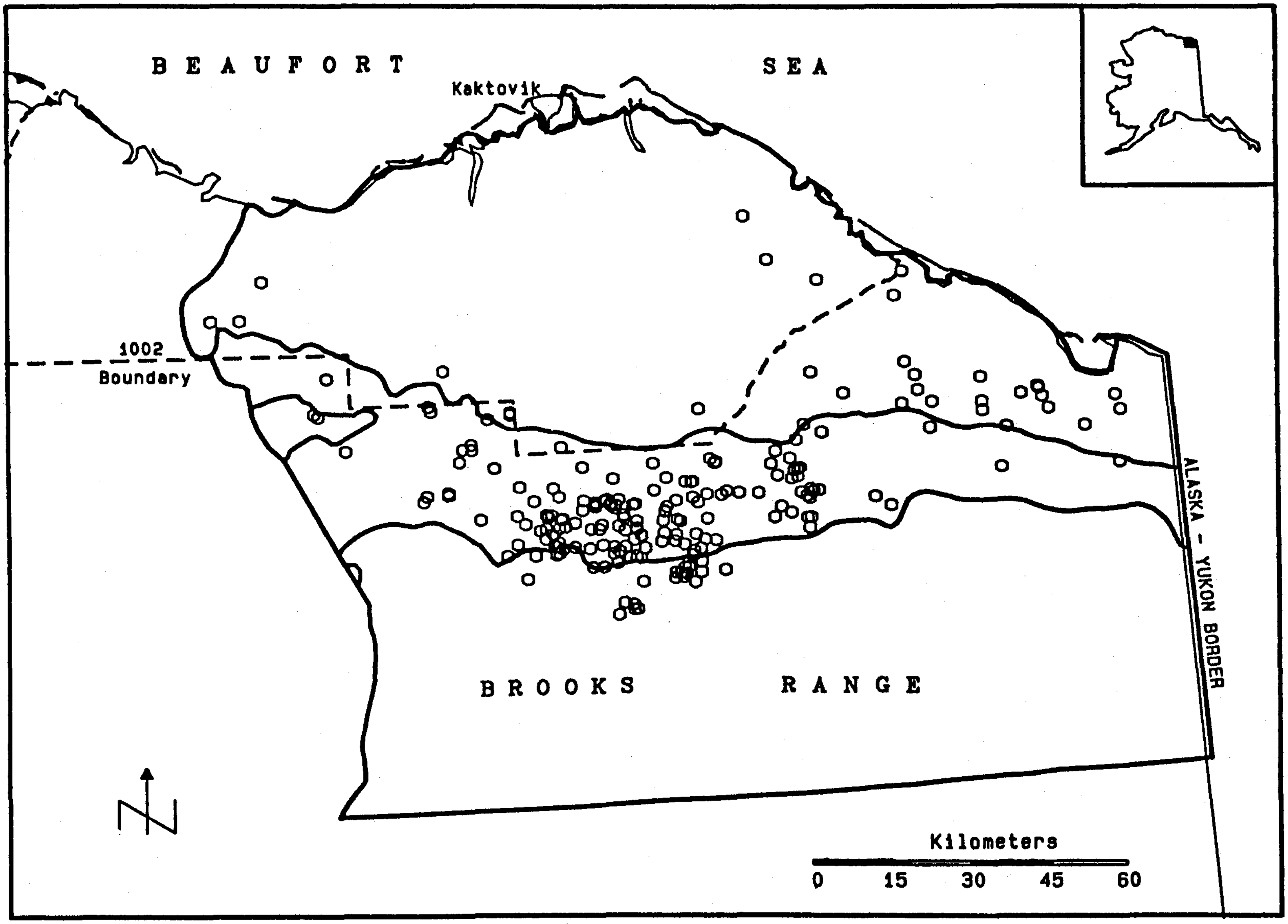

Figure 7. Radio-relocations of female caribou accompanied by calves in the 1002 study area located on and near the coastal plain of the Arctic National Wildlife Refuge, Alaska, 29 May - 22 June, 1988.

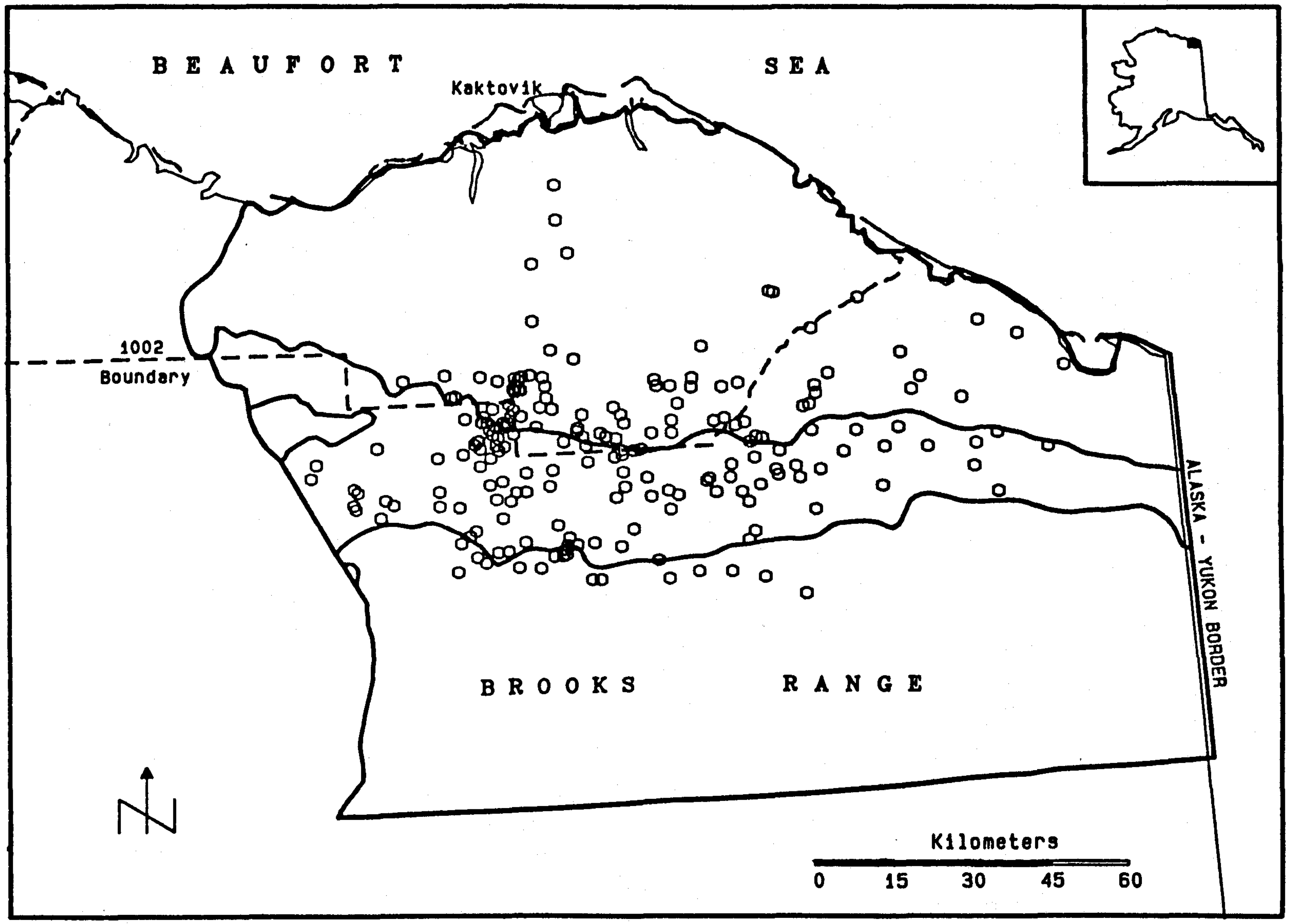

Figure 8. Radio-relocations of female caribou accompanied by calves in the 1002 study area located on and near the coastal plain of the Arctic National Wildlife Refuge, Alaska, 29 May - 22 June, 1989.

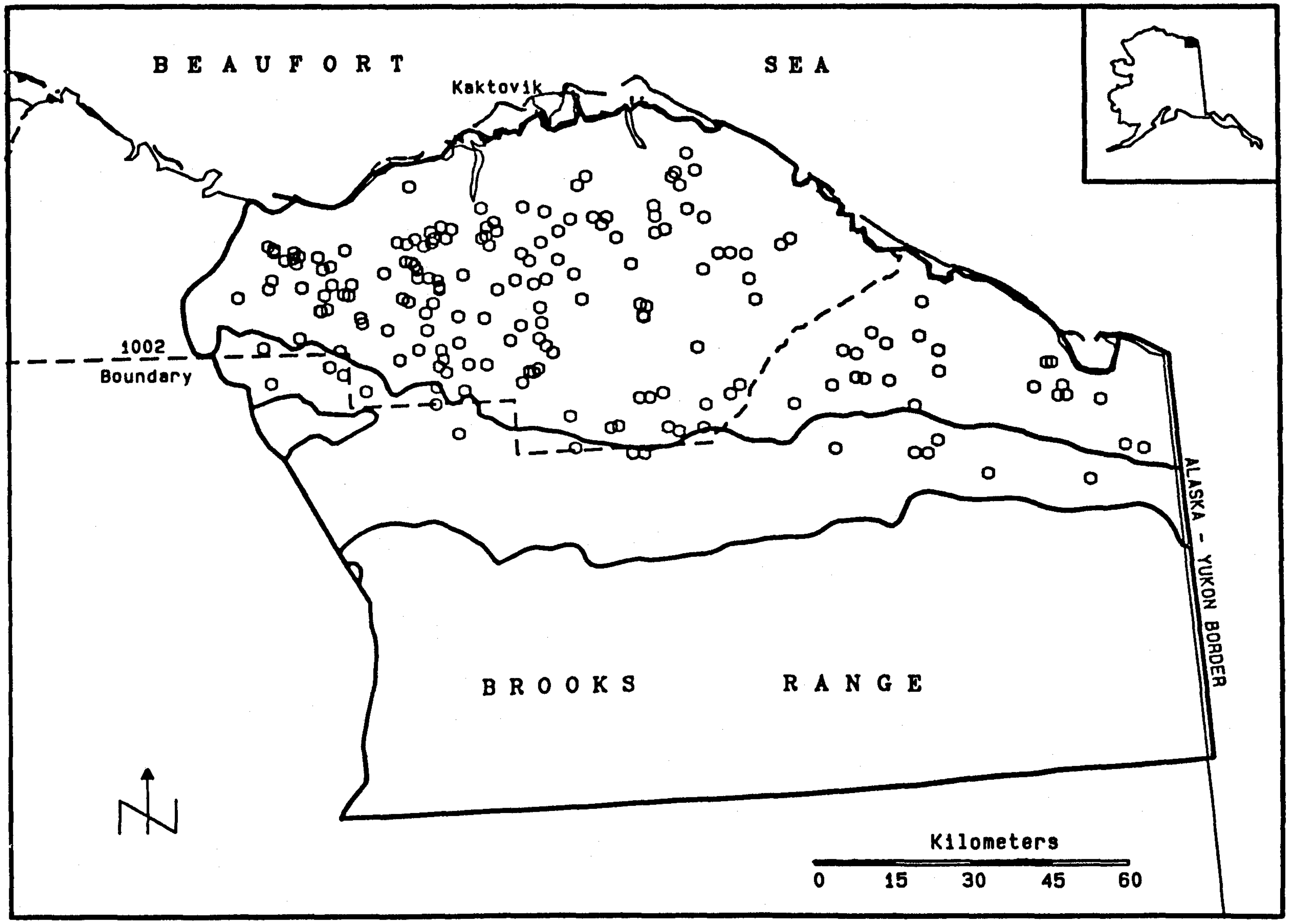

Figure 9. Radio-relocations of female caribou accompanied by calves in the 1002 study area located on and near the coastal plain of the Arctic National Wildlife Refuge, Alaska, 29 May - 22 June, 1990.

was snow free prior to the beginning of the calving period (see Table 3). Pearson (1976) found that bears in the Barn Mountains of the Yukon Territory moved north along drainages in the spring and onto the coastal plain. Earlier studies in ANWR also indicated a general northward movement in the late spring and early summer (Garner and Reynolds 1986). Snow melt, similarly, may influence brown bear distribution patterns in ANWR as it appears to for the PCH and brown bears in other areas (Mundy and Flook 1973, Valkenburg 1976, Martinka 1971).

Multi-Response Permutation Procedure analyses may not have detected changes in bear distributions, because only a small segment of ANWR brown bear population appeared to shift their use patterns to include the coastal plain. Between 0 - 25% of the radio-collared bears in this study used the coastal plain at any one time during calving. Reynolds and Garner (1987) reported in the western Brooks Range that brown bears did not extend their established seasonal range to include calving caribou, but moved to those portions of their ranges where caribou were available. Pearson (1976) also did not detect a shift in home ranges of bears to take advantage of migrating caribou in the Barn Mountains of the Yukon Territory. Results from this study indicated that the majority of brown bears in ANWR behaved similarly.

The positive association observed for bear and caribou distributions during time interval 1988 (8-12 June) may be a function of a combination of factors including: 1) calving chronology, 2) changing calf vulnerability to predation by brown bears over time, and 3) seasonal snow melt patterns. Peak calving occurs during the first week of June each year with calving having been essentially completed by 15 June (Garner and Reynolds 1986). Calves are most vulnerable to predation by bears during a relatively short period of time when they lack adequate mobility to escape (Garner and Reynolds 1986). Thus, one might expect the greatest number of highly vulnerable calves to be available to bears just after the peak of calving. In 1988, when caribou calved primarily in the foothills, radio-tracking studies indicated that bears also remained in the foothills that year (Weiler et al. 1989). As a result, bears probably had greater opportunity to utilize caribou calves during time interval 3 in 1988 than during any other time interval in any year, and the significant, positive correlation observed for that time interval may be a reflection of that opportunity. During time interval 3 in 1989, the association between bears and caribou was not as strong as in 1988 possibly because calving caribou were found primarily in the northern foothills and southern coastal plain at that time. In contrast, bear and caribou distributions were independent during time interval 3 in 1990, possibly because calving caribou were found on the coastal plain at that time.

There may be a relationship between seasonal snow melt patterns, post-perinatal calf mortality ($\geq$ 48 h after birth), and the annual trends in brown bear-caribou association that we observed. In 1988, when bears and caribou remained in the foothills through the calving period, only positive associations were observed (Table 4). In 1989, when caribou calved primarily in the northern foothills and southern coastal plain, bear-caribou associations were still mostly positive. However, in 1990, when calving occurred primarily on the coastal plain, only negative associations were observed. This trend in bear-caribou association is consistent with Fancy and Whitten's (1991) findings of higher post-perinatal calf mortality for calves of radio-collared cows through the month of June in 1988 (12%) and 1989 (9%) than in 1990 (0%).

Proximity among radio-collared caribou and brown bears appeared to be related to annual and seasonal snow melt patterns and the chronology of calving. Mean distances between radio-collared bears and radio-collared caribou were smallest in 1988, increased slightly in 1989, and were largest in 1990. The average distance between caribou and brown bears tended to decrease from the early calving period (time interval 1), through the late calving period (time interval 3), and then increase through the pre-aggregation period (time interval 5) (see Table 5). These results are consistent with results of the paired point-to-animal distances analyses suggesting that the potential for caribou/brown bear interaction is greatest when snow melt on the coastal plain is delayed and when the majority of calves have been born, but are still vulnerable to predation by bears.

Wolves

During the calving period, radio-collared wolves were relocated predominately in the foothills and mountains and were less often relocated on the coastal plain. During that period, radio-collared wolves were frequently found at or near their dens, all of which were located in the mountains and foothills. Since 1982, there have been no reported cases of wolf dens on the coastal plain (Weiler and Garner 1987, this study). Fancy and Whitten (1991) found that losses of caribou calves were greatest in years when caribou calved in the foothills as opposed to years when calving occurred on the coastal plain. They speculated that the differential mortality was due to predators. They did not differentiate between types of predation. Based on our radio relocation data and wolf den site location information, wolves appear to be more abundant in the mountains and foothills than on the coastal plain. However, our data are biased against younger and dispersing wolves. Weiler and Garner (1987) hypothesized that younger and dispersing wolves may utilize the coastal plain more than older wolves.

All wolf packs with access to traditional caribou calving grounds made movements that appeared to be associated with calving caribou. In 1989, several members of the Sadlerochit pack were relocated on the coastal plain near caribou during the calving period. It is worth noting that this pack did not den that year and the pack was comprised of young, nonbreeding animals. Also in 1989, wolves of the Egaksrak and Aichilik packs made extensive movements onto the coastal plain during the time of caribou aggregations. In 1990, members of the Aichilik pack were relocated on several occasions on the coastal plain in the vicinity of caribou. Twice they were observed on or near caribou carcasses. Thus, our data does indicate that wolves in ANWR made excursions from their denning areas onto the coastal plain and utilized caribou.

There was no statistical difference in pup production between wolves with access to traditional caribou calving grounds (4.3 pups/litter) and wolves without access to traditional calving grounds (4.0 pups/litter). Weiler and Garner (1987) reported litter sizes ranging between 3.0 and 4.75 for wolves in ANWR in 1984 and 1985. In the north central Brooks Range, Stephenson and Johnson (1972) reported 5.2 pups/litter for wolves without access to traditional caribou calving grounds. Our data gave no indication that access to traditional caribou calving grounds of the PCH enhanced wolf productivity.

Golden Eagles

Little work has been done on golden eagles in northern Alaska. Surveys prior to 1989 were opportunistic, and generally only known nest sites were visited. Although the 1989 nesting survey was the most intensive ever undertaken in or near the 1002 area, this effort was minimal relative to the approximately 5500 km^2 study area. In addition, during this study, surveys conducted during the incubation stage were limited. As a result, breeding pairs which occupied territories but failed to fledge young and, subsequently abandoned the nest, were most likely missed by surveys conducted later in the year. Regardless, this study identified several new nesting territories and the general distribution pattern of breeding golden eagles in and near the 1002 area was established. A minimum estimate of the number of nest territories within 30 km of the 1002 area is 27, based on nest clusters identified during partial surveys, 1988-1990, and then extrapolating to include the entire study area. Specifically, a total of 170 nest structures are now known in the study area, although many of these are probably alternate nests within a single nesting territory. The actual number of nesting territories in the study area is unknown and likely will take several years of study to determine.

The number of young (nestlings at least 6 weeks old) observed varied considerably among years, most likely because of varied survey intensity among years. The number of young per successful pair, a measure of productivity not affected by survey intensity, was remarkably consistent between years. The number of young per successful pair in our study was lower than the 1.45 young per successful pair observed in Denali National Park in 1988 (C. McIntyre, pers. comm.) and the 1.5 average reported by Ritchie and Curatolo (1982) in interior Alaska. Campbell (1960) suggested that the northern Brooks Range was near the northern limit for successful nesting by golden eagles. The low productivity figures for the 1002 study area could be a reflection of marginal nesting conditions. Further study is necessary to confirm this.

Initial capture efforts in 1988 demonstrated the difficulty and expense involved in capturing golden eagles in the 1002 area. A variety of factors contributed to our limited success. First, study objectives called for fitting radio collars to eagles prior to the arrival of caribou onto the coastal plain to calve, however, relatively few eagles were on the coastal plain at that time. Second, flat terrain and calm winds are essential for this type of capture, because of the eagle's ability to use terrain to avoid close approach by helicopters, and because winds provide eagles, even those with a full crop, with adequate lift for takeoff. In 1988, calving occurred primarily in the foothills, wind speeds were generally over 10 mph, and few eagles with large crops were seen prior to calving. As a result, conditions were generally unsuitable for capturing eagles. Last, attempts to capture adult golden eagles at nest sites using bait failed, either because the birds were extremely wary or because adults spent little time at the nest, since their nestlings were older, or both.

Golden eagles that were captured and instrumented during our study proved difficult to track. A golden eagle in Denali National Park was radio-tagged and observed for a 2 month period; the transmitter on that bird was not visible after about 2 weeks. Solar transmitters would last about two weeks after being covered. Although solar transmitters have functioned for 3 to 4 years on other raptors, solar packages apparently are not suitable for golden eagles. In our study, the loss of radio contact with instrumented eagles in 1988 was likely the result of the solar cells becoming covered with feathers and subsequent failure of the transmitters shortly thereafter.

Prey remains collected and identified during this study indicate that nesting golden eagles take a variety of prey species. An accurate assessment of the proportion of caribou in the diet of nesting golden eagles, and the importance of caribou relative to productivity, will require more intensive study.

Nonbreeders are a segment of the golden eagle population in northern Alaska that was not studied during 1988-1990. Mauer (1985, 1986) suggested that a sizeable number of immature golden eagles (1 to 4 years old) arrive on the coastal plain in association with caribou and utilize the caribou as a food source during calving. The size of this non-breeding segment is unknown, but estimates range from 50 to over 100 individuals. This segment of the population is the most difficult to study. Individuals are not generally associated with territories and are extremely mobile and difficult to track with conventional telemetry systems. Food habits are difficult to ascertain because there is no convenient location to collect prey remains. Immature golden eagles are frequently seen feeding on caribou, but the relative importance of caribou in their diet remains unknown.

MANAGEMENT IMPLICATIONS

Our results suggested that brown bears, resident wolves, and nesting golden eagles used the foothills to the south and east of the traditional caribou calving areas more than the coastal plain. Fancy and Whitten (1991) suggested that caribou will incur higher calf predation rates if petroleum exploration and development displace calving caribou from traditional calving grounds on the coastal plain to the foothills to the south and east. To fully develop models of PCH population dynamics for use in estimating the potential effects of petroleum exploration and development, additional information relative to predators is required. Necessary information includes density estimates and predation rates on caribou calves for brown bears, wolves, and golden eagles. Sparrowe et al. (1991) in a review of North Slope Alaska caribou research made the following recommendation: "Expand predation research to include [golden eagle] and possibly wolf populations. Study of [golden] eagles as predators of PCH calves is inadequate, yet mortality studies of radio-tagged calves indicate that eagles may be more important predators than are [brown] bears or wolves."

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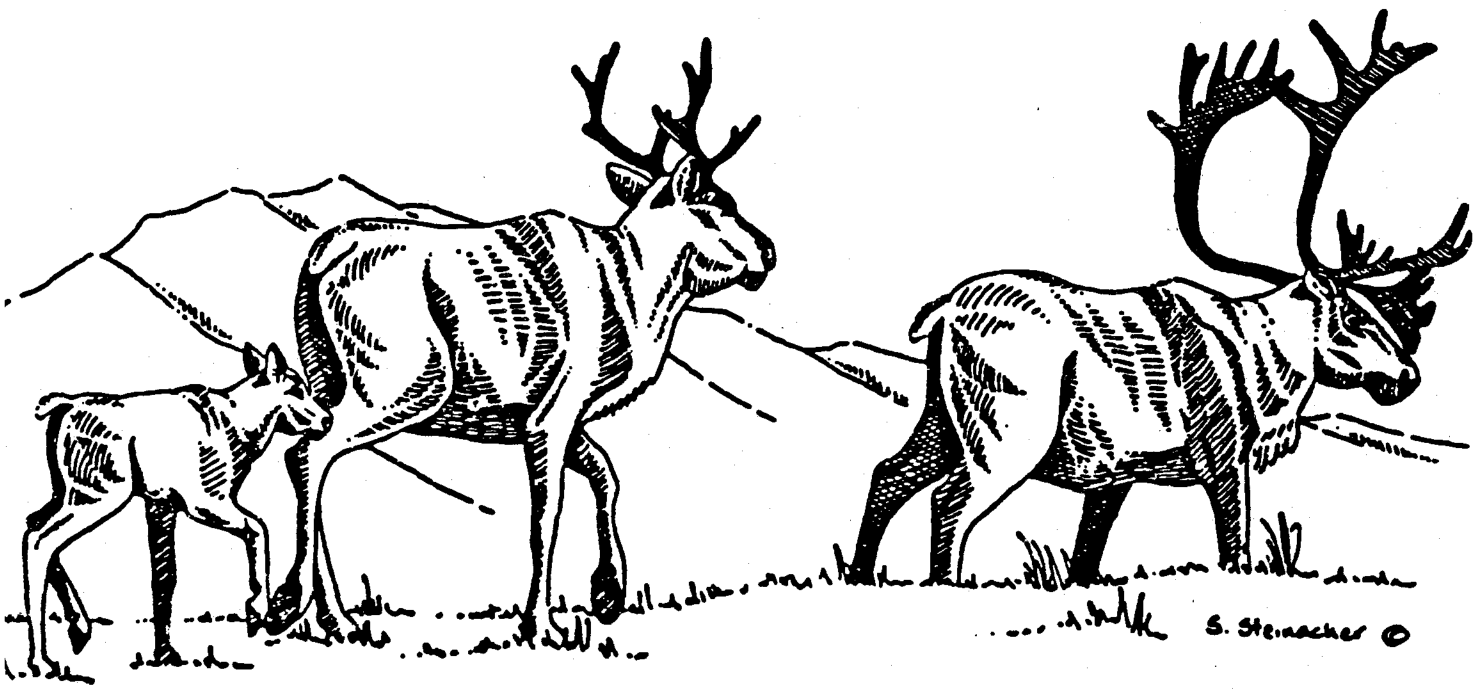
TERRESTRIAL RESEARCH

1002 AREA - ARCTIC NATIONAL WILDLIFE REFUGE



Interim Report - 1988-1990

Submitted by : Alaska Fish and Wildlife Research Center
&
Arctic National Wildlife Refuge

RESEARCH ON THE POTENTIAL EFFECTS OF PETROLEUM DEVELOPMENT ON WILDLIFE AND THEIR HABITAT, ARCTIC NATIONAL WILDLIFE REFUGE

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