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United States Department of the Interior

ALASKA FISH AND WILDLIFE RESEARCH CENTER
Fish and Wildlife Service
1011 E. Tudor Rd.
Anchorage, Alaska 99503

IN REPLY REFER TO:

February 20, 1992

MEMORANDUM

TO: A. Robyn Thorson
ARD

FROM: Chief, Mammals Branch
AFWRC

SUBJECT: Policy Review

Please review the attached manuscript for potential conflicts with current Service policy.

Thank You.

Young, D. D., T. R. McCabe, G. W. Garner, and H. V. Reynolds.

TITLE: Use of a distance-based test of independence to measure brown bear-caribou association in northeastern alaska.

Abstract: We investigated the relationship between populations of radio-collared brown bear (*Ursus arctos*) and calving caribou (*Rangifer tarandus*) on the Arctic National Wildlife Refuge, Alaska between 29 May and 22 June, 1988-1990. A distance-based test of independence was used to measure the association between ~~concurrent (i.e., within 5-day time intervals~~) brown bear and caribou distributions during 5 consecutive time intervals. A sample of 552 brown bear and 592 caribou radio-relocations was used in the analyses. Brown bear and caribou distributions were positively associated ($P < 0.05$) during time interval 8-12 June, 1988. This may be a function of the combined effects of calving chronology, the timing of calf susceptibility to predation by brown bears, and seasonal snowmelt patterns. Interpretation of results is confounded in

that equally strong responses (i.e., 'attraction' and 'avoidance' behaviors) of bears and caribou may cancel each other resulting in no significant correlations.

INTRODUCTION

In 1988, the U. S. Fish and Wildlife Service initiated a study to investigate relationships between predators and calving caribou (*Rangifer tarandus*) on the Arctic National Wildlife Refuge (ANWR) in northeastern Alaska. This study was in response to the Final Legislative Environmental Impact Statement for ANWR indicating that potential impacts of petroleum exploration and development on wildlife resources of ANWR would be major on caribou... (Clough et al. 1987). A primary concern is that calf survival may decline if the Porcupine caribou herd (PCH) is displaced during the calving period from traditional high density calving areas (i.e., the coastal plain) to peripheral areas (i.e., the foothills) where predators (brown bears (*Ursus arctos*), wolves (*Canis lupus*), golden eagles (*Aquila chrysaetos*) are believed more abundant.

Our objective was to determine whether brown bear distributions and movements were independent of calving caribou distributions. Sih (1984) in discussing the conflicting behavioral responses between predator and prey (i.e., predators concentrate their efforts in regions of higher prey densities, but prey avoid areas that predators frequent) stated that "if the predator's response dominates, then predator and prey spatial distributions should be positively correlated. In contrast, if the prey response dominates, a negative correlation is expected. If the two responses are of equal strength, even if both responses are very strong, we would observe no pattern in the overlap of the spatial distributions of predators and prey." In congruence with Sih's observations, our analysis of brown bear-caribou association was designed to determine whether populations of brown bears and calving caribou were distributed independently and, if not, were the distributions positively or negatively associated.

One approach to measuring the association between discrete populations involves "nearest neighbor" analysis techniques. Nearest neighbor analyses were first introduced in forestry to estimate the number of plants in a study area region and to test the "randomness" of plant patterns (Cottam and Curtis 1949). ~~Later~~, Pielou (1961) developed an 'absolute' nearest neighbor technique to measure the association, or segregation, between two species of plants. More recently, Diggle and Cox (1983) developed "distance-based" nearest neighbor techniques to measure the association among multivariate populations. Because "distance- based" methods provide greater precision in measuring the association between populations, we chose to use it in our investigation of brown bear-caribou association on ANWR.

We thank airplane pilots R. Kaye, D. Miller and D. Sowards and helicopter pilots K. Butters, D. Gomert, and G. Gulick. M. Mastellar, S. Fancy, and K. Whitten assisted with radio-tracking flights. J. Greslin provided computer programming assistance. G. Weiler provided administrative and logistical support. Joint funding for this study was obtained from the Alaska Fish and Wildlife Research Center and the Alaska Department of Fish and Game.

STUDY AREA

The 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 both the distributions of calving Porcupine herd caribou and brown bears with access to calving caribou, 1988-1990. The PCH (n = 178,000 in 1989) uses the coastal plain and foothills of the study area as calving grounds, although intensity of use of specific localities varies from year to year (Reynolds and Garner 1987).

The study area was divided into 3 broad physiographic zones: the coastal plain, generally flat with elevations < 300 m; the foothills, characterized by buttes and ridges, with elevations generally 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.

A detailed description of the physiography, vegetation, and climate of the study area is provided in Garner and Reynolds (1982).

METHODS

Brown bear capture, radio-collaring and aging procedures followed those described by Reynolds (1976) and Garner et al. (1983, 1984, 1985) ~~in northern Alaska~~, except Tilazol (*tilelamine hydrochloride* and *zolzepam hydrochloride*; A. H. Robins Co., Richmond, Va.) was the immobilizing agent used between 1988 and 1990. Brown bears ~~monitored in this study~~ were initially captured and radio-collared between the years 1982 and 1990. The age composition of our sample of radio-collared bears (Table 1) is similar to that described for other North Slope brown bear populations (Reynolds 1980, Garner et al. 1985). However, the sex composition of our sample was biased towards females. Our sample was large with respect to the size of the brown bear population on the study area, based on a 1983 estimate of 108 bears (estimate included all age classes) on the north slope of ANWR from the Canning River to the Canadian boundary (Garner et al. 1984:350), an area roughly 25% larger than that of our study area. ~~Preliminary analyses indicate that~~ the ANWR bear population has been stable between 1982 and

1990 (Reynolds et al. in prep).

Caribou capture and radio-collaring procedures were described by Fancy and Whitten (1991). Distributions of radio-collared caribou were assumed geographically representative of the PCH population based on comparisons between distributions of radio-collared individuals and 1) distributions of the PCH determined from photo surveys conducted in 1987 and 1989 (unpubl. data); and 2) distributions of calving caribou conducted in 1988 (Harris et al. 1989).

Radio-collared brown bears and caribou were located from fixed-wing aircraft from late May through June at approximately 3-5 day and 1-3 day intervals, respectively. Brown bear and caribou radio-relocations (relocations) were plotted on U.S.G.S 1:63,360 scale topographic maps, then computer digitized in Universal Trans Mercator coordinates and entered into the Simple Graphics Language geographic information system (J. Greslin, AFWRC, 101 12th Ave, Fairbanks, AK).

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'. In the event a caribou lost her calf, then that individual was excluded from all further analyses for that year. To control for variation in relocation sample size among individual bears and caribou, only 1 relocation/animal/5-day time interval was used in the analyses. In instances where multiple relocations were obtained for an individual animal within a single time interval, relocations were averaged to produce a single arithmetic mean location. The sampling period was 29 May - 22 June (calving period), 1988-1990. Based on factors such as time of caribou arrival onto the calving grounds, time of peak calving, period of greatest calf vulnerability to predation by brown bears, and time of post calving aggregation (Garner and Reynolds 1986), 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 populations of radio-collared bears (n = 47, 53, 46, 1988-1990, respectively) and caribou (n = 55, 47, 53, 1988-1990, respectively) were distributed independently during concurrent time periods 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) ~~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.

RESULTS

Brown bear and caribou distributions

Six-hundred eighty-nine brown bear and 1158 caribou relocations were obtained during the sampling periods, 1988-1990. ~~Of these,~~ 552 brown bear and 592 caribou relocations ~~(i.e., events)~~ resulted after multiple relocations of individuals within time intervals were averaged to produce arithmetic mean locations (Table 2). Calving caribou were relocated primarily in the foothills in 1988, the northern foothills and southern coastal plain in 1989, and the coastal plain in 1990. During calving, brown bears were relocated primarily in the foothills in all years, although bear relocations on the coastal plain increased from 1988-1990.

Paired point-to-animal distances analyses

Bear and caribou distributions were positively correlated ($\underline{P} < 0.05$) during time interval 1988_3 (Table 2). During all other time intervals, bear and caribou distributions were ~~statistically~~ independent (_P_ > 0.05). Distributions of bears and caribou tended to be positively correlated in 1988 and 1989, and negatively correlated in 1990.

DISCUSSION

The positive association observed for bear and caribou distributions during time interval 1988_3 (8-12 June) may be ~~a function~~ due to ~~of a combination of factors including:~~ 1) calving chronology, 2) changing calf vulnerability to predation by brown bears over time, and 3) seasonal snowmelt patterns. Peak calving occurs during the first week of June each year with calving having been essentially completed by 15 June (Garner and Reynolds 1986:229). 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 1986:247). Thus, one might expect, the greatest number of highly vulnerable calves to be available to bears just after the peak of calving. In 1988, caribou calved primarily in the foothills as a result of the latest breakup on record; the coastal plain was snow covered until late June (Fancy and Whitten 1991). Radio-tracking studies indicated that bears also remained in the foothills that year (Young et al. 1991). 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 (Fig. 2). During time interval 3 in 1989, the positive 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 (Fig. 3). In contrast, bear and caribou distributions were independent during time interval 3 in 1990, possibly because calving caribou were found primarily on the coastal plain then (Fig 4).

means nothing— use the term "late calving"

There may be a relationship between seasonal snowmelt 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 breakup was unusually late and bears and caribou remained in the foothills through the calving period, only positive associations were observed (Table 2). In 1989, when breakup proceeded normally and caribou calved primarily in the northern foothills and southern coastal plain, bear-caribou associations were still mostly positive. However, in 1990, when breakup was the earliest ever recorded (Fancy and Whitten 1991) and calving occurred primarily on the coastal plain, only negative associations were observed. Fancy and Whitten (1991) reported 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%), although~~, they~~ did ~~not~~ show ~~the~~ cause ~~of this.~~

cite to causes of peri-natal & post-perinatal mortality

We recommend viewing these results cautiously for several reasons. First, the "distance-based" method we used was developed for stationary objects (i.e., used in forestry) not highly mobile species like bears and caribou. Sih (1984) observed that when both predators and prey are mobile and there is no spatial refuge, the two responses (i.e., predators concentrating their efforts in regions of higher prey densities vs. prey avoiding areas that predators frequent) might cancel one another so that no clear pattern is observed. Thus, even though our analyses of bear and caribou distributions indicated that the two were independent during all but 1 time interval, the hypotheses that bears were 'attracted' to caribou or that caribou 'avoided' bears cannot be dismissed.

Second, we have no available information to determine what densities of calving caribou may be required to 'attract' bears to calving caribou. There may have been sufficient numbers of 'outliers' not represented by our sample of radio-collared animals such that some associations between bears and caribou may have gone undetected.

Third, we compared distribution of bears only to those of female caribou with calves. Data from related studies at ANWR indicate significant differences in the spatial distributions of cows with calves versus barren cows; barren cow distributions tended to be shifted to the south of cows with calves. Bears could have been associated with segments of the PCH that we did not investigate.

Fourth, we did not have valid concurrent relocations of bears and caribou (i.e., we were forced to compare relocations collected over 5-day intervals to due small sample sizes and data gaps resulting from poor weather days). As a result, there was the potential for comparing relocations collected several days apart (e.g., in measuring from a sample point, the nearest bear event may have been a relocation from day 1 of a particular time interval, while the nearest caribou event may have been a relocation from day 5 of that time interval).

Fifth, we used arithmetic mean locations in instances when more than 1 relocation for a particular animal was obtained within a single 5-day time interval. This, resulted in comparisons being made using some 'artificial' events rather than 'actual' events. Comparisons using only 'actual' events would have provided more accurate measures of bear-caribou association.

Sixth, observed correlations may be due to bears and caribou being concentrated in the same area (e.g., the foothills in 1988) due to an independent environmental event (e.g., snow) that effects them both.

You spend so much time putting down your results - why publish the paper?

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Table 1. Age and sex composition of radio-collared brown bears on the Arctic National Wildlife Refuge, Alaska, 1988-1990.

Age/Sex class	1988 Number	1988 Percent	1989 Number	1989 Percent	1990 Number	1990 Percent
Adult:						
Male	11	23.4	14	26.4	14	30.4
Female	28	59.6	30	56.6	24	52.2
Subadult[a]:						
Male	3	6.4	4	7.5	3	6.5
Female	5	10.6	5	9.4	5	10.9
Total	47	100.0	53	100.0	46	100.0

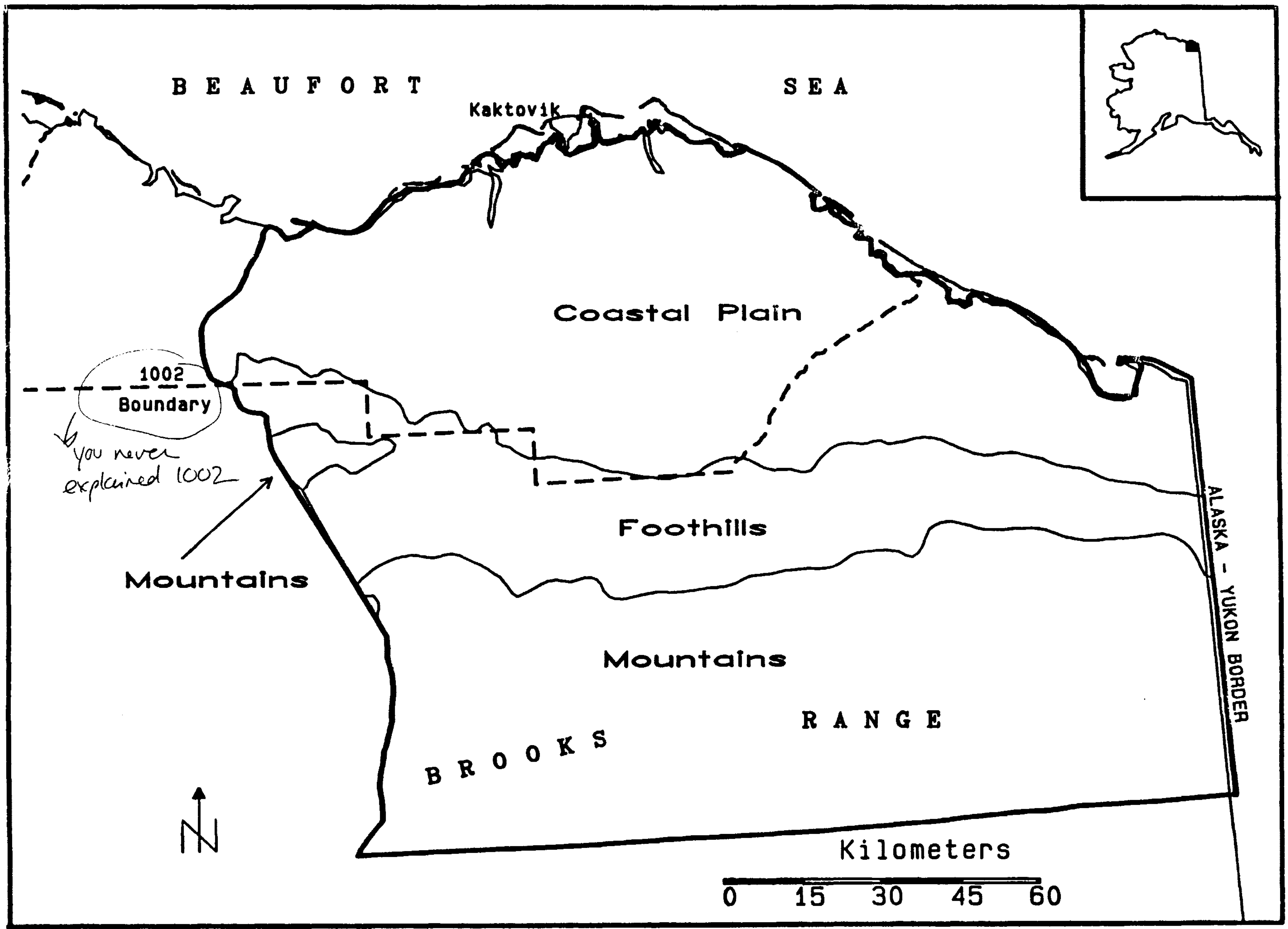
[a] $<$ 6 years of age and independent (2 and 3 year-old radio-collared cubs accompanied by sows are not represented).

Table 2. Sample sizes, Kendall's coefficients of rank correlation (KRCC) and probability values by time interval for paired point-to-animal distances analyses of concurrent radio-relocations of female caribou accompanied by calves and brown bear groups from 29 May - 22 June, 1988-1990, on the Arctic National Wildlife Refuge, Alaska.

Time Interval[a]	Number Bear Relocations	Number Caribou Relocation	Number Sample Points	KRCC	*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.

LIST OF FIGURES



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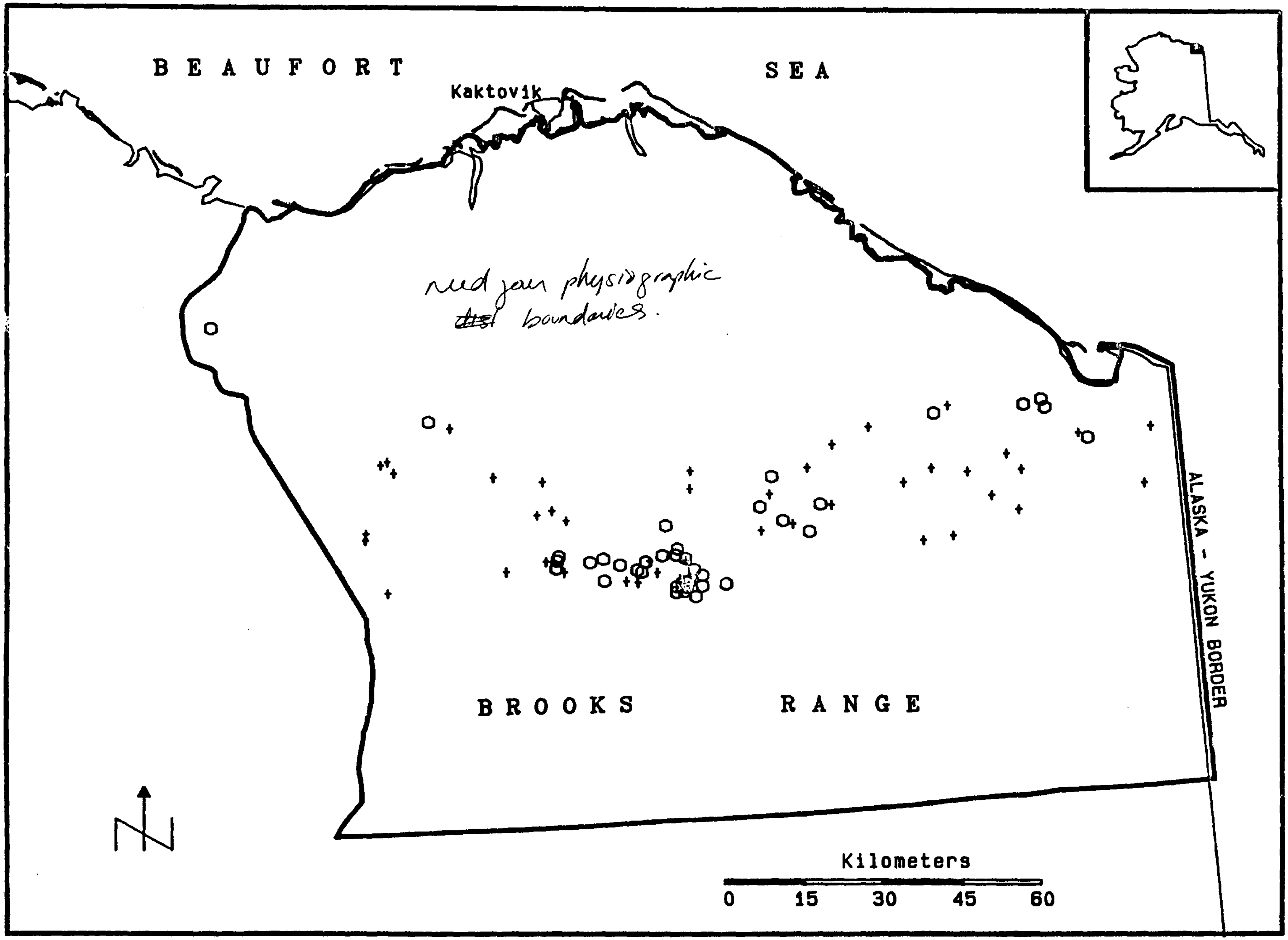
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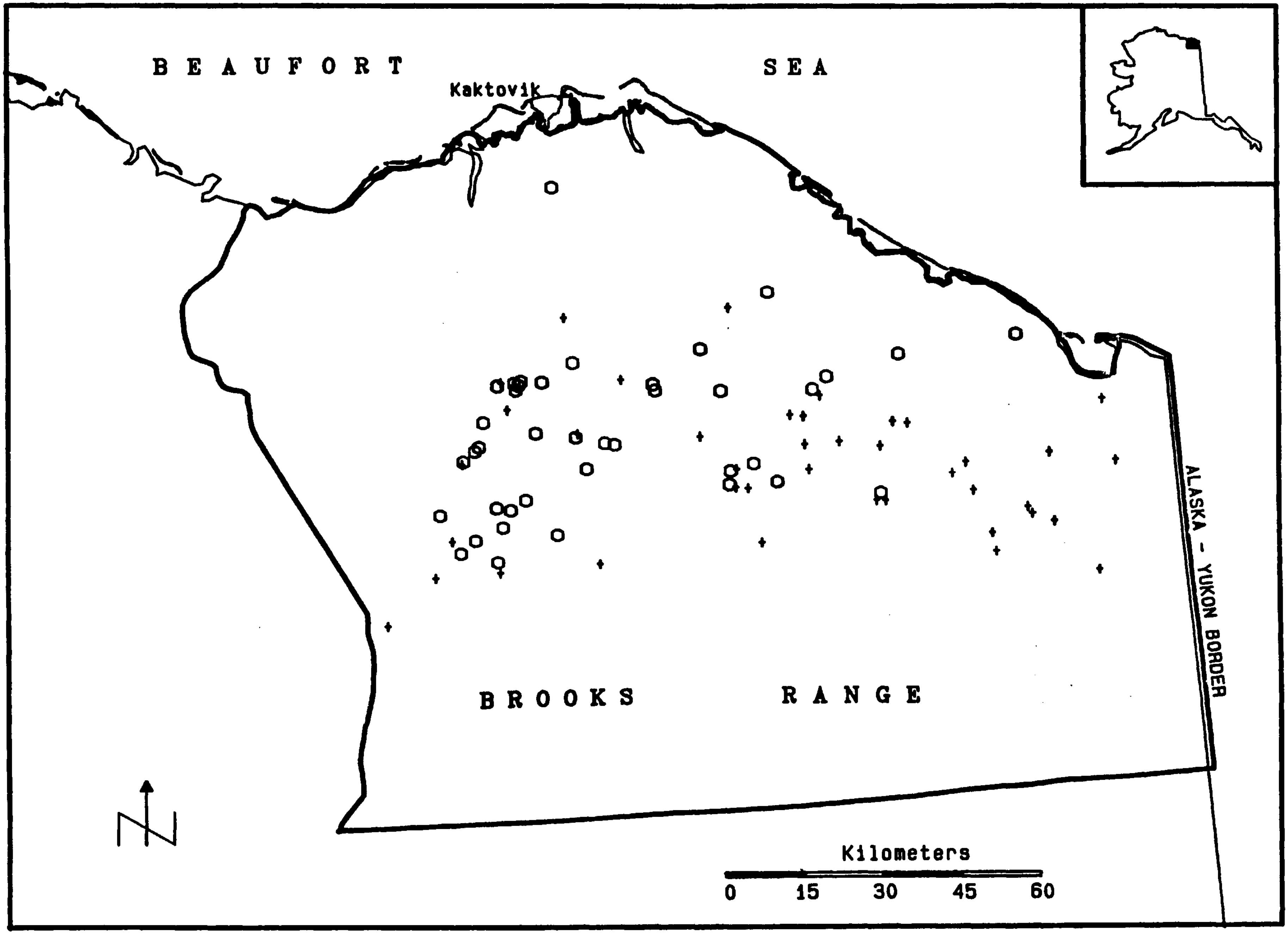

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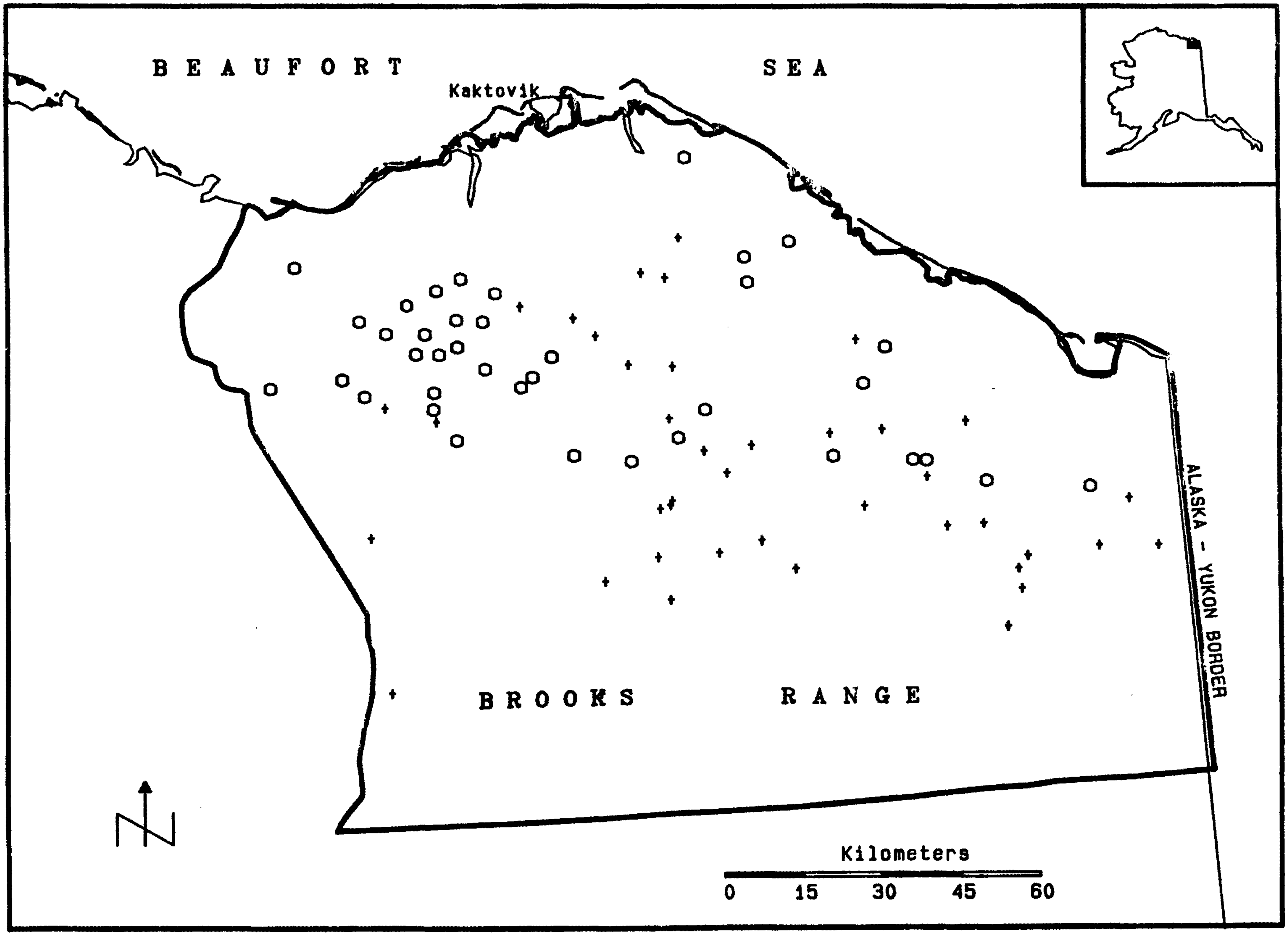
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