AN EVALUATION OF SATELLITE TELEMETRY FOR MONITORING MOVEMENTS OF CARIBOU IN THE CENTRAL ARCTIC HERD, ALASKA, 1984

FINAL REPORT

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Executive Summary

1. A cow caribou (with a calf), belonging to the Central Arctic Herd, was collared with a satellite transmitter in the Kuparuk Oilfield in 1984. From 19 June to 17 August, the radio transmitted 18 hours per day for a total of 1080 hours, 80 hours more than expected.
2. A total of 348 locations were recorded, for a mean of 5.8 locations per day or one location every 3.1 hours of transmission time.
3. The location of 13 direct observations of the radio-collared cow averaged 0.52 miles from the nearest satellite-fixed location.
4. Data from a temperature sensor in the radio-collar revealed mean temperatures of 46°F during the post-calving season, 52°F during mosquito season, and 54°F during oestrid fly season.
5. Data from an activity sensor in the collar indicated that the cow was less active during post-calving than during the other two seasons.
6. The satellite-fixed locations of the radio-collared cow provided detailed data on movement patterns during the three seasons studied.
7. During post-calving, the cow remained near the coast between the Oliktok Point and Milne Point roads and traveled an average of 5 miles per day.
8. During mosquito season, the cow's range expanded to include the entire area between the Colville River and Prudhoe Bay. The cow crossed the Oliktok Point and Milne Point roads at least 10 times. The mean distance traveled per day increased to 14 miles; this increase was undoubtedly due to harassment by mosquitoes.
9. During oestrid fly season, the cow moved inland. The mean distance traveled dropped to 9 miles per day. For the first time in the study she

was found near the Spine Road-Kuparuk Pipeline corridor (in three different areas). Her movement pattern and association with the pipeline were probably a result of harassment by oestrid flies.

INTRODUCTION

Conventional radio telemetry, in which radio-collared animals are tracked from the ground or from aircraft, is an effective, widely used technique for monitoring animal movements (e.g., Amlaner and Macdonald 1980, Cheeseman and Mitson 1982). In recent years, advances have been made in the use of satellites for receiving transmissions from radio-collars (Craighead et al. 1972, Gandy 1982, Kolz et al. 1982, Mate 1984). Satellite-based receivers offer several advantages over aircraft- or ground-based receivers: animals can be tracked in all weather conditions, the cost per location is lower, and the risks to personnel are greatly reduced. The last two considerations are especially important when compared with tracking from aircraft in remote areas. The major disadvantages of satellite telemetry are that the precision and accuracy of the locations can vary, transmissions can only be monitored when a satellite is passing overhead, and there are only limited numbers of transmitters and satellites available.

Satellite telemetry is based on the Doppler Effect; as the satellite passes overhead it uses the shift in radio-wave frequency it receives to determine the location of the transmitter. This technique rests on several assumptions. The frequency of the transmission must be extremely stable, because the calculated location is based on the point in space at which the satellite receives the exact radio frequency programmed into the transmitter. Temperatures below $-4^{o}F$ will affect the stability of the frequency transmitted. It is also assumed that the elevation of the transmitter is constant. Location accuracy declines as the difference between the actual and assumed elevations increases.

The only satellite system available to the private sector for location information is the French ARGOS System, using United States NOAA meteorological gical satellites. Two satellites are now in operation; plans call for the use of two satellites until at least 1990 (ARGOS Bulletin, October 1984).

Telonics, Inc. (Mesa, Arizona) recently developed a satellite-compatible transmitter suitable for use on caribou. The availability of that transmitter provided the impetus to pursue a study of caribou movements using satellite telemetry.

This study was initiated to determine the effectiveness of satellite telemetry for monitoring the spring and summer movements of a caribou in the Central Arctic Herd (CAH) of Alaska. The specific objectives of this study were as follows:

1. to collect data on the movement patterns and activity of a caribou, and to collect concurrent data on ambient air temperature, in and near the Kuparuk Oilfield;
2. to determine the accuracy of satellite-fixed locations of the radio-collared caribou;
3. to determine the number of locations fixed under field conditions; and
4. to determine if the satellite transmitter would function throughout the expected life span of the battery.

STUDY AREA

The study area was bounded by the Beaufort Sea on the north, the Colville River on the west, and the Putuligayuk River on the east, and extended inland approximately 20 miles (Figure 1). This area encompasses the Kuparuk Oilfield and the western portion of the Prudhoe Bay Oilfield. Detailed information on physiography, climate, and vegetation is presented by Wahrhaftig (1965) and Walker et al. (1980).

METHODS

Field work began on 19 June 1984, when biologists from the Alaska Department of Fish and Game and Alaska Biological Research placed a radio-collar on a cow caribou near Milne Point. The cow was accompanied by a calf.

The frequency of the satellite transmitter was 401.650 MHz (UHF). The transmitter was programmed to operate 18 hours per day, from 0400 to 2200 Alaska Daylight Savings Time. This transmission schedule was based on computer-generated predictions of the satellite orbits, which indicated the time and angles of elevation at which the satellites would pass over the study area. The schedule of 18 hours on and 6 hours off was selected to maximize the number of locations fixed over the life of the transmitter by interrupting transmissions during late-night hours, when the satellites seldom passed over the study area.

The satellite transmitter sent a pulse of data once each minute. Data

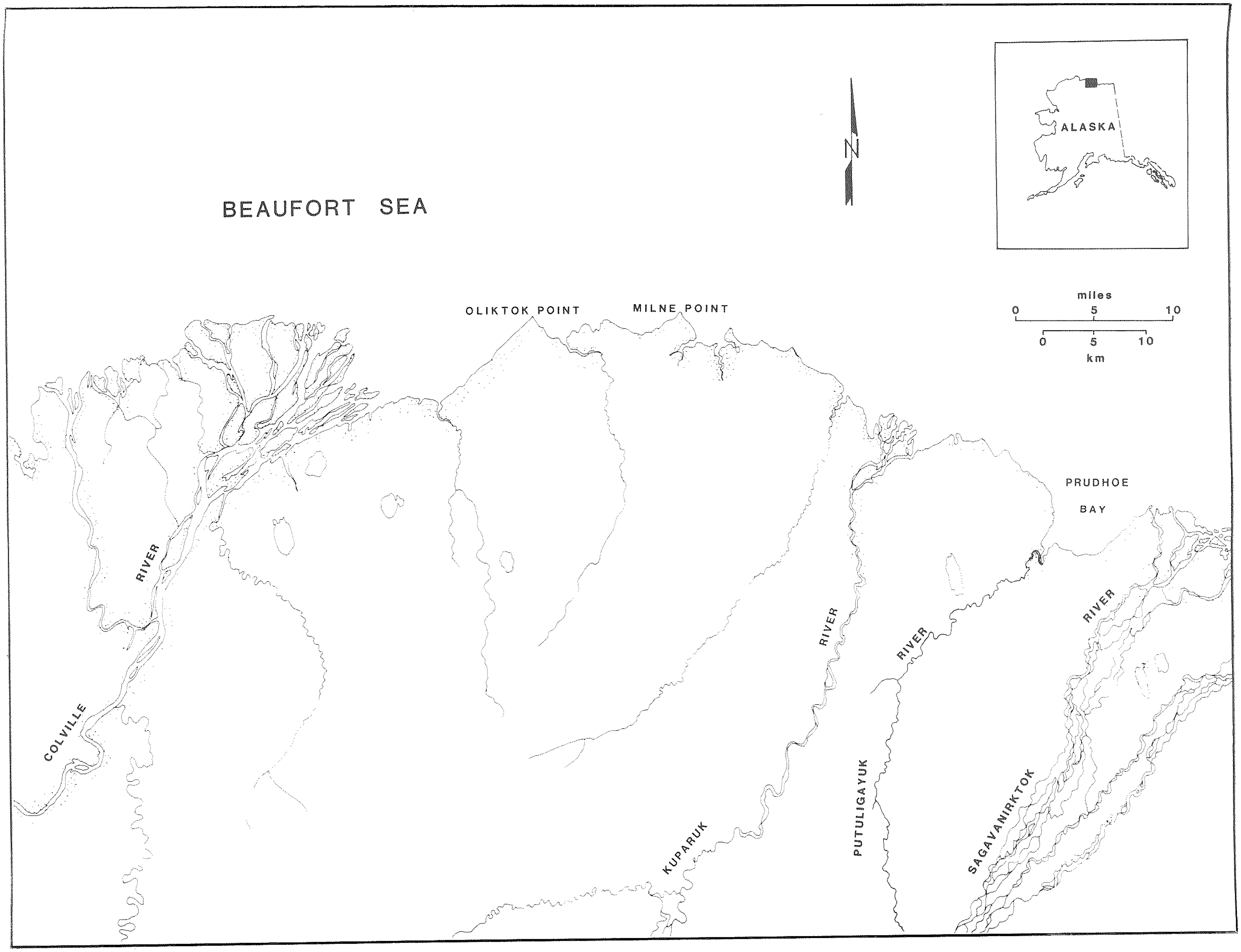

Figure 1. Location of study area for CAH satellite-telemetry study, 1984.

were relayed via satellite to one of several ground stations around the world, then transferred to the ARGOS Service Center for decoding and compilation. Monthly computer print-outs were mailed from the ARGOS Service Center to our office. Data could also be transferred daily between computers via a telephone modem.

The following data were received:

1) the date, time, and latitude and longitude (to the nearest thousandth of a degree) of each location;

2) the temperature of the collar; and

3) an activity count that represented the number of times a mercury switch in the collar had been activated in the last 30-minute period (measured every hour and half hour) preceding transmission. The maximum rate possible was 1 per minute, for a maximum count of 30 in a single half-hour period.

Prior to being placed on the caribou, the radio-collar was carried to several sites in the Kuparuk Oilfield between 21 and 26 May to test the accuracy of the satellite location system. A second transmitter, with a frequency of 150.121 MHz, was also attached to the collar; this transmitter was used to locate the caribou through standard radio-telemetry techniques, which were described by Lawhead and Curatolo (1984). The caribou was monitored periodically from a Piper PA-18 "Super Cub" aircraft to obtain accurate locations for comparison with satellite fixes. Date and time were recorded for every sighting and the location was marked on a 1:63,360-scale U.S. Geological Service topographic map.

All locations were mapped according to the three time periods studied: post-calving season (19-30 June), mosquito season (1-31 July), and oestrid fly season (1-18 August). All data were entered into a Vector 4 micro-computer (Vector Graphics, Inc., Thousand Oaks, CA) for analysis.

RESULTS AND DISCUSSION

Life of the Radio-collar

The satellite transmitter functioned from 19 June to 17 August 1984 for a total of 1080 hours, which was 80 hours (8 percent) more than expected. The next generation of transmitters, to be built this spring, are expected to last 20 percent longer due to stronger batteries and reduced electrical drain from the radio components (D. Beaty, pers. comm.).

Number of Locations

A total of 348 locations were recorded, for a mean of 5.8 (SD=2.5) locations, or one location every 3.1 hours, during the 18 hours of transmission per day (Table 1). Additional locations would have been recorded if the NOAA-8 satellite had not stopped working in late June, leaving only one satellite for the remainder of the project. The launching of the NOAA-9 satellite on 12 December 1984 restored the two-satellite system, which will result in a greater number of potential fixes per unit time in the future. The diurnal distribution of location fixes was consistent except during 0400-0500, 0700-0800, 1500-1600, and 1900-2200, when the number of locations decreased (Figure 2). These declines may have resulted from fewer satellite passes during those periods or from satellite orbits that made reception difficult (e.g., low angle of elevation during the pass). The 0700-0800 and 1500-1600 declines were probably caused by the pattern of satellite passes, which created a gap in coverage. These results suggest that radio transmissions should cease 2 to 3 hours before periods when the satellites are known to be absent (based on satellite orbit predictions), to maximize the

Table 1. Seasonal means for locations, distances traveled, radio-collar temperatures, and activity counts of a cow caribou monitored by satellite telemetry, 1984.

Season	Mean Location		Mean Number of Locations per Day	Mean Minimum Distance Traveled Between Locations (miles)	Mean Minimum Distance Traveled per Day (miles)	Mean Temp. (^{o}F) of Radio Collar	Mean Activity Count	n*
	Latitude	Longitude						
Post-Calving (19-30 June)	70.42(0.04)[1]	150.08(3.93)	4.9(2.1)	1.2(1.3)	5.3(2.2)	45.7(11.2)	16.3(12.3)	58
Mosquito (1-31 July)	70.38(0.09)	149.76(0.54)	5.9(1.7)	2.4(2.4)	14.2(5.9)	52.3(7.7)	24.0(9.5)	184
Oestrid Fly (1-17 August)	70.22(0.08)	149.79(0.27)	6.2(3.5)	1.3(1.2)	9.0(3.8)	53.8(11.2)	20.8(11.0)	106
Overall (19 June-17 August)	70.34(0.11)	149.82(1.66)	5.8(2.5)	1.8(1.9)	11.0(4.6)	51.6(9.9)	21.7(10.8)	349

* n = total number of locations
1 number in parentheses is one standard deviation

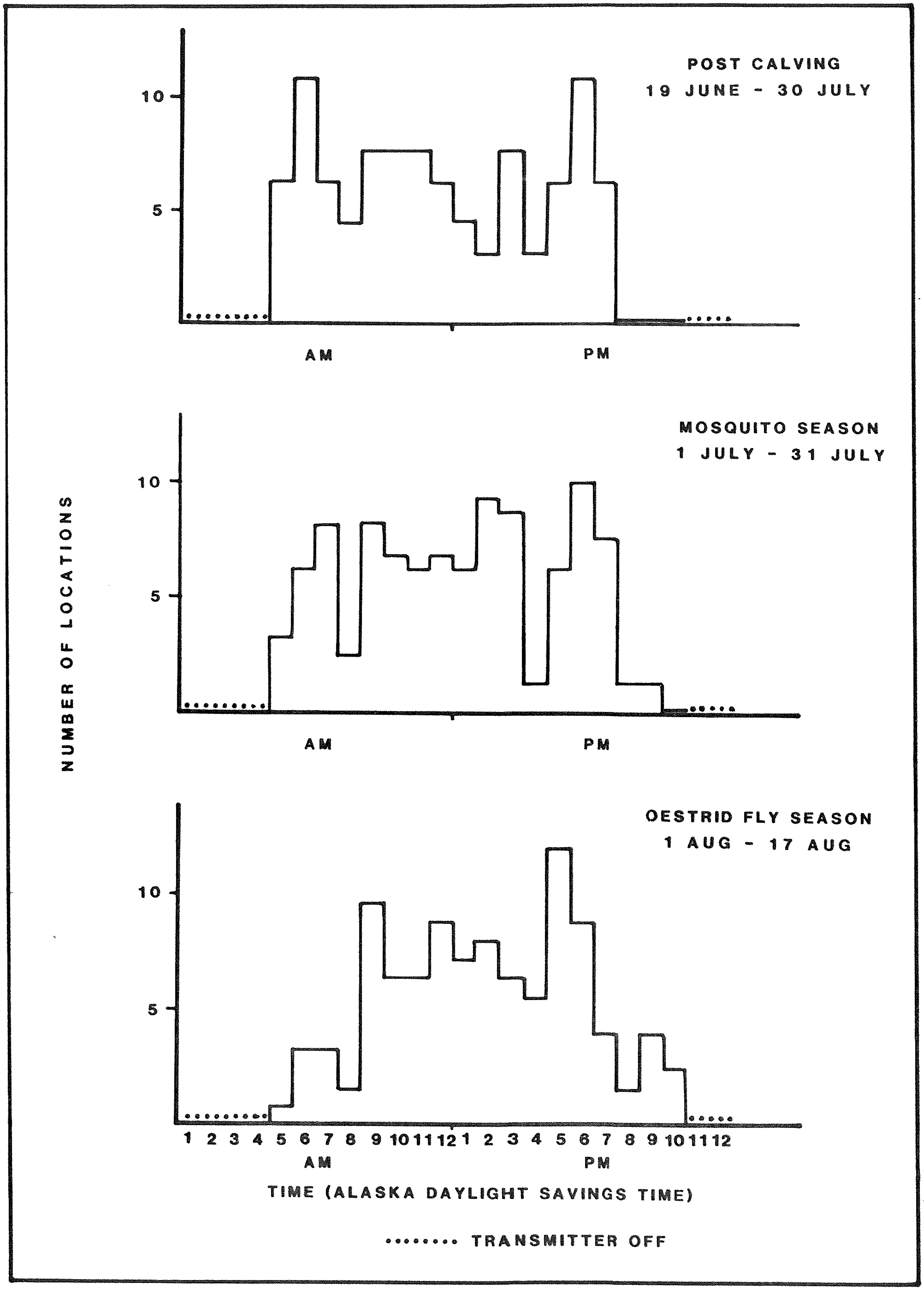

Figure 2. Diurnal distribution of satellite-fixed locations of a cow caribou in the CAH, 1984.

number of locations fixed. Three hours of continuous transmission should be adequate to fix locations on a regular basis. This time-frame overlaps the 1-hour periods when few locations were fixed, and takes into account the average time between locations (3.1 hours).

Accuracy of Locations

Two procedures were used to determine the accuracy of the locations fixed by the satellite. First, the radio-collar was placed at five known sites in the study area during late May. Thirteen satellite fixes were obtained for those five sites. The mean difference between the satellite-fixed locations and the true locations was 0.62 (SD=0.46) miles. Second, 13 locations of the radio-collared cow were obtained from direct sightings during aerial and ground surveys in July. During those surveys, we were unable to locate the cow at precisely the same moment that the satellite did. The sighting locations averaged 0.52 (SD=0.49) miles and 58.2 (SD=86.0) minutes from the nearest satellite-fixed locations.

These margins of error indicate that the accuracy of locations obtained is satellite are satisfactory for the purposes of most studies. Indeed, even locations plotted from direct observations contain some error, depending on the type of map used and the ability of the observer to record the animal's location accurately. A shortcoming of the present satellite system is the inability to determine specific locations, such as which side of a pipeline a caribou is on when the animal is very near the structure. In practice, this problem would probably occur infrequently and, at least in some cases, could be resolved by close examination of the preceding and subsequent locations.

Temperature and Activity Sensors

The mean temperature of the collar during transmission was lower during post-calving than during mosquito season and oestrid fly season (Table 1). Although a cooler mean temperature early in the summer is to be expected, these data are of limited use because of the variability in times of day at which the data were collected and because of the potential effect of solar heating on the collar.

The activity counts, with a possible range of 0 to 30 per half-hour period, averaged 16 during post-calving, 24 during mosquito season, and 22 during oestrid fly season (Table 1). These data indicate that the cow was less active during post-calving than during the other two seasons, as is also demonstrated by the low rate of movement during post-calving (see below). The higher activity counts during the insect seasons undoubtedly were a result of insect harassment. Although insect activity is positively correlated with air temperature (White et al. 1975), we found no correlation between the activity counts and the collar temperatures. This lack of correlation is probably due to the extreme sensitivity of the mercury switch in the counter, which precluded differentiation among various activities except on a gross scale.

The counter may aid in determining relative amounts of activity during different seasons, but probably cannot be used to gather accurate data for energy budget analysis. The counter does act as a mortality sensor; one can presume that the animal has died if more than two consecutive zero readings are received.

Movement Patterns

The movement patterns of the radio-collared cow differed among the post-calving, mosquito, and oestrid fly seasons (Figures 3, 4, and 5). During almost the entire post-calving period the cow remained between the Oliktok Point and Milne Point roads, moving an average of 5 miles per day (Table 1). The cow remained within an area that hosts a relatively high density of caribou during the calving season (see Cameron et al. 1983, Curatolo and Reges 1984).

The cow crossed the Milne Point Road at least twice, but tended to be located at least 1 mile from any road during this period (Figure 3). Cows may be more wary when their calves are very young (Lent 1966), which may account for this movement pattern. In the future it may be possible to determine if structures such as pipelines and roads are being avoided by caribou by using relatively few satellite-radio-collared animals, because of the high number of locations fixed.

The movement pattern of the cow changed considerably after the emergence of mosquitoes (Figure 4). During mosquito season the cow traveled as far west as the Colville River and as far east as Prudhoe Bay, crossing the Milne Point and Oliktok Point roads a minimum of six and four times, respectively, and traveling a mean distance of 14 miles per day (Table 1). The movements of this cow generally fit within the entire summer range used by caribou in the Kuparuk Oilfield in 1983 (see Lawhead and Curatolo 1984), and illustrate several important characteristics of CAH movements during mosquito season. First, mosquito-harassed caribou travel into the wind until they reach mosquito-relief habitat at or near the coast (White et al. 1975); river deltas are favored as relief habitat (Cameron 1983, Lawhead and Curatolo 1984). Because the prevailing summer winds in the study area are from the ENE (Walker et al. 1980), caribou in the Kuparuk Oilfield often use the Kuparuk River

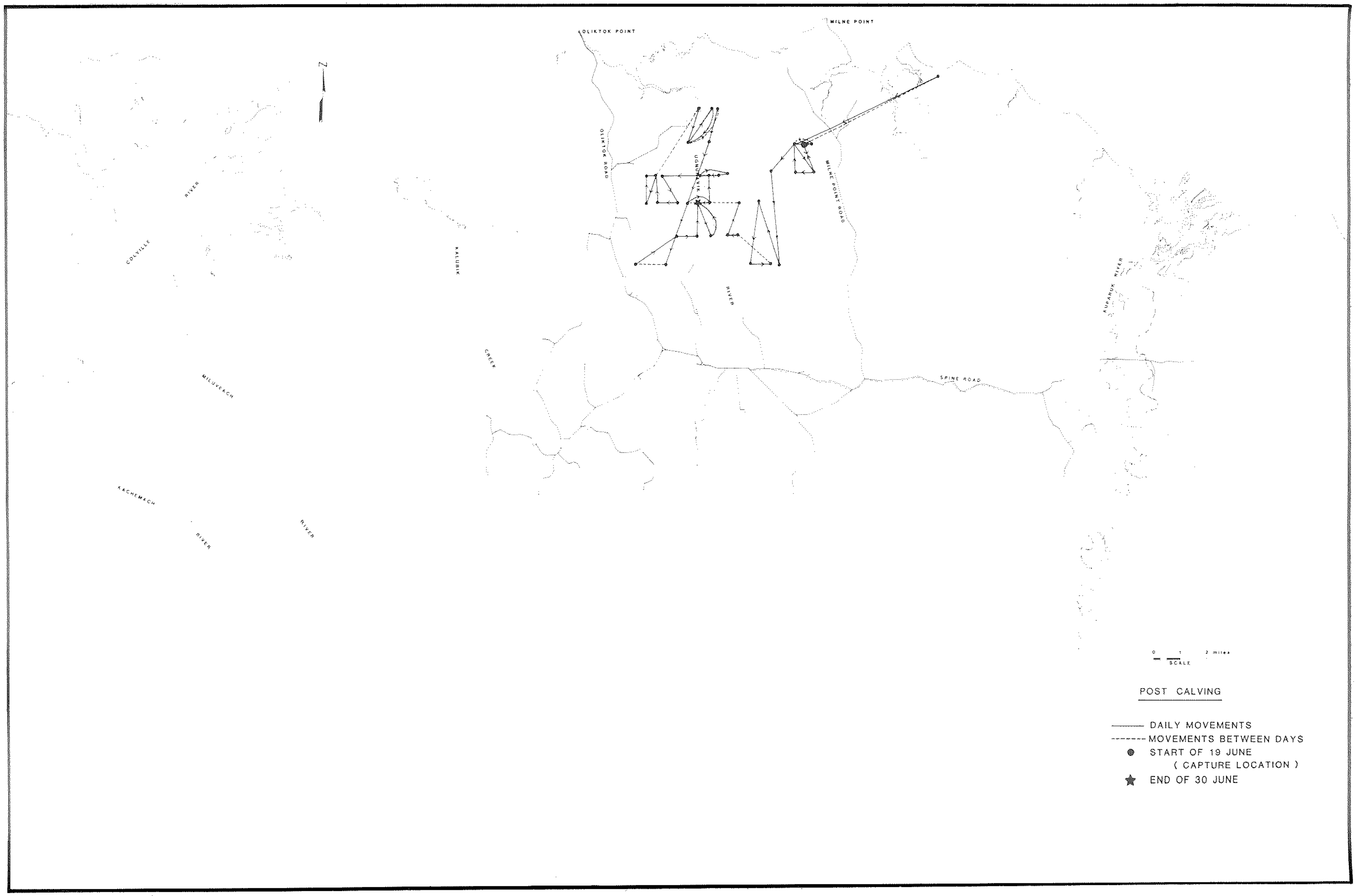

Figure 3. Movements of a satellite-radio-collared cow in the CAH during the post-calving period, 19-30 June 1984.

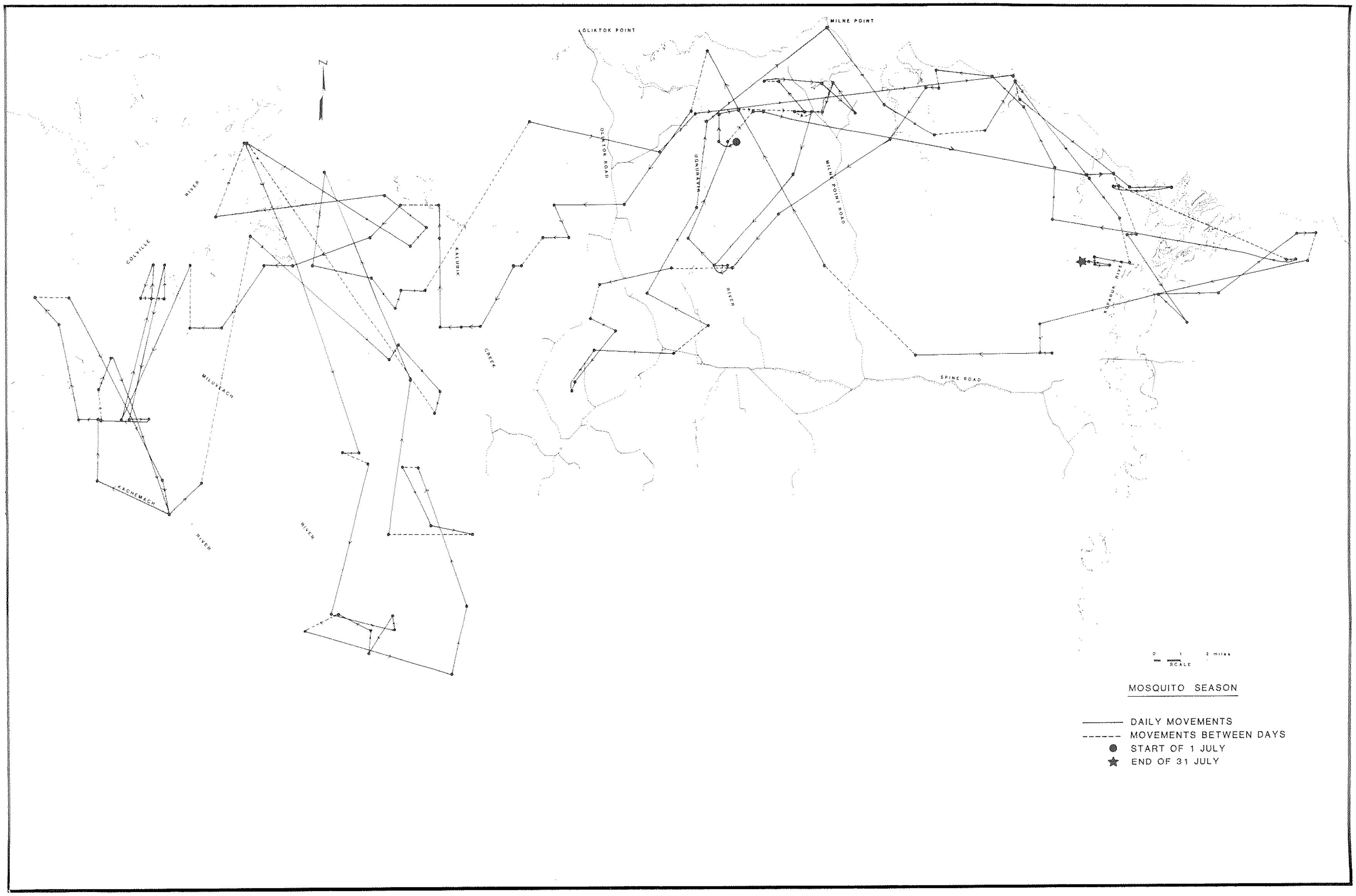

Figure 4. Movements of a satellite-radio-collared cow in the CAH during the mosquito season, 1-31 July 1984.

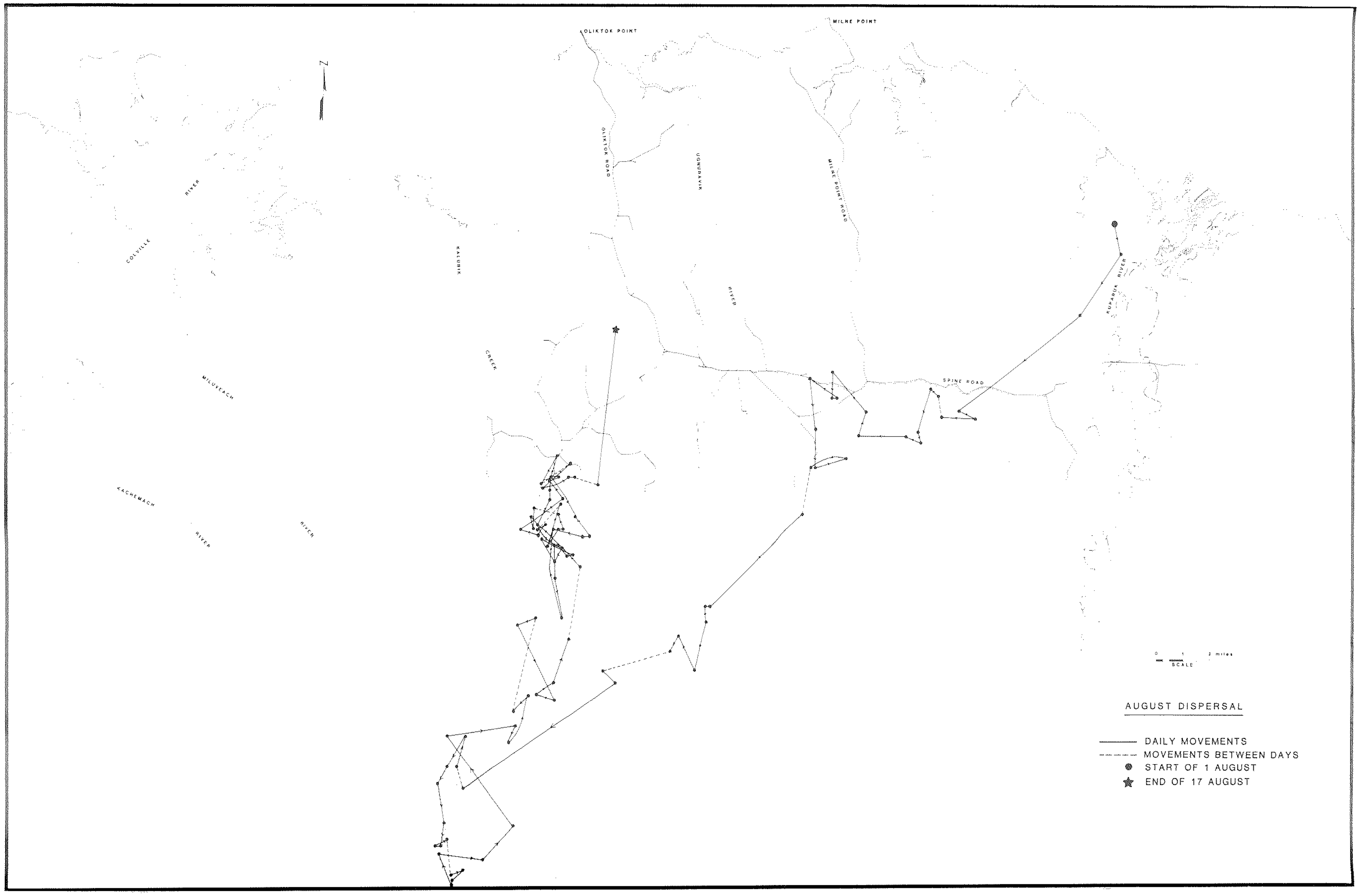

Figure 5. Movements of a satellite-radio-collared cow in the CAH during the oestrid fly season, 1-17 August 1984.

delta (Lawhead and Curatolo 1984). In 1984, however, the frequency of westerly winds was abnormally high (Lawhead 1984), causing caribou to seek relief from mosquito harassment in the vicinity of the Colville River delta. This occurrence accounts for the unexpected number of locations near the Colville River in Figure 4. Second, in response to severe mosquito harassment, CAH caribou usually travel east or west near the coastline (depending on wind direction), which is cooler and windier than inland areas; the movements of the collared cow reflect this tendency. Third, as mosquito harassment subsides during cool, windy weather, CAH caribou move inland; the collared cow moved relatively far inland (near the Miluveach River) (Figure 4) only during prolonged periods of cool weather.

During oestrid fly season, the radio-collared cow left the areas of the coastal plain used during mosquito season and moved inland (Figure 5). The mean minimum distance traveled per day decreased to 9 miles during this period (Table 1), probably due to the long periods of standing typically engaged in by caribou during oestrid fly season (Espmark 1968). The cow was found near the Spine Road-Kuparuk Pipeline corridor in three separate areas (Figure 5). This association probably resulted from oestrid fly harassment, because CAH caribou often select roads and pipelines as fly-relief habitat (Curatolo and Murphy 1983).

CONCLUSIONS

The satellite transmitter used in this study worked well under summer field conditions and allowed intensive monitoring of the movements of a cow caribou in the CAH. The caribou was located an average of about six times per day, which far exceeded the results of standard ground or aerial telemetry studies of this species. In addition, locations were recorded regardless of weather conditions, allowing a continual documentation of the animal's travels during a two-month period. Locations fixed by satellite were within one-half mile of the true locations, which is accurate enough for the purposes of most movement studies.

The high number of location fixes potentially available through satellite telemetry can provide the data necessary to answer important management questions regarding caribou. Examples of further applications worth pursuing include documentation of caribou responses to man-made structures, segregation by sex due to selection of different habitats, and clarification of range-use patterns. As satellite telemetry is refined, the data needed to address such issues will become more accessible, thereby allowing greater cost-effectiveness of research funds and increasing the amount of information available for making management decisions.

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