Evaluation of a satellite telemetry system for monitoring movements of caribou

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Abstract: A cow caribou from the Central Arctic Herd was collared with a satellite-monitored radio transmitter in the Kuparuk Oilfield, Alaska, in 1984. From 19 June to 17 August, the radio transmitted 18 hours per day. A total of 346 locations were recorded, for a mean of 5.8 locations per day or one location every 3.1 hours of transmission time. The location of 13 direct observations of the radio-collared cow averaged less than 1 km from the nearest satellite-fixed location. The satellite-fixed locations of the radio-collared cow provided detailed data on movement patterns during the three seasons studied. The cow traveled an average of 8 km day^{-1}, 23 km^{-1}, and 14 km day^{-1} during the post-calving season, mosquito season, and oestrid fly season, respectively.

Key words: caribou, telemtry, satellite, movements, petroleum development.

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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. In recent years, advances have been made in the use of satellites for receiving transmissions from radio-collars (Gandy, 1982; Kolz *et al.*, 1982). Satellite-based receivers offer several advantages over aircraft- or ground based receivers: animals can be tracked in all weather conditions, the cost per location may be lower, the risks to personnel are greatly reduced and additional information can be gathered from auxiliary sensors. The last two considerations are important when comparing satellite telemetry to aircraft telemetry 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 the availability of transmitters and satellites is limited.

Satellite telemetry is based on the Doppler effect; as the satellite passes overhead, changes in radio-wave frequency are measured and used to calculate the location of the transmitter. The accuracy of this technique depends on oscillator stability, which is affected by temperature. The transmitter will not function below —40°C. Calculation of locations assumes that elevation of the transmitter is constant. Location accuracy declines as the differenee between the actual and assumed elevations increases.

The only satellite system available to the private sector for location information is the TIROS-N Series satellites, using the ARGOS (Centre National d'Etudes Spatiales, France) Data Collection System. Two satellites were in operation during this study; 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 (Pank *et al.*, 1985). The availability of that transmitter provided the impetus to pursue a study of caribou movements using satellite telemetry.

This study was intiated to determine the effectiveness of satellite telemetry for monitoring the late-spring and summer movements of a caribou in the Central Arctic Herd (CAH) of Alaska. Two specific objectives were addressed:

1) to determine the daily movement patterns of a caribou, and
2) to determine the reliability and accuracy of satellite-fixed locations of the radio-collared caribou.

Study area

The study area was bounded by the Colville River on the west and the Kuparuk River on the east, and extended inland approximately 32 km. This area encompasses the Kuparuk Oilfield and the western portion of the Prudhoe Bay Oilfield. Detailed informatin on physiography, climate, and vegetation is prestented by 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 collar with conventional and satellite transmitters 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 duty-cycle was 18 h day^{-1}, from 0400 to 2200 Alaska Daylight Savings Time; this transmission schedule corresponded to the maximal number of overpasses by the satellite. A pulse of data was transmitted to the satellite once each minute. These data were relayed to a ground station and then transferred to the ARGOS Service Center (Toulouse, France) 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 ARGOS and our computer via a telephone modem.

The data received included the date, time, and latitude and longitude (to the nearest thousandth of a degree) of each location, the temperature of the collar, and an activity count. The distanee traveled by the cow was determined by measuring the straight-line distance between consecutive locations. The collar temperature and activity count did not correlate with ambient air temperature and behavior, respectively (Pank *et al.*, 1985), and are not discussed in this paper.

The standard beacon transmitter was used to locate the caribou through standard radio-telemetry techniques. The caribou was located

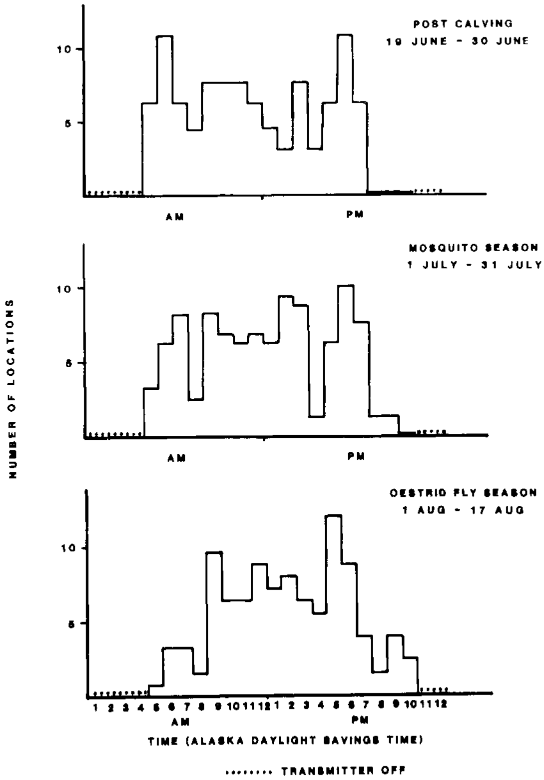

Fig. 1. Diurnal distribution of satellite-fixed locations of a cow caribou in the Central Arctic Herd, Alaska, 1984.

periodically from a Piper PA-18 "Super Cub" aircraft to obtain accurate locations for comparison with satellite fixes.

Prior to being placed on the caribou, the radio-collar was placed at several sites in the Kuparuk Oilfield between 21 and 26 May to compare the satellite-fixed locations with known locations. Locations of the radio-collar and the caribou were determined from 1:63 360-scale U. S. Geological Survey topographic maps.

Results and discussion

Life of the satellite transmitter

The satellite transmitter functioned from 19 June to 17 August 1984 for a total of 1080 h, 80 h (8%) longer than expected. The next generation of transmitters, built in 1985, are expected to last 20% longer due to stronger batteries and reduced electrical drain from the transmitter (D. Beaty, pers. comm.).

Number of locations

A total of 346 locations were recorded, for a mean of 5.8 (SD=2.5) locations per day, or one location every 3.1 h of transmission time (Table 1). Additional locations would probably 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 diurnal distribution of locations fixed was consistently low during certain periods (Fig. 1). Few locations were collected during 0400 - 0500 and 1900 - 2200 because few satellite passes occurred during those periods and because some satellite orbits made reception difficult (e.g., low angle of elevation during the pass). During 0700 - 0800 and 1500 - 1600, few locations were collected due to the pattern of satellite passes, which created a gap in coverage. These results indicate that radio transmissions should be timed to coincide with periods when satellite passes are most frequent (based on satellite orbit predictions), to maximize the number of locations fixed. Three hours of continuous transmission should be adequate to fix one location on a regular basis.

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 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 known locations was 1.0 km (SD=0.74). 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 less than 1 km from the nearest satellite-fixed locations.

The differences between known and fixed locations indicate that the accuracy of locations obtained by satellite should be satisfactory for the purposes of many 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 an accurate location.

Movements patterns

The movement patterns of the radio-collared cow differed among the post-calving, mosquito, and oestrid fly seasons (Fig. 2, 3 and 4). During most of the post-calving period the cow remained between the Oliktok Point and Milne

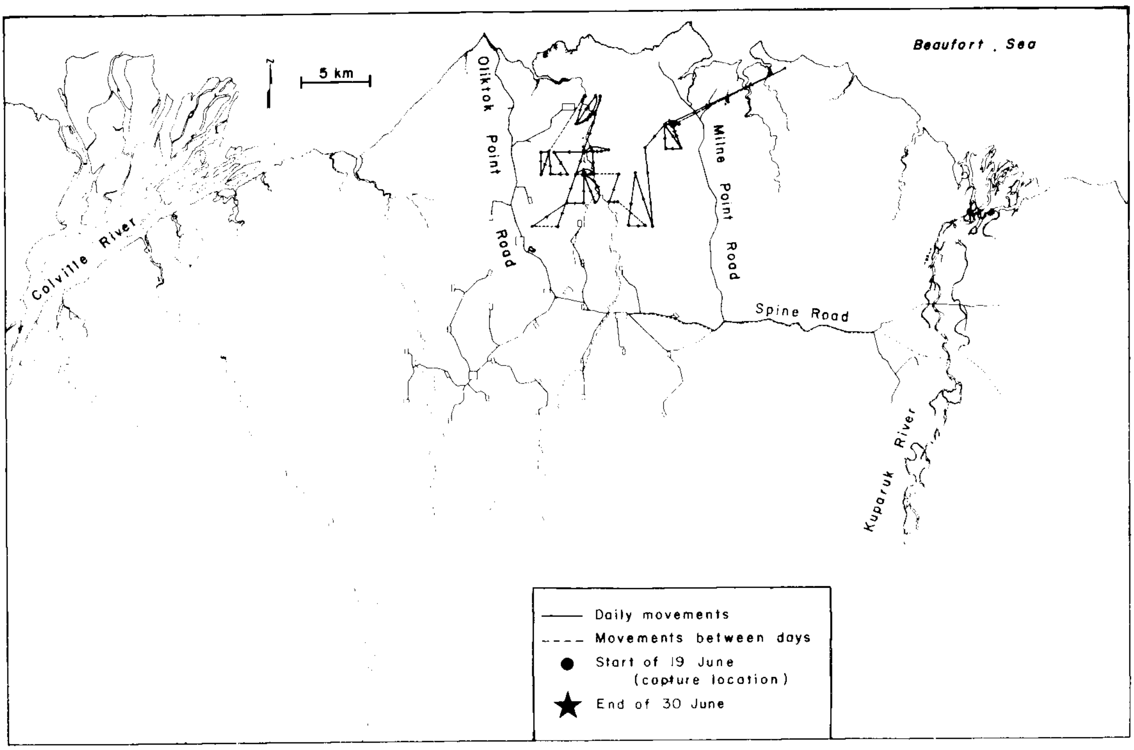

Fig. 2. Movements of a satellite-radio-collared cow in the Central Arctic Herd, Alaska, during the post-calving period, 19-30 June 1984.

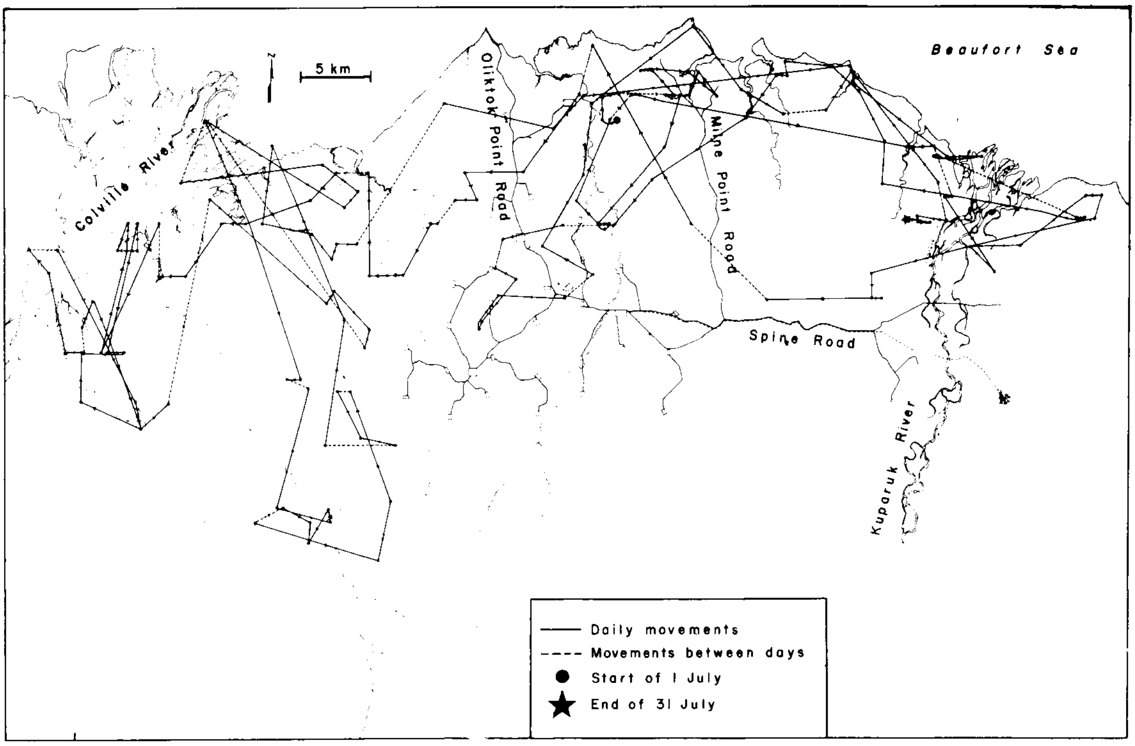

Fig. 3. Movements of a satellite-radio-collared cow in the Central Arctic Herd, Alaska, during the mosquito season, 1-31 Juli 1984.

Point roads, moving an average of 8 km day^{-1} (Table 1). The cow remained within an area that had a relatively high density of caribou during the calving season (Cameron *et al.*, 1983).

The cow crossed the Milne Point Road at least twice, but tended to be located at least 1.6 km from any road during this period (Fig. 2). Cows may be more wary when their calves are very young (Lent, 1966), which may account for this distribution. 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 (Fig. 3). During mosquito season the cow traveled a mean distance of 22.5 km day^{-1}, moving as far west as the Colville River and at least 10 km east of the Kuparuk River, and crossing the Milne Point and Oliktok Point roads a minimum of six and four times, respectively.

The movements of this cow generally fit within the entire summer range used by caribou in the Kuparuk Oilfield in 1983. (Lawhead and Curatolo, 1984), and illustrate three 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 delta during the mosquito season (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 number of locations near the Colville River (Fig. 3). Second, in response to severe mosquito harassment, CAH caribou usually travel east or west near the coastline (depending on wind velocity and 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 (White *et al.*, 1975; Curatolo and Murphy, 1983); the collared cow moved relatively far inland (Fig. 3) 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 (Fig. 4). The mean minimum distance traveled per day decreased to 14.5 km 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 (Fig. 4). This association may have resulted from oestrid fly harassment, because CAH caribou sometimes select roads and pipelines as fly-relief habitat (Curatolo and Murphy, 1983). The collared cow was observed standing under a pipeline on 1 August (S. Murphy, pers. comm.).

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 obtained regardless of weather conditions, allowing a continuous record of the animal's movements during a 2-month period. Locations fixed by satellite were within 1.0 km 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.

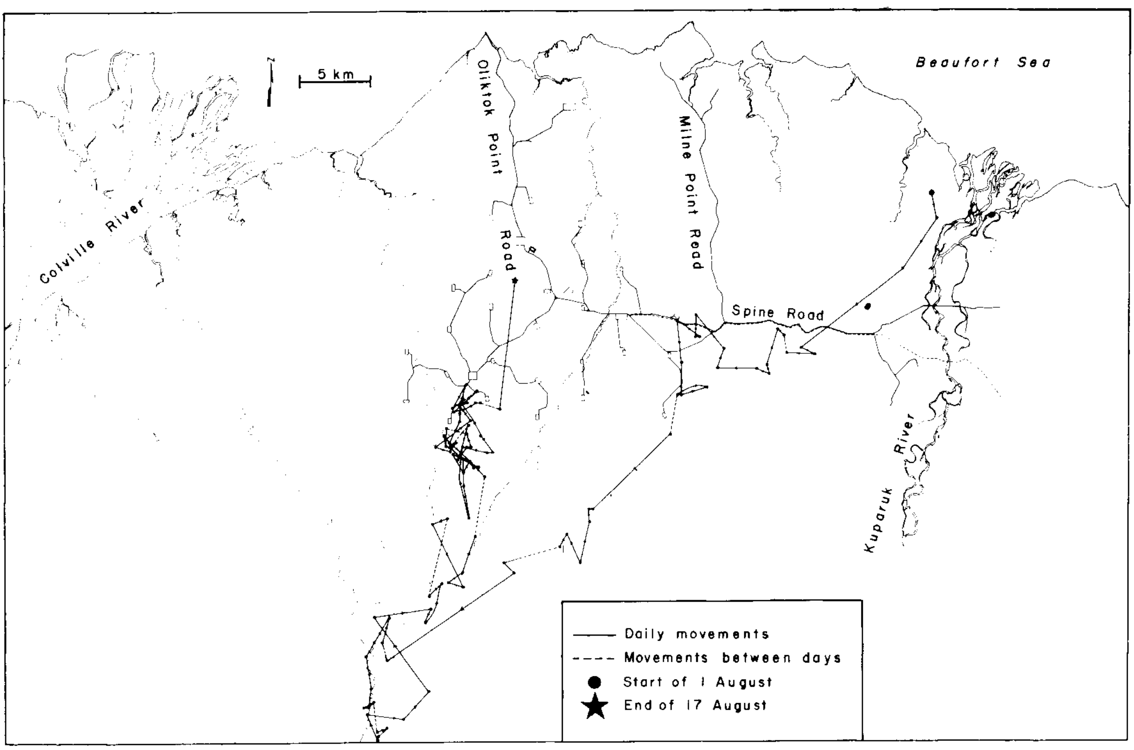

Fig. 4. Movements of a satellite-radio-collared cow in the Central Arctic Herd, Alaska, during the oestrid fly season, 1-17 august 1984.

Table 1. Seasonal means for locations, number of locations, and distances traveled, for a cow caribou monitored by satellite telemetry, 1984.

Season	Mean location		Mean number of locations per day	Mean minimum distance traveled per day (km)	N[a]
	Latitude	Longitude			
Post-calving (16-30 June)	70.42 (0.04)[b]	149.62 (0.09)	4.7(2.1)	8.5(3.5)	59
Mosquito (1-31 July)	70.38 (0.09)	149.76 (0.54)	5.9(1.7)	22.8(9.5)	184
Oestrid fly (1-17 August)	70.22 (0.08)	149.79 (0.27)	6.2(3.5)	14.5(6.1)	106
Overall (19 June-17 august)	70.34 (0.11)	149.75 (0.43)	5.8(2.5)	17.7(7.4)	346

[a] n=total number of locations
[b] Number in parentheses is one standard deviation.

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