DISTRIBUTION AND MOVEMENTS OF CARIBOU IN RELATION TO THE KUPARUK DEVELOPMENT AREA

FIRST INTERIM REPORT

by

Raymond D. Cameron and Kenneth R. Whitten
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SUMMARY

1. The calving grounds of the Central Arctic were surveyed by helicopter in June 1978, and periodic surveys of the West Sak Road were conducted by light truck between mid-July and mid-August 1978.

2. The overall density of calving caribou was highest west of the Kuparuk River, and a particularly large concentration was observed between the Arctic Coast and the West Sak Road.

3. The relative paucity of calving caribou observed within or near the Prudhoe Bay complex supports previous evidence for avoidance of that area by parturient/maternal cows.

4. During calving, mean calf percentage for caribou observed within 8 km (ca. 5 mi) of the West Sak Road (18%) was significantly lower ($p < 0.05$) than that estimated for caribou at greater distances (41%).

5. During July and August, caribou observed from the West Sak Road were representative of caribou in the general region in terms of mean calf percentage.

6. Specific areas of relatively high caribou occupancy were identified along the West Sak Road (0–2.5 mi, 5.0–7.5 mi, 17.5–20.0 mi); the majority of road crossings were also in these areas.

7. In general, the timing and position of caribou sightings along the West Sak Road correlated with changes in insect activity.

8. Recommendations for spring and summer operations in the Kuparuk Development Area include traffic limitations, strategic location of facilities and appropriate scheduling of construction/maintenance activities, the intent being to minimize local disturbance of caribou on adjacent calving and summer range.

BACKGROUND

In recent years much interest has been focused on the effects of oil development on fish and wildlife resources, and barren-ground caribou (*Rangifer tarandus granti*) are among the species which have attracted attention. The present study addresses specific concerns involving caribou and potential conflicts with present and future development near Prudhoe Bay.

Past studies have established the existence of two large herds of caribou in northern Alaska, the Western Arctic and Porcupine Herds, with respective calving areas on the extreme western and eastern ends of the Arctic Slope. Movements of both herds have been known to extend centrally to the Sagavanirktok River (Hemming 1971). In addition, Cameron and Whitten (1979) have recently identified a separate herd of about 5,000

caribou whose range is centered on the Trans-Alaska Pipeline (TAPS) route. Seasonal movements are primarily north-south, between calving grounds near the coast and winter range in the northern foothills of the Brooks Range. Based on summer surveys, Gavin (1973) reported a steady decrease in caribou numbers in this central region, from 26,000 in 1969 to 2,500 in 1972, roughly paralleling a decline of the Western Arctic Herd from 242,000 in 1970 (Hemming 1971) to 64,000 in 1976 (Davis, pers. comm.). It now appears that despite occasional influx from the larger adjacent subpopulations, the "Central Arctic Herd" (CAH) remains intact and calves regularly in this region of the Arctic Slope.

The petroleum industry has now been working in the Prudhoe Bay area for more than 10 years, commencing with pre-discovery exploration, reaching greatest activity during the TAPS project and continuing as a combination of active production and sustained exploration. Although coastal development is now concentrated between the Kuparuk River and the west channel of the Sagavanirktok River, other leases between the Colville and Canning Rivers are currently being explored, and lateral expansion of the present industrial complex appears likely. In fact, in 1977 a road (West Sak Road) was built across the Kuparuk River extending west approximately 20 mi, and exploratory drilling was initiated; definite plans are now being developed for the extraction and transport of oil deposits in this area.

The calving grounds and primary summer range of the Central Arctic Caribou Herd coincide roughly with this coastal band. In recent years, calving activity has clearly decreased in the immediate vicinity of the Prudhoe Bay complex but still occurs on a regular basis to the east and west (Cameron and Whitten 1978). In addition, avoidance of this central area during summer by cows and calves has been well documented (Cameron and Whitten 1977, 1978; Cameron et al. 1979). Such local abandonment of range has paralleled a steady increase in activity associated with oil exploration, production and transport. Further expansion of the Prudhoe complex and the potentially detrimental effects on range occupancy and free movements of caribou are our principal concerns at present.

The desirability of preserving the integrity of caribou calving grounds has long been recognized by wildlife biologists. These areas are used repeatedly and are of presumed importance to the reproductive success of a herd. Calving grounds are also thought to be focal points for seasonal movements, and unimpeded access to these areas may be critical to the integrity of the herd itself. Similarly, avoidance of portions of traditional summer range may well trigger fragmentation of a herd and isolation of its components, particularly if accompanied by restriction of movements within and between seasonal ranges.

To what extent a caribou herd can tolerate displacement from such critical or traditional portions of its range is not known, nor are the consequences predictable in terms of reproduction and mortality. Unlike the more tangible forces of hunting and predation, the effects of disturbance may be insidious or manifested only at some threshold stimulus. The responses of caribou to man-made structures and human presence are not

well understood, and the acceptable limits of such disturbance are ill-defined. Indeed, the disturbance variable itself is difficult to quantify. For example, it is possible that the aggregate influence of the Prudhoe Bay oilfield far exceeds the sum of the individual components.

The present investigation relates specifically to the Kuparuk Development Area. Major goals of this program are: 1) to identify areas along the West Sak Road that are important in terms of caribou occupancy and seasonal/daily movements; 2) to develop recommendations as to timing of construction and other activities, placement of major facilities and location of special crossing structures; 3) to identify and quantify the major sources of disturbance, the responses of caribou to these stimuli and, if possible, determine the permissible levels; 4) to document the long-term responses of caribou to known levels of disturbance; and 5) to assess the ultimate effects (if any) on herd integrity and productivity.

OBJECTIVES

This project was designed to achieve the following immediate objectives:

1. Calving

   a. To determine the distribution and density of caribou calving in the vicinity of the Kuparuk Development Area.

   b. To compare the above data with the same parameters obtained elsewhere between the Colville and Canning Rivers.

2. Summer

   a. To determine the location, group composition and movements of caribou in the vicinity of the West Sak Road during July and August; and to identify road crossing locations and/or established trail systems intersecting the road.

   b. To identify major routes of caribou movement within and across the Kuparuk Development Area with special reference to the existing and planned road-pipeline system.

   c. To identify specific sites used by caribou for insect relief.

METHODS

The distribution of caribou within the calving grounds of the CAH was determined using a series of north-south transects flown on 11-14 June by Bell 206B helicopter. Flight lines extended from the Arctic coast to 70°N latitude and were distributed at lateral intervals of 2, 3 and 6 mi (3.2, 4.8 and 9.7 km, respectively) as shown in Figure 1; survey emphasis was on the Kuparuk Development Area. A front-seat observer and the pilot searched primarily in the direction of flight, and two rear-seat observers searched to each side of the aircraft. A

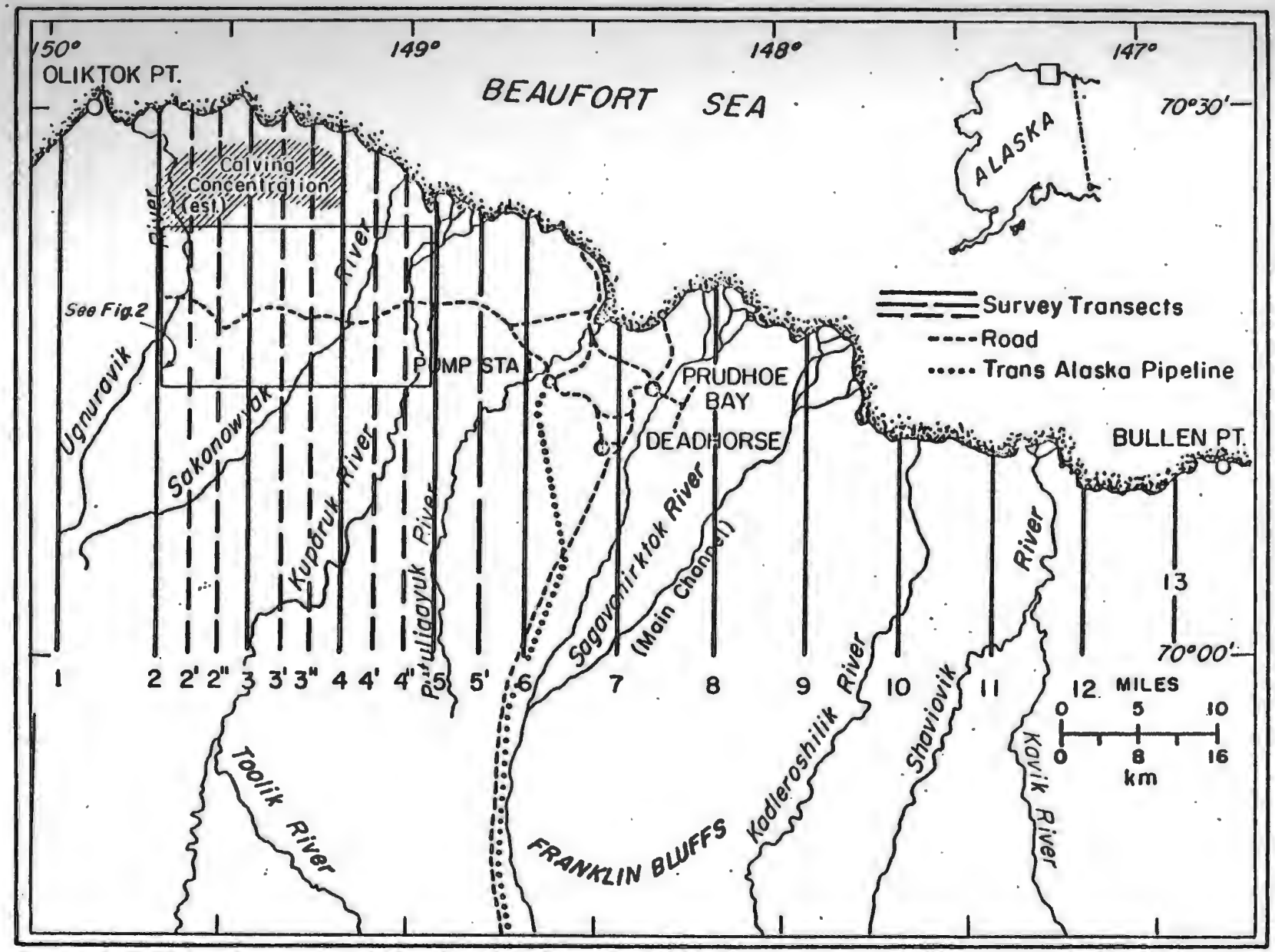

Fig. 1. Aerial survey transects, an observed calving concentration, and the route of the West Sak Road.

1:63,360 scale USGS topographic map was used for navigation and position identification. For convenience, individual transects were established on actual township and section lines. Magnetic courses corresponding to true north and south were flown, and minor adjustments were made as necessary by ground reference. Except to obtain data on group size and composition, airspeeds of between 110-130 km/hr and altitudes of 30-50 m above terrain were maintained. Only caribou sightings within approximately 1 map mi (1.6 km) of each flight line were recorded. Individuals were classified on the basis of genitalia, body size and/or antler development as bulls, cows, calves, yearlings or adults (i.e. unknown sex, older than calf). With few exceptions, group composition could be ascertained with the aid of binoculars by hovering briefly at distances ranging from 50 to 300 m; otherwise, a landing was made nearby and caribou were classified using a spotting scope. A number assigned to each observation (i.e. a single group, or separate groups in close proximity) was noted on the map, and pertinent data were referenced to that number.

At irregular intervals between 18 July and 18 August 1978 standardized surveys of the West Sak Road were conducted by light truck. Inclusive times for each survey and the data recorded are given in Appendix II. Usually only one driver/observer was involved. Both sides of the road were searched along its entire length, from a point just east of the Kuparuk River to the terminus at W.S. 12 (Fig. 2). Survey speed ranged between 25 and 50 km/hr, depending on road conditions and visibility. To ensure maximum coverage of the adjacent terrain, additional searches were made using binoculars at scheduled stops for weather measurements (see below), and also at strategic points from which overall viewability of the immediate area was best. Caribou were classified as above, except that an "unknown" category (i.e. caribou unclassified as to sex or age) was added. Location of each caribou sighting (in road mi; Fig. 2), initial observation distance north or south of the road (estimated in m; irrespective of subsequent movement), and the direction of any subsequent road crossings were recorded; and the approximate position of each group was noted on a 1:63,360 USGS map. Observation time varied with group size and observation distance but generally ranged between 5 and 20 min.

Weather data were recorded at five sites along the West Sak Road (Fig. 2) during each survey. Ambient temperature was determined using a hand-held mercury thermometer, and local wind velocity was estimated with a portable anemometer as the average reading over 20-30 sec; both measurements were taken 150-180 cm above ground level. National Weather Service hourly sequence reports for Deadhorse Airport were obtained from the Arctic Environmental Information and Data Center, University of Alaska, for July and August 1978.

Rates of vehicular traffic on the West Sak Road were estimated through the use of an automatic infrared trail/traffic counter (Scientific Dimensions, Inc., Albuquerque, NM), positioned immediately west of the access road to the Mobil Strip (Fig. 2). Counter readings were obtained at irregular intervals, and mean hourly frequencies of vehicle passage were calculated for periods ranging from a few hours to 6 days.

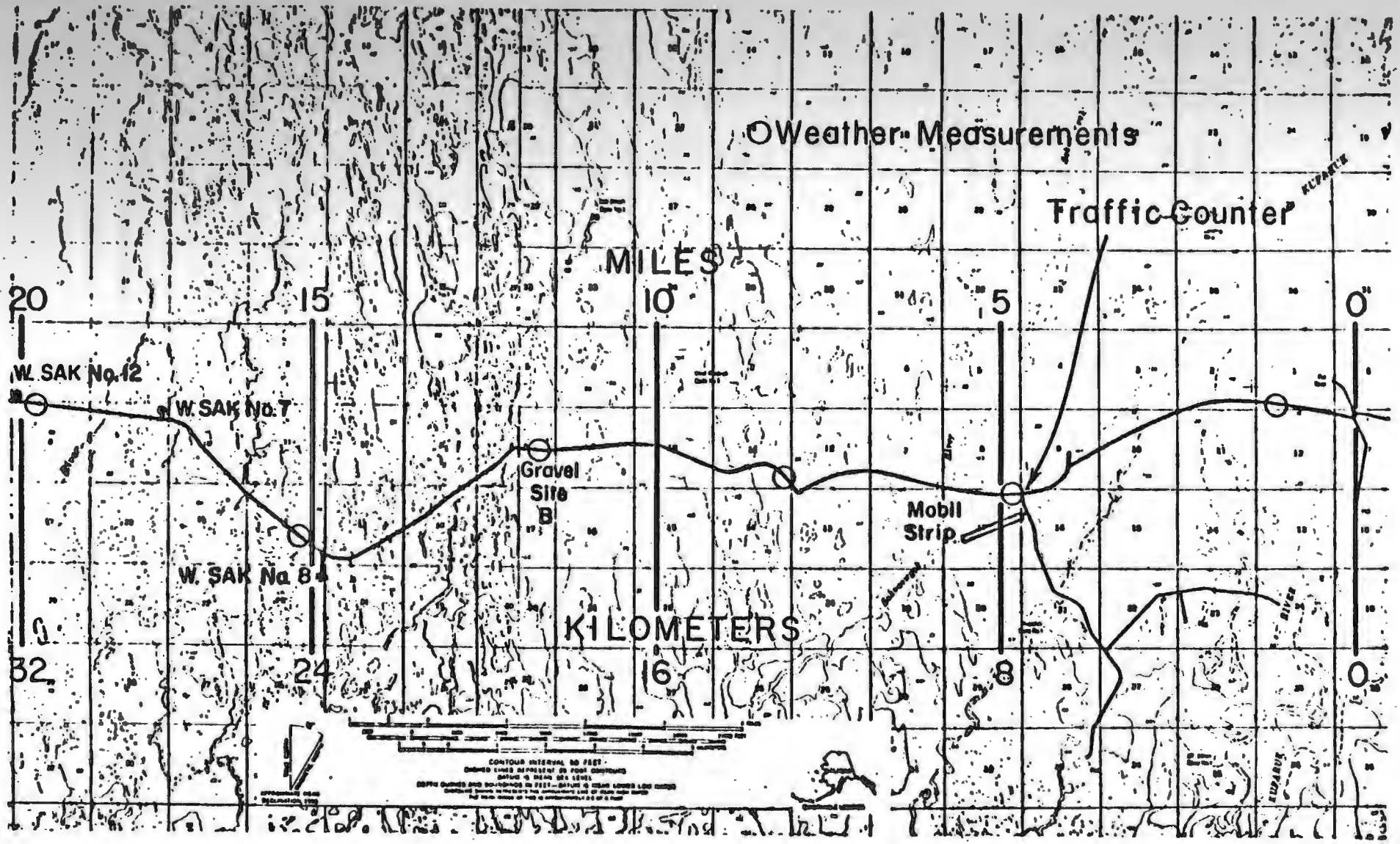

Fig. 2. Location of traffic counter and weather recording sites along the West Sak Road (see Fig. 1).

Established trails intersecting the West Sak Road were identified and mapped on 28 August using a Cessna 180. The entire West Sak route was paralleled twice, immediately south of the road westbound and immediately north of the road eastbound. The right-seat observer sketched the location of visible trails on a 1:63,360 USGS map.

The sex and age composition of post-calving aggregations was determined on 25-26 July as part of a separate study. Survey and classification procedures are described in a previous report (Cameron and Whitten 1978).

Statistical differences between expected and observed parameters of caribou group composition were identified by chi-square contingency analysis, and means were compared using Student's t-test. Significance was evaluated at the 95 percent confidence level.

FINDINGS AND DISCUSSION

Caribou Distribution and Group Composition during Calving

A total of 964 caribou in 120 groups were observed during surveys of the calving grounds; the composition of each group is listed in Appendix I by observation number. Total caribou and calf numbers applicable to each survey transect are given in Figure 3. Relatively more caribou were observed west of the Kuparuk River than elsewhere to the east. However, transect length was extremely variable, generally decreasing from west to east (Fig. 1), and the total number of caribou observed from a given flight line was partially attributable to the total area surveyed and does not necessarily reflect caribou density in that area. To permit a direct comparison of observations associated with the various transects, caribou sighting rates (i.e. no. of caribou/km linear coverage) were calculated for each whole-number transect (i.e. those spaced at regular 9.7-km intervals; see Fig. 1). Figure 3 shows that mean caribou sighting rate was highest at 2.3 caribou/km for a survey line intersecting the West Sak Road near its midpoint; intermediate values of 0.7-1.4 caribou/km were calculated for the extreme eastern and western transects and for the three others intersecting the West Sak Road; and rates below 0.4 apply to the remaining transects located roughly between the Kuparuk and Shaviovik Rivers. Calf sighting rates, although predictably lower overall, followed the same trend.

Since survey coverage extended approximately 1.6 km to either side of each flight line (see Methods), sighting rates are indices of caribou density and regional means can be calculated. Thus, mean sighting rates for total caribou and calves, respectively (again, based on whole-number transects), were 1.24 and 0.44/km west of the Kuparuk River, 0.62 and 0.19/km between the Kuparuk and the Sagavanirktok Rivers, and 0.34 and 0.15/km east of the Sagavanirktok River. Corresponding minimum densities for total caribou and calves within the above regions, respectively, are estimated at 38 and 14/100 km^2, 19 and 6/100 km^2, and 11 and 5/100 km^2. Minimum density within the entire area was approximately 25 total caribou/

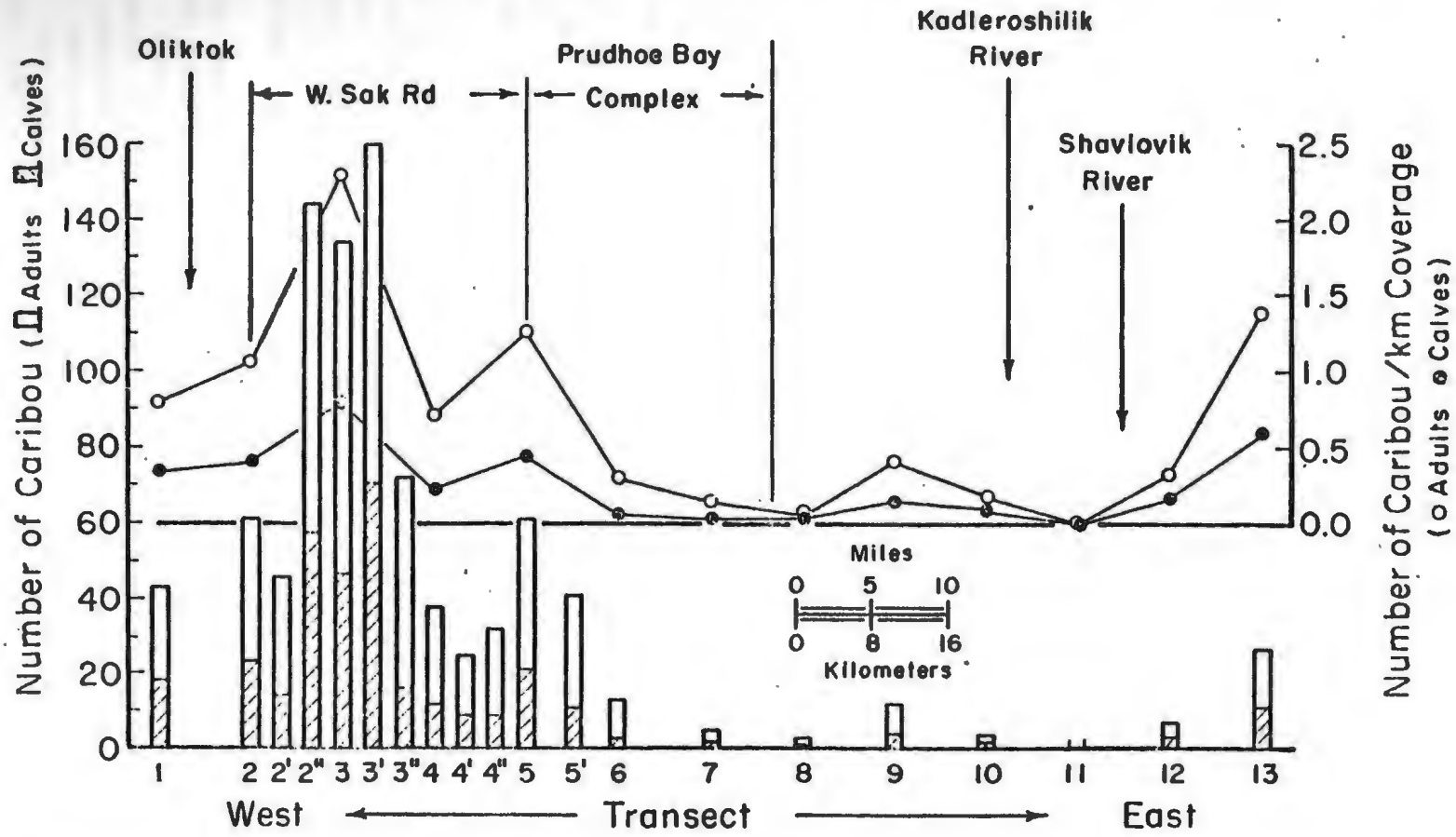

Fig. 3. East-west distribution of caribou (N of 70° latitude) during calving, and the corresponding sighting rates for each whole-number transect (see Fig. 1), 11-14 June 1978.

100 km^2. Overall calf density was approximately 9/100 km^2. Thus, disregarding the unknown effect of early neonatal mortality, maternal cows and calves occupied the calving grounds at an estimated minimum density of 18/100 km^2 or about one cow-calf pair for every 11 km^2.

Overall, calves constituted 36 percent of the caribou sighted in June, and ratios of 82 calves, 3 bulls and 39 yearlings per 100 cows were calculated. Non-maternal adult caribou were variably distributed within the area surveyed. Regional calf proportions averaged 35 percent west of the Kuparuk River, 31 percent between the Kuparuk and the Sagavanirktok Rivers, and 44 percent east of the Sagavanirktok River. Thus, although highest density calving occurred west of the Kuparuk River, the calf-adult ratio was highest east of the Sagavanirktok River. The area of lowest density between the Kuparuk and Sagavanirktok Rivers was associated with the lowest regional percentage of calves. The Prudhoe Bay complex lies within this region of the coastal zone, and the data suggest underrepresentation of maternal caribou--despite the fact that survey transects included areas some distance from local structures and the network of roads.

The sharp increase in sighting rate at the easternmost extent of our surveys (Fig. 3) suggests the presence of a second concentration of calving caribou in the vicinity of Bullen Point and/or farther east. Gavin (pers. comm.) has observed calving in the general area of the Canning River delta and believes that such caribou move in from wintering areas in the western Sadlerochit Mountains. Additional calving was known to occur on Franklin Bluffs (see Fig. 1); composition was estimated by Gavin (pers. comm.) as follows: 22 percent calves; 51 calves, 63 yearlings and 22 bulls per 100 cows (N=153).

Caribou distribution in relation to the Arctic coast also varied regionally during calving. Survey results west of the Kuparuk River are compared with those between the Kuparuk and Sagavanirktok Rivers in Figure 4. Because extremely short transects were flown east of the Sagavanirktok River (Fig. 1), a further comparison with the eastern region was not possible. West of the Kuparuk River, 72 percent of total caribou and 70 percent of all calves were within 16 km of the coast. In contrast, between the Kuparuk and Sagavanirktok Rivers; 86 percent of total caribou and 95 percent of all calves were between 24 and 40 km from the coast, and no calves were observed within the 8-24 km interval. The major portion of the Prudhoe Bay complex is within this 24-km coastal band between the Kuparuk and Sagavanirktok Rivers.

Clearly, the distribution of calving caribou may vary markedly from year to year, ranging from the occurrence of distinct concentrations as indicated by the present data to the more uniform distribution observed in 1977 (Cameron and Whitten 1978). Such natural variability severely limits the identification of disturbance-induced abnormalities. However, the present data support previous evidence for avoidance of the Prudhoe Bay area by cows and young calves (Cameron and Whitten 1977, 1978; Cameron et al. 1979).

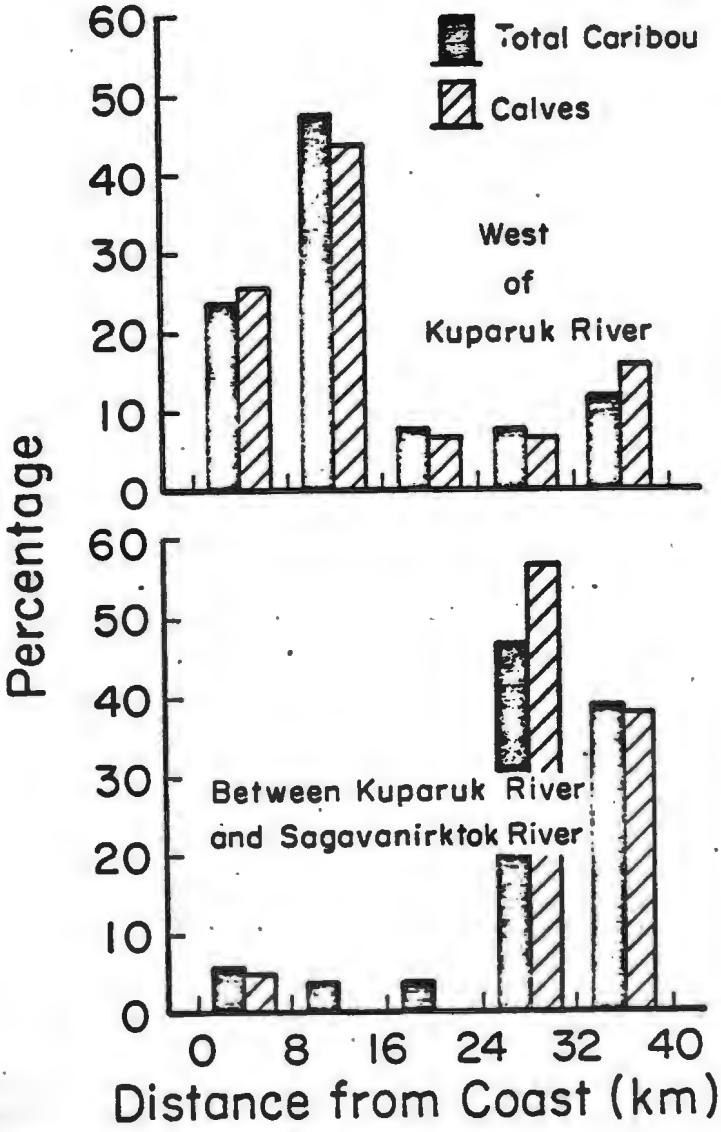

Fig. 4. Distribution of caribou in relation to the arctic coast, 11-14 June 1978.

Figure 5 shows the north-south distribution of caribou in relation to the West Sak Road during the calving period. A distinct peak in total caribou and calf numbers was observed within a zone 8-16 km north of the road, whereas distribution to the south was comparatively uniform. The position of this concentration coincides with that of the peak shown in Figure 3 and to relatively high numbers west of the Kuparuk River and within 16 km of the coast (Fig. 4). The approximate geographic location of this calving "pod" is given in Figure 1; minimum density is estimated at 281 caribou/100 km^2 or 112 cow-calf pairs/100 km^2, which is equivalent to more than 1 cow-calf pair per km^2.

The proportion of calves also varies among the intervals shown in Figure 5. Chi-square contingency analysis was employed to determine if the observed calf percentages were related to distance from the road. Mean calf percentage within 8 km (18%) was significantly lower than that for the combined intervals between 8 and 20 km north and south of the road (41%). Further, the percentage of calves within the latter intervals was identical for the north and south sides, even though corresponding caribou densities differed by a factor of 10. Beyond 20 km to the south mean calf percentage (25%) again decreased significantly, possibly reflecting transition from the active calving area.

Except for minor maintenance activity at W.S. 12 (see Fig. 2), there was no human or vehicular activity along the West Sak Road shortly before, during or immediately after calving. Despite the absence of obvious disturbance, local abnormalities in group composition are indicated (Fig. 5), suggesting partial avoidance of the area by calving caribou. It is possible that the road itself, the mere presence of a few structures and stored equipment, and minor human activity combined to produce an adverse stimulus. However, the statistical comparisons applied to these data assume random distribution of an unaltered population and do not account for selection of calving habitat on the basis of terrain, forage, predator abundance and/or traditional use. Nevertheless, while coincidence cannot be ruled out, neither can it be confirmed. If indeed local deviations in group composition reflect a response to disturbance, an extreme sensitivity of calving caribou is indicated, with active avoidance of areas where seemingly minor environmental alterations have occurred.

Summer Distribution and Group Composition of Caribou in the Vicinity of the West Sak Road

Pertinent data on all caribou observed from the West Sak Road are listed in Appendix II, and the overall distribution of sightings is summarized in Figure 6. Of an aggregate total of 1,667 caribou in 184 groups observed from the road, 944 or 57 percent were to the north, 651 or 39 percent were to the south, and 72 or 4 percent were west of the road terminus at W.S. 12 (see Fig. 2). Because of frequently extreme observation distances and occasional heat distortion, complete sex and age data could not be obtained for all groups. If one or more individuals within a group could not be classified (i.e. designated "unknown"; see Methods), the entire group was deleted from composition calculations; only 827 individuals (50%) in 154 groups could be classified adequately.

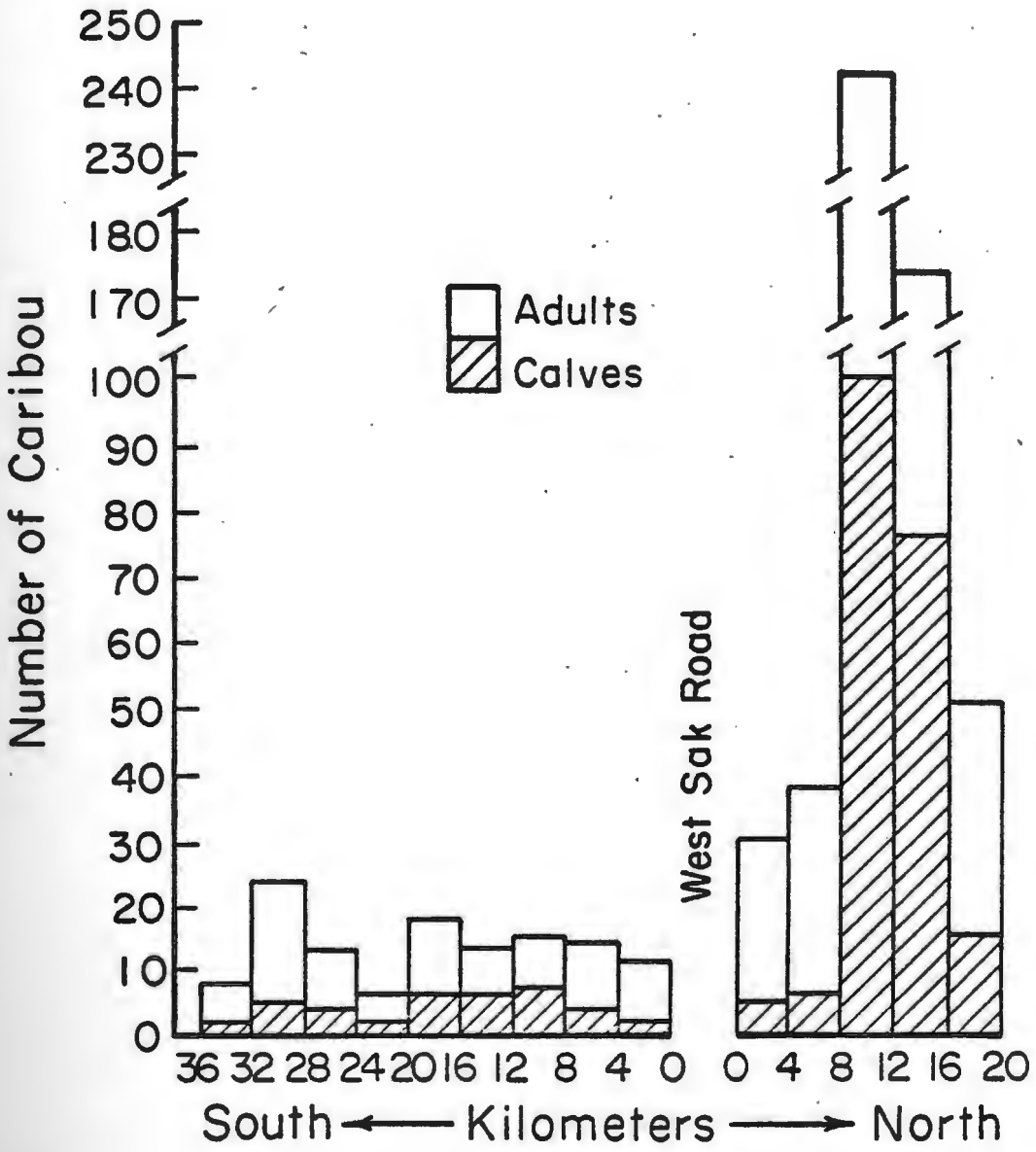

Fig. 5. Distribution of caribou in relation to the West Sak Road, 11-14 June 1978.

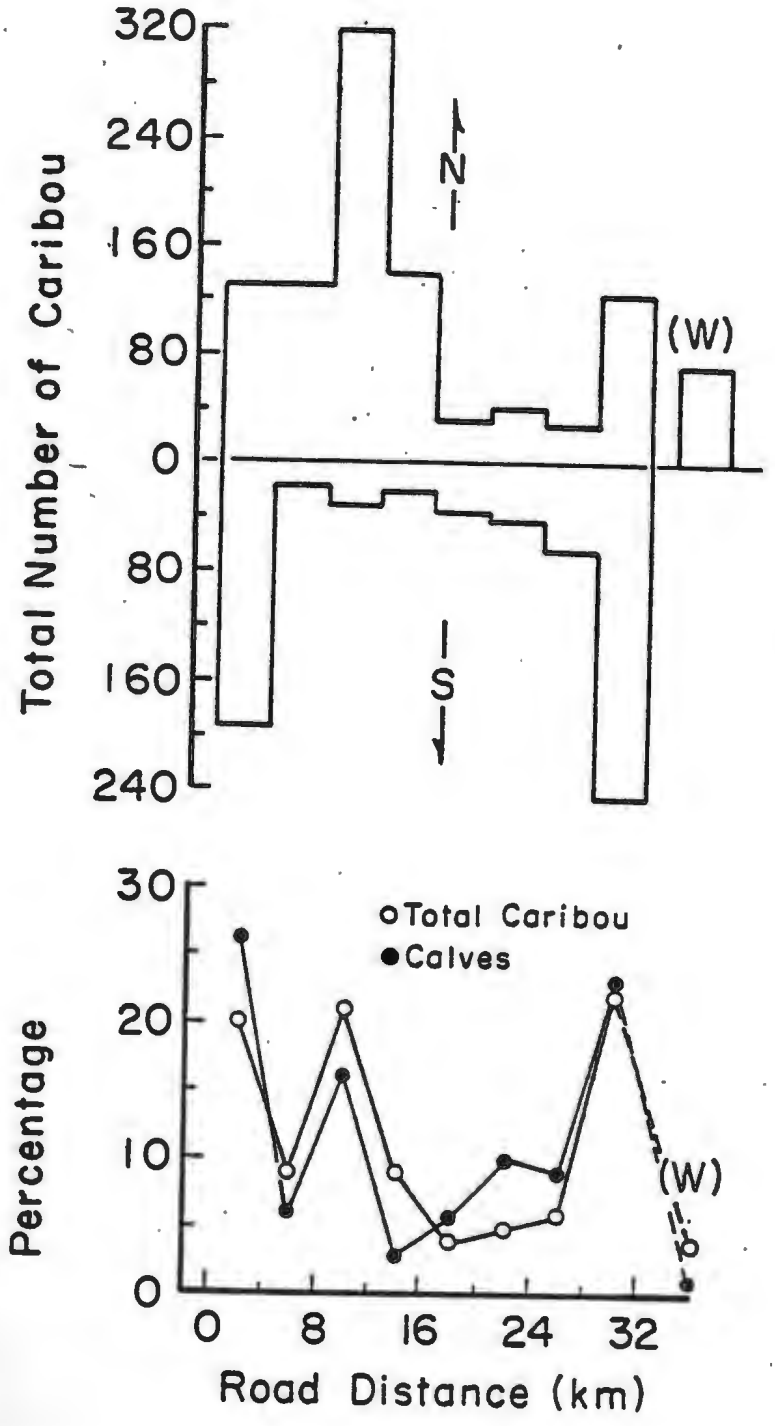

Fig. 6. Overall distribution of caribou observed along the West Sak Road, 18 July-18 August 1978.

In addition, yearlings, cows and young bulls were frequently difficult or impossible to distinguish for the same reasons cited above, and numerous caribou older than calves were simply classified as "adults" (see Methods). Consequently, composition ratios (i.e. number of bulls, calves and yearlings/100 cows) are unreliable, and calf percentage was considered the only reasonable basis for comparison. Calves represented an overall mean of 26 percent of caribou classified from the West Sak Road; means for total sightings and for groups both north and south of the road (calculated using observations within 8-km road segments) were not significantly different.

Sex and age composition data obtained through extensive post-calving surveys by helicopter on 25-26 July indicated that the mean proportion of calves between the Colville and Canning Rivers was approximately 25 percent; composition ratios were 54 calves, 50 bulls and 16 yearlings/100 cows (Cameron and Whitten, unpubl.). Although this point-in-time determination does not account for calf mortality and changes in the proportion of adults present during previous or subsequent road surveys, it is likely a reliable estimate of overall sex and age composition of caribou on this portion of summer range. The close agreement of the mean calf percentages obtained by road and aerial surveys provides strong evidence that caribou near the West Sak Road were representative of those in the general area.

Because the intensity of road traffic and human activity during summer 1978 was considerably higher than originally anticipated (see next section), there was some concern that avoidance-induced changes in group composition might occur in the immediate vicinity of the West Sak Road. To test for this response, calf percentages for three intervals of distance from the road (0-500, 600-1,000 and more than 1,000 m) were compared. No abnormalities were apparent; all three means were between 25 and 26 percent.

Figure 6 also shows that most caribou were observed along three distinct segtions of the West Sak Road. Aggregate caribou observations within the 0-4, 8-12 and 28-32 km intervals (totaling only 37% of the road length) represented 63 percent of the total; similarly, 65 percent of total calves sighted were within these same intervals. Thus, although caribou were observed along virtually the entire road route, three "nodes" of occupancy are clearly identifiable.

A total of 281 individual caribou in 23 separate groups were observed crossing the West Sak Road (see Appendix II). Crossing direction was overwhelmingly to the north; excluding one group of 5, for which no direction was recorded, 266 caribou (96%) in 18 groups (82%) crossed in a northerly direction. Of 221 caribou classified, 27 percent were calves, indicating that group composition of crossing caribou was similar both to that of caribou sighted from the road and to overall estimates obtained during post-calving aggregation.

Sections of the road corresponding to peak caribou occupancy (Fig. 6), together with the number and direction of crossings applicable to each are depicted in Figure 7. Ninety-four percent of all crossings were within these same areas and, of those, virtually all were within the initial and final 4 km of the road. Higher crossing activity at the latter sites is also suggested by the frequency distribution given in Figure 6, which shows a near balance of north-south sightings at each end of the road. The preponderance of northerly crossings at the three locations shown may reflect a tendency for insect-induced coastal movements to be routed along river drainages (Cameron and Whitten, unpubl. observ.). Thus, the Kuparuk, Sakonowyak and Ugnuravik Rivers are within the areas indicated in Figure 7. In contrast, the return inland appears to be more leisurely and occurs as a widely dispersed movement of smaller groups (Cameron and Whitten, unpubl. observ.). This may account for the paucity of southward crossings in areas where northward routes predominated. Still, southbound crossings over the entire road represent only 4 percent of the total. Although such imbalance is conceivably coincidental (i.e. a function of survey scheduling), it more likely reflects actual events. We believe that oscillatory movements of caribou were abnormally short during summer 1978, and that our observations reflect a gradual northern drift followed by nearly continuous coastal occupancy through mid-August (see next section). Given a particularly severe insect season this response could be considered normal. On the other hand, one might speculate that northern movements across the road occurred freely under the strong stimulus of insect attack, whereas the periodic absence or scarcity of insects was insufficient to induce an inland return. Thus, it is possible that the amplitude of oscillations within the coastal zone was dampened by a restriction of southbound movements across the West Sak Road. This is highly conjectural, however, and further study is necessary to fully describe the interrelationship between insect activity, as controlled by weather, and the summer ecology of caribou.

Eight caribou trails were identified in the immediate vicinity of the West Sak Road. Five of these obviously extended across the road but only two were within designated nodes of caribou occupancy (Fig. 7). Hence, even though observed northbound crossings were concentrated in the vicinity of drainages (see above), such movements may actually be quite diffuse. A possible exception is the Kuparuk River where major movements were confined to the floodplain; however, annual flooding would preclude the permanence of resultant trails. Most trails identified along the West Sak Road were in constricted areas along lake margins, but usually disappeared in the absence of natural channels. This suggests that lakes direct local routing in some areas and, further, that the adjacent soft ground tends to accentuate and preserve established trails. It should be noted, however, that discontinuous local trails do not necessarily indicate major routes of movement. In contrast, caribou trail systems on the coastal plain, in the foothills and through mountain passes often continue for long distances and more accurately reflect major movements within and between seasonal ranges (LeResche and Linderman 1975).

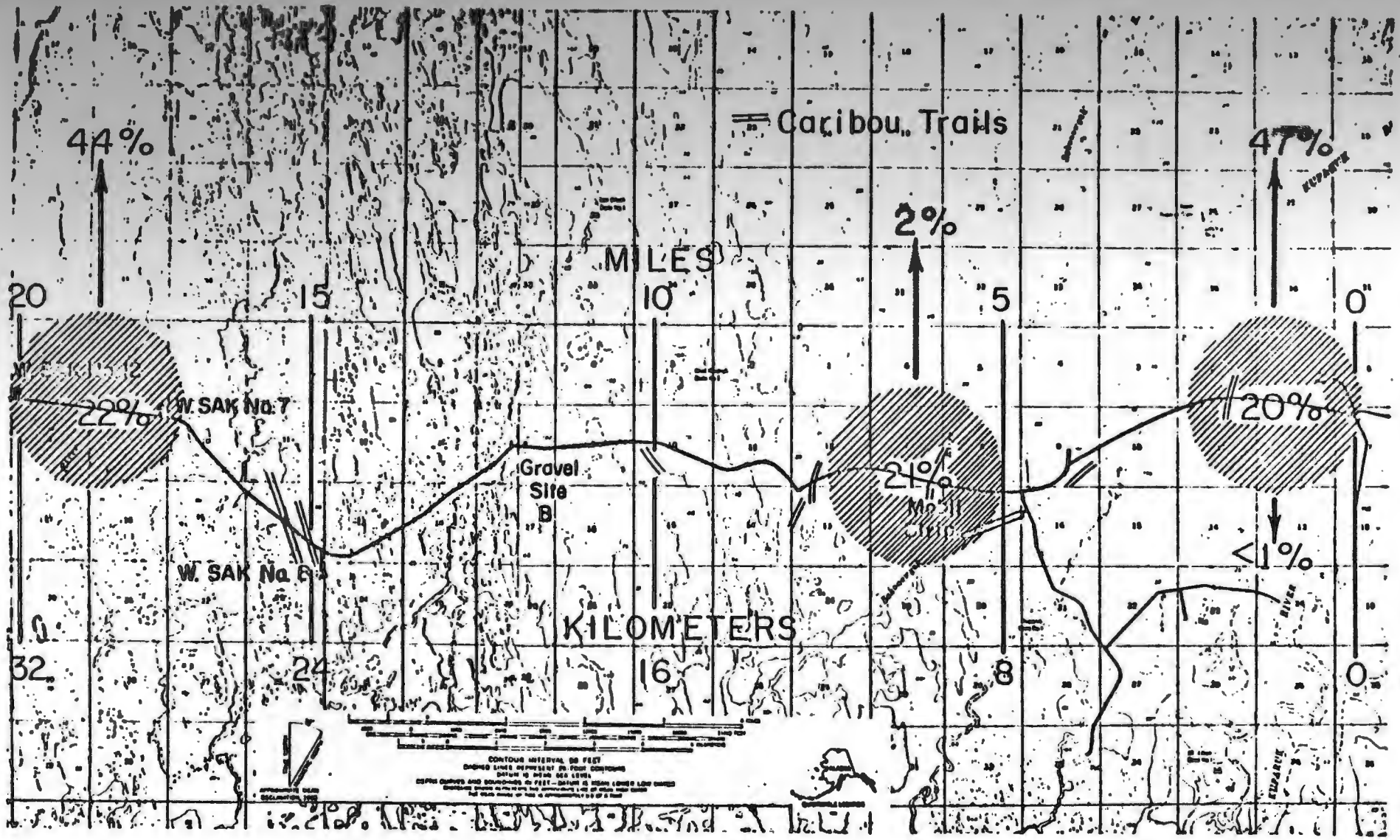

Fig. 7. Principal areas of caribou occupancy along the West Sak Road (from Fig. 6) and the crossings (direction, percentage of total) applicable to each, 18 July–18 August 1978.

To summarize, the combined July/August data show: 1) that caribou occupying summer range in the vicinity of the West Sak Road were representative of caribou in the general region in terms of mean calf percentage, 2) that the mean composition of groups crossing the road was similarly representative and, finally, 3) that, while there are no well-defined local trail systems, relative occupancy was highest and crossings were most frequent within three specific sections of the road.

Chronology of Caribou Observations along the West Sak Road in Relation to Insects and Local Traffic

Previous studies have shown that midsummer movements of caribou are tied closely to the level of insect harassment. Mosquito activity is directly related to temperature and inversely related to wind velocity (White et al. 1975, Roby 1978), and on warm, calm days large groups of caribou move to coastal areas where cool offshore breezes and sparse vegetation provide some relief from harassment. When mosquitoes are scarce or absent, caribou disperse inland to feed. Thus, oscillatory movements occur between relief habitat on or near the coast and preferred feeding sites inland (Child 1973, White et al. 1975, Roby 1978). In response to changing weather and insect density these movements can be extensive and rapid--up to 40 km in a 24-hr period (Cameron and Whitten, unpubl. observ.). The West Sak Road, located some 10-20 km inland (Fig. 1), may therefore intersect such movements.

White et al. (1975) reported that mosquitoes were noticeably active between 25 June and 10 August and that warble flies were present between 23 July and 15 August. Our own observations generally concur with these earlier reports. However, a change in the responses of caribou to insect harassment was evident in early August as oestrid flies (i.e. nose bot and warble flies) began to replace mosquitoes as the dominant insect pest (see Curatolo 1975, Roby 1978). Oestrid fly harassment increases with temperature but, in contrast to mosquito activity, increases also with wind velocity (Roby 1978). Caribou under oestrid fly attack generally do not aggregate on river deltas or coastal sand dunes, but instead disperse inland in small groups and seek relief on unvegetated gravel bars or ridgetops. This tendency for inland dispersal would again result in contact with the West Sak Road.

Temperature and wind data from Deadhorse airstrip were used as a continuous indicator of weather conditions along the West Sak Road, which is approximately the same distance inland. Means of temperature and wind velocity for each 4-hr period between 16 July and 18 August are given in Figure 8. Similar data were recorded periodically at six sites along the West Sak Road (Fig. 2), and the mean values are shown for comparison. West Sak temperatures were either the same as or slightly higher than Deadhorse readings. While such differences may be real, they may also be due to the higher readings generally obtained at the westernmost road stations; these are farther inland (Fig. 1), and temperature generally increases with distance from the coast during

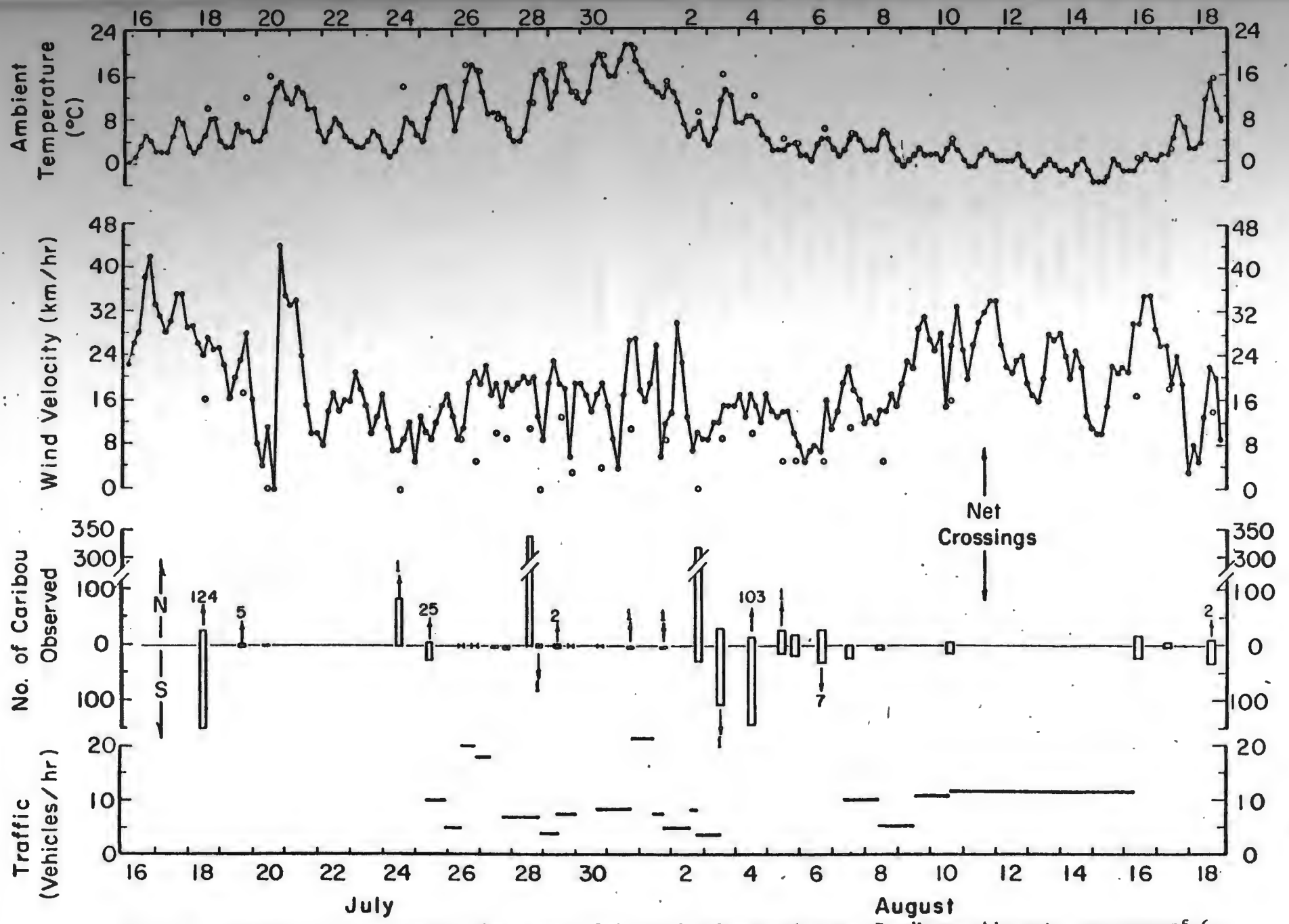

Fig. 8. Changes in local weather (● = mean of 4 hourly observations at Deadhorse Airport, o = mean of 6 measurements from the West Sak Road), traffic and the number of caribou sightings/road crossings.

summer (Haugen and Brown 1975). In contrast, wind velocity along the West Sak Road was consistently lower than at Deadhorse. This is likely due to different methods of measurement. White et al. (1975) found that wind velocities measured at 1.0-1.5 m above ground level (G: e.g. West Sak) varied consistently with readings from elevated weather stations (W: e.g. Deadhorse) according to G = 1.0+0.5 W; adjusted West Sak values are similar to corresponding means calculated from Deadhorse values. Thus, Deadhorse weather observations can be used directly, and their continuous nature permits an assessment of conditions along the West Sak Road both prior to and during the various caribou surveys.

The relationship between insect harassment and temperature/wind velocity has been described by White et al. (1975) for the Prudhoe Bay area (Fig. 9). Under calm conditions insects became active at temperatures above 6°C; above 8.5°C insect harassment was moderate and above 13.5°C severe harassment could be expected. Within these temperature ranges, mosquito activity is clearly moderated by higher winds. Thus, weather data in Figure 8 (as interpreted in Fig. 9) indicate a potential for insect (mosquito) harassment between 18 July and 4 August (excluding 23 July) and again on 17-18 August. According to both sources of weather data, conditions conducive to severe harassment were present on 20, 25, 26 and 28-31 July and 1 August, and data from the West Sak Road indicate the possibility of severe harassment on 24 July and 3 August. It should be noted, however, that some days conducive to harassment included variable periods of cool or windy weather, usually late at night or early in the morning hours.

On the morning of 18 July, during a period of moderate mosquito harassment, large numbers of caribou approached from the south and moved across the West Sak Road toward insect relief areas near the coast. By the evening of 19 July few caribou remained near the road and, of those, most were also moving north. With severe harassment on the 20th, only two caribou were seen. Moderate to severe harassment continued through the 22nd, but the 23rd was cool and windy. Mosquito density was moderate to severe when caribou surveys began again on 24 July, and several groups of caribou were seen on the north side of the road, possibly having dispersed inland during cool weather on the previous day. With severe mosquito harassment continuing on the 25th, a few caribou appeared from the south and moved across the road toward the coast (there had been some cool windy weather during the previous night). Moderate to severe harassment prevailed on 26 July and no caribou were seen during road surveys. A few animals were observed on the 27th as conditions moderated; and on the morning of the 28th, following a cold, windy night, large numbers were seen north of the road. By afternoon most of those caribou had again moved north, and very few were present along the road during the period of severe harassment which persisted through 1 August; of those observed, several were northbound toward insect relief areas. On 2 August, after a cool night, caribou returned to the north side of the road; an additional cool night may have resulted in continued inland movement, as relatively large numbers were seen south

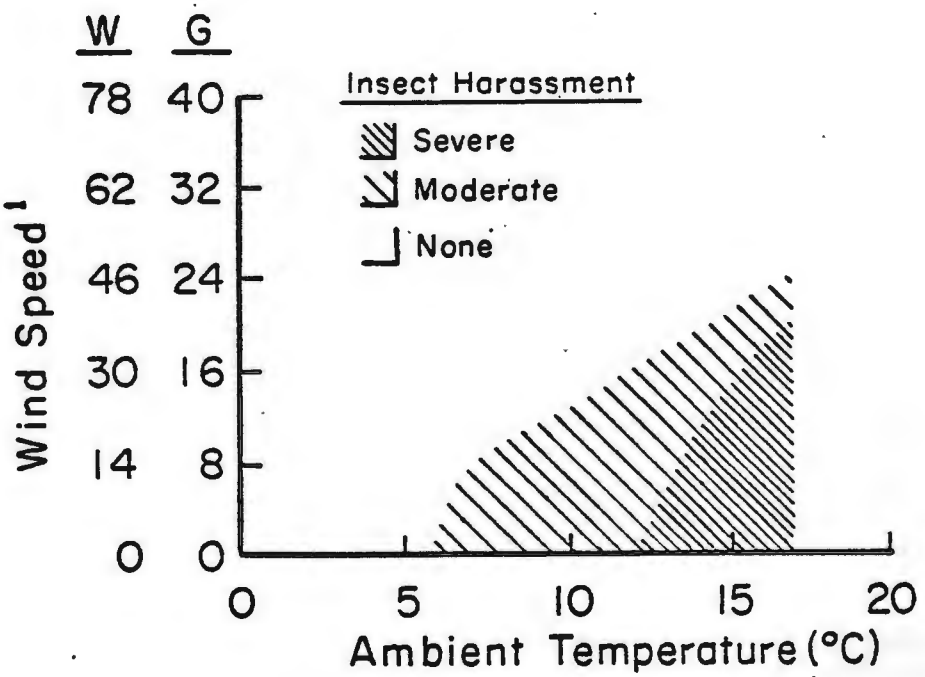

Fig. 9. The effect of temperature and wind velocity on level of insect harassment (modified from White et al. 1975).

[1] km/hr; measured from an elevated weather station (W) or near ground level in the field (G).

of the road on 3 August. Insect harassment was moderate to severe on the 3rd, and continued to be moderate on the 4th when numerous northbound caribou again crossed the road. Relatively few caribou were observed from the road between 5 and 16 August; seven southbound crossings on the 6th were the only movements detected (this is consistent with the reactions of caribou to oestrid flies as described above). The insect season had probably ended by 17 and 18 August.

Aerial surveys on 20, 25 and 31 July confirmed that, during periods of severe insect attack, large groups of caribou were present on coastal relief habitat between the Kuparuk and Kalubik Rivers. Successive relocations of six radio-collared caribou also support the patterns of movement indicated by weather data and sightings along the West Sak Road. One radio-collared caribou, observed just south of the West Sak Road on 18 July, had moved roughly halfway to the coast by the next day. On 19 July, two more collared caribou appeared just south of the road, and another was found between the road and the coast. By 20 July all four had moved to the coast where two additional collared caribou were also seen. All six caribou were again located near the coast on 25 and 31 July. Of these, one moved inland by 9 August and was observed just south of the road on 24 August; two others moved southward by 25 August; and one was observed just west of the road terminus on 24 August. The remaining two were not relocated until October and, by then, were well southeast of the study area.

It should be noted that discrete sites were not regularly sought out by caribou as insect relief areas. Virtually the entire beach zone was occupied at one time or another, and rapid movements paralleling the coast were common during the height of the insect season. However, during periods of particularly severe mosquito harassment there was a greater tendency for aggregation on coastal deltas, prominent points and occasionally in shallow water offshore. In short, the entire beach zone appears to be important from the standpoint of insect relief. Any preference for specific areas emerged only under extreme conditions.

Any separate effects of vehicular traffic were apparently obscured by the strong relationship between caribou presence along the West Sak Road and insect activity. Although all high traffic rates corresponded to low caribou sighting rates, low or medium levels of traffic were associated with a wide range in sighting frequency (Fig. 8). Hence, the relationship between traffic and caribou use of the West Sak Road is inconsistent, whereas the effect of weather/insects on caribou movements is more or less predictable. However, even the insect-caribou interrelationship has not been quantified adequately in terms of the precise mechanism by which insect chronology/density controls the onset, speed and direction of caribou movements. A thorough knowledge of the normal responses of caribou to insect activity is required before the separate effects of additional stimuli (e.g. road traffic, various structures, human presence) can be identified and their importance assessed. Nevertheless,

since caribou avoidance of other road areas has been well-documented (Cameron and Whitten 1977, 1978; Cameron et al. 1979), any high rates of traffic on the West Sak Road will remain an item of concern. Fortunately, heaviest traffic in 1978 (in excess of 20 vehicles/hr) occurred during periods of severe insect harassment, when caribou were concentrated near the coast.

RECOMMENDATIONS

Based on the foregoing data and considering the known sensitivity of caribou to disturbance on calving grounds and summer range, we recommend the following until such time as more specific--and perhaps less restrictive--guidelines can be developed:

A. Activities

1. No construction activity should occur in the Kuparuk Development Area during the active calving period (ca. 1 June-20 June); a ban on road maintenance would also be highly desirable.

2. No construction, and only essential road maintenance operations should be permitted during the last week of May, and between 8 July and 15 August. Hopefully, this policy will allow normal staging of parturient caribou and insure unrestricted movement across the West Sak Road during the period of highest insect activity.

3. Summer road repairs and facilities relocation should be scheduled between 21 June and 7 July, and/or between 16 August and 15 September.

4. At no time during the spring and summer months should road or air traffic within the Kuparuk Development Area exceed the minimum required for specific maintenance, restoration, relocation and/or production functions. Road traffic should be screened carefully to avoid unauthorized and unnecessary use, and authorized trips should be scheduled as infrequently as practicable, using vehicle convoys if appropriate. Low-level flights (i.e. less than 500 ft) should be prohibited, and the frequency of helicopter and fixed-wing operations reduced to the greatest extent possible. In general, transport activities from midday through late afternoon are less likely to conflict with caribou during the insect season.

B. Structures and Facilities

1. Permanent facilities should include only those absolutely essential to oil production. Temporary facilities should be similarly minimal and restricted to sites of permanent development.

2. Facilities should not be located in areas regularly occupied by large numbers of caribou and/or where crossings are known to be frequent. Accordingly, placement of facilities within 4 km of each end of the West Sak Road (0-2.5 and 17.5-20.0 mi) and within the 8-12 km road interval (5.0-7.5 mi) should be avoided.

3. Oil feeder lines should be buried and consolidated wherever possible. Compulsory above-ground sections should be located in non-sensitive areas (see Fig. 7) with appropriate crossing provisions.

ACKNOWLEDGMENTS

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Appendix I. Survey observations on the calving grounds, 11-14 June 1978.

Obs. No.	Total No.	B	C	ca	Y	A	Obs. No.	Total No.	B	C	ca	Y	A
20	6		2	2	2		56	3		1	1	1	
21	4		2	2			57	2				2	
22	2		1	1			58	6		2	2	2	
23	6		3	3				6		2	2	2	
24	4		2	2			59	2		1	1		
25	2		1	1			60	13		7	6		
	2		1	1				4		1	1	2	
	1				1			2		1	1		
	2				2		61	2		1	1		
26	5		3	2			62	4		3		1	
27	2		1	1			63	11		5	5	1	
28	5		3	2				34		17	15	2	
29	2		1	1			64	5		2	2	1	
30	3		1		2		65	4		2	2		
31	4		2	2			66	2		2			
32	6		3	3			67	4		2	2		
33							68	1		1			
34	1				1		69	31		17	13	1	
35	14		7	7			70	1					1
	14		4	4	6		71	12		6	5	1	
	3				3		72	2		1	1		
36	2		1	1			73	12		6	5	1	
37	4				4			2		2			
38	4		2	2			74	18		9	9		
39	6		3	3			75	8		4	4		
40	4		1		3			3		2		1	
41	2		1		1			20		10	10		
42	4				3	1	76	2		1	1		
43	4		2	1	1			31		16	14	1	
44	7		2	1	4		77	5		2	2	1	
45	2		1	1			78	1		1			
46	2		1	1			79	2		1	1		
47	2		1	1			80	2		1		1	
48	2		1	1			81	7		3	3	1	
49	2				2		82	1				1	
50	2		1	1			83	5		2	2	1	
	4		2	2			84	1				1	
	2				2		85	3	1	1		1	
	2		1	1			86	1				1	
	4				4		87	2		1	1		
	2		1	1			88	4		2	2		
	1				1		89	1				1	
51	4		1	1	2		90	3		1	1	1	
52	1					1	91	2				2	
53	3		1	1	1		92	3				2	1
54	4		2	2			93	2		1		1	
55	4		2	2			94	3				3	

Appendix I. Continued.

Obs. No.	Total No.	B	C	ca	Y	A	Obs. No.	Total No.	B	C	ca	Y	A
95	1					1	131	2		1	1		
96	6		2	2	2		132	2		1	1		
97	4		2	2			133	3		2	1		
98	48		22	22	4		134	4	1	2	1	1	
	2		1	1				2		1	1		
	2		1	1			135	2		1	1		
	12		4	4	4		136	2		1	1		
99	51		25	22	4		137	3		1	1	1	
100	1		1				138	7		3	3		1
101	20		10	9	1		139	2		1	1		
	5		2	2	1		140	3				1	2
	2		1	1				2		1			1
102	4		2		2		141	2				2	
103	2				2		142	3		1	1	1	
104	5				5		143	1				1	
105	2		1	1			144	2		1	1		
	9		5	3	1		145	2		1	1		
106	4		2	2			146	1		1			
	4		2	2			147	2	2				
107	10		4	4	2		148	1					1
108	1				1		149	4		2	2		
	2		1		1		150	3		1		2	
109	7		4		3		151	4		2	2		
110	3				3		152	2				2	
	5		2	2	1		153	2		1	1		
	5		2	2	1		154	5		2	2	1	
111	3		2		1			10		5	5		
112	1		1				155	4		2	2		
113	2		1	1			156	1		1			
114	3	3					157	3		1	1	1	
115	3				3		158	1				1	
116	2		1	1				2		1	1		
117	4		2	2			159	9		3	3	3	
118	2		1	1			160	8		3	2	3	
119	3				3		161	2		1	1		
120	3	1				2	162	2		2			
121	2	2					163	2		1	1		
122	2		1		1		164	2		1	1		
123	6		3	3			165	4		2	2		
124	2		2				166	1		1			
	3		1	1	1		167	4		2	2		
125	2		1	1			168	2		1	1		
126	8		4	3	1		169	2		1	1		
127	1		1				170	6		3	3		
128	3		1	1	1		171	2		2			
129	1	1					172	3		2		1	
130	4		2	2			173	1	1				

Appendix I. Continued.

Obs. No.	Total No.	B	C	ca	Y	A
174	3		2		1	
175	3				3	
176	1	1				
177	3		1	1	1	
178	2		1		1	
179	3				3	
180	2	1	1			
181	1					1
182	2		1	1		
183	4		2	2		
184	3				3	
185	2		1	1		
186	2		1	1		
187	6		4	2		
188	6		3	3		
189	4		2	2		
190	4		2	2		
191	1					1
192	4		2	2		
193	1		1			
194	6		3	3		
195	4		2	2		
196	4		2	2		
197	3		2	1		
198	7		4	2	1	
199	1				1	
200	2		1	1		
Totals	964	14	424	346	166	14

B = bulls, C = cows, ca = calves, Y = yearlings, A = adults

Note: Due to low flight visibility, observations 1-19 were discarded; the applicable transects were subsequently resurveyed.

Appendix II. Caribou observations from the West Sak Road, 18 July-18 August, 1978.

Date	Time	Obs. No.	Total No.	B	C	ca	Y	A	U	Location[1] (mi)	I.O.D.[2] (m)	N/S[3]
18 July	1000-1545	1	22		8	8		6		19.6	1000+	S(X)
		2	5		2	2		1		19.6	1000	N
		3	13		5	5		3		19.7	1000+	N
		4	60						60	19.6	1000+	S(X)
		5	52						52	20.0	1000+	W
		6	14		5	5		4		19.1	1000+	S(X)
		7	28	5	8	6	2	7		18.1	1000	S(X)
		8	8						8	15.3	1000+	N
		9	25	2		3		9	11	15.6	1000+	S
		10	3	1				2		14.7	1000+	N
19 July	1400-1800	1	5		1	1	3			2.3	0	S(X)
		2	1	1						6.4	600	N
		3	1	1						20.0	800	W
20 July	1000-1200	1	1	1						6.8	600	S
		2	1				1			10.4	800	S
24 July	-	1	1	1						1.6	300	S(X)
		2	5	5						1.6	200	N
		3	3	3						1.7	200	N
		4	75						75	2.8	1000+	N
		5	2		1	1				6.8	400	N
25 July	0850-1200	1	1				1			13.7	0	S(X)
		2	6		4	2				6.2	0	S(X)
		3	18	9	7	2				1.7	0	S(X)
		4	3	2			1			1.5	100	N
		5	2	2						0.2	200	N
26 July	0930-1130	No Caribou Observed										
	1930-2130	No Caribou Observed										
27 July	0800-1030	1	2	2						1.6	300	S
	1630-1830	1	6	4			2			3.1	1000+	S
28 July	0900-1300	1	2	2						1.4	200	S
		2	76	11	38	16	9	2		1.8	600	N
		3	60	6	26	11	7	5	5	5.0	1000+	N
		4	3		2	1				7.2	1000+	N
			71	5	41	19	6			7.2	1000+	N
			8						8	7.2	1000+	N
			2						2	7.2	1000+	N
			26			9		14	3	7.2	1000+	N
		5	95						95	9.4	1000+	N

Appendix II. Continued.

Date	Time	Obs. No.	Total No.	B	C	ca	Y	A	U	Location[1] (mi)	I.O.D.[2] (m)	N/S[3]
	1930-2200	1	1	1						1.6	150	N
		2	1	1						1.6	300	S
		3	1		1					1.7	0	N(X)
		4	1	1						2.5	600	S
29 July	0930-1150	1	2		1	1				0.8	0	S(X)
		2	1	1						1.0	100	N
	1930-2200			No Caribou Observed								
30 July	1630-1800			No Caribou Observed								
31 July	1400-1700	1	1		1					1.8	30	S(X)
1 August	1815-2000	1	1				1			14.9	50	S(X)
2 August	1700-1930	1	1					1		1.7	1000	N
		2	18						18	2.0	1000+	N
			19						19	2.0	1000+	N
		3	26			5			21	2.0	500	S
		4	24						24	3.0	1000+	N
		5	3		1	1	1			3.8	150	S
			10		5	4	1			3.8	200	N
		6	25						25	5.3	1000+	N
		7	105						105	6.1	1000+	N
		8	30						30	7.7	1000+	N
		9	9						9	10.1	1000+	N
		10	38						38	19.9	1000+	N
		11	39			10			29	18.4	1000+	N
3 August	0945-1300	1	1					1		2.2	1000+	N
		2	10		4	4		2		3.9	1000+	N
		3	1	1						4.7	100	N(X)
		4	6	1	2	2	1			5.1	500	S
		5	5		1	1	2	1		13.2	1000+	S
		6	1					1		17.7	500	S
		7	3		2	1				17.9	300	N
		8	7	2	2	2	1			18.6	800	S
		9	7		2	2	1	2		18.3	500	N
		10	7		2	2		3		18.8	1000+	S
		11	3		1	1	1			20.0	1000	W
		12	1					1		20.0	1000+	W
		13	9		4	4	1			20.0	1000	N
		14	3	3						20.0	1000+	W
		15	68	7		13			48	19.5	1000+	S
		16	5						5	20.0	1000+	W
		17	14		7	7				16.9	1000+	S

Appendix II. Continued.

Date	Time	Obs. No.	Total No.	B	C	ca	Y	A	U	Location[1] (mi)	I.O.D.[2] (m)	N/S[3]
4 August	-	1	3	1	1	1				-	800	S
		2	1	1						2.0	1000+	S
		3	2	2						2.8	1000+	N
		4	1	1						3.3	1000+	N
		5	1					1		3.6	1000+	N
		6	1	1						7.5	1000+	S
		7	2					1	1	7.9	1000+	S
		8	3		1	1		1		10.3	1000+	S
		9	1					1		10.8	1000+	N
		10	2	1				1		11.4	1000+	N
		11	2	2						12.6	600	S
		12	2		1	1				13.2	1000+	S
		13	1					1		13.5	1000+	S
		14	2		1	1				13.8	1000+	S
		15	1					1		14.0	1000+	S
		16	5	1	1	1		2		16.9	1000+	S
		17	1					1		17.9	1000+	S
		18	4		2	2				17.1	400	N(X)[4]
		19	4		1	1	1	1		18.5	800	S
		20	1					1		18.3	1000+	S
		21	1					1		20.0	1000+	S
		22	4		2	2				14.3	600	N
		23	52	11	17	13	7	4		1.2	800	S(X)
		24	8		4	4				1.2	1000+	S(X)
		25	44	5	14	14	3	8		1.3	1000	S(X)
		26	11	8	1	1	1			0.4	1000+	S
5 August	0830-1200	1	7	2	2	1	1	1		1.2	1000	S
		2	5						5	7.3	1000+	N
		3	8	2	1	1		4		7.7	1000+	S
		4	15	1	6	5	2	1		13.8	600	N
		5	4					4		14.3	1000+	N
		6	5	1				4		16.4	1000+	N
		7	1	1						0.4	0	S(X)
	1830-2100	1	4	4						0	800	S
		2	4		2	2				0.7	200	S
		3	1	1						1.8	1000+	S
		4	1					1		2.5	1000+	S
		5	4					4		4.2	1000+	N
		6	2		1	1				4.8	100	S
		7	5		2	2		1		5.7	1000+	N
		8	3		1	1	1			13.8	50	N
		9	2		1	1				14.3	500	S
		10	5	1	2	2				15.6	1000	S
		11	4	1	1	1		1		15.5	800	N
		12	4		1	1		2		20.0	1000+	N

Appendix II. Continued.

Date	Time	Obs. No.	Total No.	B	C	ca	Y	A	U	Location[1] (mi)	I.O.D.[2] (m)	N/S[3]
6 August	1550-1830	1	3		1	1		1		7.0	1000+	N
		2	1					1		10.2	1000+	N
		3	6					6		11.4	1000+	N
		4	2		1	1				12.9	1000+	S
		5	1					1		13.9	1000+	S
		6	2		1	1				13.4	1000+	S
		7	2					2		13.9	1000+	S
		8	2		1	1				14.0	1000+	S
		9	8	2	2	2		2		13.6	1000+	S
		10	2	2						14.5	1000+	S
		11	1	1						14.7	800	S
		12	7	2	2	2		1		16.8	1000+	S
		13	2		1	1				17.6	1000+	S
		14	3					3		17.6	1000+	S
		15	3	1	1	1				18.2	800	N
		16	1	1						15.3	300	N
		17	3						3	15.8	1000+	N
		18	3		1	1		1		13.7	1000+	N
		19	2						2	13.1	1000+	N
		20	7	1	1	1	4			12.0	600	N(X)
7 August	1000-1345	1	3		1	1	1			0.7	200	S
		2	1					1		1.2	900	S
		3	4		2	2				6.1	800	S
		4	4		2	2				7.0	500	S
		5	7		2	2		3		11.1	1000+	S
		6	1	1						15.3	400	S
		7	3		1	1			1	19.3	1000+	S
		8	2						2	20.0	1000+	W
		9	4		1	1		2		20.0	1000+	W
8 August	0945-1200	1	4		2	2				10.5	1000	S
		2	4		2	2				11.5	1000+	S
10 August	1230-1600	1	5	2	1	1		1		14.5	1000	S
		2	3					1	2	19.0	1000+	S
		3	6		3	3				17.9	1000+	S
		4	3						3	16.1	1000+	N
		5	1					1		14.2	1000+	N
16 August	0800-1130	1	4	1			1	2		6.2	600	S
		2	3	1	1			1		8.5	1000+	S
		3	5		1	1		3		9.8	1000+	N
		4	16	3	6	3	3	1		12.0	600	S
		5	5	1	2	2				14.0	1000	N
		6	5		2	2	1			9.0	800	N
		7	3		1	1		1		8.2	1000+	N

Appendix II. Continued.

Date	Time	Obs. No.	Total No.	B	C	ca	Y	A	U	Location[1] (mi)	I.O.D.[2] (m)	N/S[3]
17 August	0730-1100	1	4		2	2				6.7	600	S
		2	4		1	1	1	1		12.1	1000	N
18 August	1350-1700	1	5		2	2	1			3.8	0	-(X)
		2	1		1					4.8	200	S
		3	1	1						4.8	1000+	S
		4	1	1						5.5	800	S
		5	4	1	2	1				6.1	350	N
		6	1	1						7.2	1000+	S
		7	1	1						7.7	1000	S
		8	1		1					8.5	100	S(X)
		9	2		1	1				8.9	200	S
		10	2		1	1				9.3	500	S
		11	1					1		9.3	1000+	N
		12	1		1					12.5	0	S(X)
		13	1	1						13.3	200	N
		14	2		1	1				15.3	1000+	S
		15	2		1	1				15.8	1000+	S
		16	4		2	2				17.7	1000+	S
		17	3		1	2				16.6	300	S
		18	1	1						18.0	1000+	S
		19	2					2		18.4	1000+	S
		20	2					2		18.9	1000+	S
		21	2		1	1				18.9	250	S
		22	2		1	1				19.0	700	N
		23	1		1					19.2	150	S
		24	3	1	1		1			19.7	1000	S
		25	1		1					19.7	300	N
		26	1					1		20.0	1000+	W

[1] Road mileage (see Fig. 2).
[2] Initial observation distance (1000+ = more than 1000 m).
[3] Initial sighting north (N) or south (S) of road; X = eventual crossing, W = West of end of road.
[4] Only one crossed.

B = bulls, C = cows, ca = calves, Y = yearlings, A = adults, U = unknowns.