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Research Progress Report

MOVEMENT PATTERNS OF THE PORCUPINE CARIBOU HERD IN RELATION TO OIL DEVELOPMENT

by
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SUMMARY

Eight caribou (*Rangifer tarandus*) in the Porcupine Herd (PCH) and 2 in the Central Arctic Herd (CAH) have been successfully relocated several times per day for the past year by a satellite tracking system. Information on location accuracy and reliability of the satellite telemetry system is discussed.

Key words: Caribou, migration, satellite radio-tracking.

CONTENTS

BACKGROUND

The Porcupine Caribou (Rangifer tarandus) Herd (PCH), numbering approximately 170,000, migrates seasonally between wintering areas in the boreal forests of northwestern Canada and northeastern Alaska and calving grounds on the arctic coastal plain within both Yukon Territory and Alaska. Large-scale development of nonrenewable resources is planned throughout this resource-rich area. Concerns about the impact of development on the PCH have been expressed by numerous government agencies, environmental groups, and subsistence users. International concern is exemplified by efforts to develop an International Agreement between the U.S. and Canadian governments to protect the PCH and its habitat.

Exploration for oil and gas is currently underway on the traditional calving grounds of the PCH and on the arctic coastal plain. It is highly likely that development will occur in the near future. PCH wintering areas in the Ogilvie and Richardson Mountains in Canada and on Venetie tribal lands in Alaska are also subject to intensive oil and mineral exploration. A road has already been built between Dawson and the MacKenzie River Delta (Dempster Highway). Protection of habitats on calving grounds and key winter ranges, and mitigation of the impacts of development require detailed knowledge of habitat use, movement patterns, and travel corridors.

The large size, remote location, and international movements of the PCH make it difficult and costly to study this herd. Monitoring movements and habitat use through direct observation or by relocating caribou equipped with conventional radio collars has proven difficult. The feasibility of using satellite radio collars to monitor daily movements of caribou in the PCH was tested in 1984. The prototype satellite radio collars (called PTT's for "platform terminal transmitters") provided accurate and reliable data at a reasonable cost. A

2nd-generation satellite transmitter was developed and deployed in 1985; 8 PTT's were placed on PCH females and 2 on Central Arctic Herd (CAH) females in April. Preliminary results demonstrate a capability for describing migration routes and movement patterns in greater detail than was previously possible. In particular, we noted extensive mid- and late summer movements in both 1984 and 1985 such as have not previously been reported. Also, activity recorders in the PTT's have the potential to provide data on daily activity patterns of caribou.

This study is 1 component of a cooperative program between the Alaska Office of Research, U.S. Fish and Wildlife Service, and the Alaska Department of Fish and Game. The overall goals of this cooperative study are to identify potential conflicts between caribou and oil development and to recommend measures for minimizing the impact of oil development on caribou and their habitat.

OBJECTIVES

To identify migration routes between summer and winter ranges and to determine movement patterns on the arctic coastal plain in relation to topographic features and broad habitat types. The U.S. Fish and Wildlife Service is the lead agency in determining habitat utilization and preferences and daily activity budgets. Objectives that are the primary responsibility of the U.S. Fish and Wildlife Service are not addressed in this report.

METHODS

Ten adult female caribou are currently equipped with collars bearing both PTT and standard transmitters. Each PTT transmits 6 hr/day, provides 2-5 locations daily, and will function for approximately 1 year. Each spring, beginning in March 1986, the collared caribou will be located and recaptured using the standard transmitters, the expired PTT's will be reclaimed, and new PTT's will be attached. If possible, the original 10 caribou will be followed throughout the study. However, in the event that most or all of the collared caribou winter in Canada in a given year, at least 2 PTT's will be deployed on different caribou in Alaska. Also, if any mortalities occur, those PTT's will be redeployed in Alaska. If any PTT's fail, they will be retrieved as soon as feasible and a new PTT placed on the same caribou, or on a new caribou in Alaska.

Migration Routes

All PTT locations will be plotted on digitized terrain maps so that migration routes and distances traveled each day can be correlated with slope, aspect, and major geographical features. Satellite locations will be supplemented by fixed-wing tracking of standard radio-collared caribou. Trail systems will be noted during tracking flights as well as at the time of general reconnaissance surveys during migration periods. Trails are clearly visible in snow, and fresh trails can also be distinguished along river bars and in tundra vegetation during summer and fall. In this way, data from satellite relocations can be compared with routes used by other members of the herd. Various migration paths will be compared for distances traveled, elevation changes, and rates of movement. Estimates of numbers, composition, and group sizes of caribou using various routes will also be possible, such as could not result from use of the PTT's alone.

Calving Areas

PTT locations during calving will be plotted on digitized terrain and habitat maps. Location of calving will be correlated with habitat types and terrain features to determine if preferences occur. Time of calving for PTT-collared caribou will be determined by observation from fixed-wing aircraft. Again, tracking of standard radio collars and general reconnaissance flights will provide comparative data on numbers and composition of caribou using the calving grounds.

Insect Relief Habitat

Periods of severe insect harassment of caribou will be identified from local weather records of wind and temperature conditions favorable to insect activity, from concurrent studies by U.S. Fish and Wildlife Service on insect activity and abundance in the Arctic National Wildlife Refuge, and/or from direct field observations.

PTT locations will be plotted on digitized terrain maps and again compared with supplemental data from standard radio-collars and general aerial surveys. Specific areas or types of habitats consistently used during insect harassment periods will be compared and any distinguishing characteristics such as vegetation type, elevation, temperature, and wind conditions, will be noted.

RESULTS AND DISCUSSION

Eight caribou in the PCH and 2 in the eastern segment of the CAH were equipped with PTT's in April 1985. One caribou was killed by a grizzly bear (*Ursus arctos*) in June, and the PTT was immediately redeployed on another caribou, which was subsequently killed by wolves (*Canis lupus*) in November. The remaining caribou were successfully tracked by the satellite with an average of 3 locations per day until March 1986. These same caribou were recaptured during March 1986 and fitted with new PTT's. In addition, 1 previously unmarked caribou was collared with a PTT. Daily collection of location data is continuing.

Each location fix for each caribou is entered into a computerized mapping system. An attribute file for that fix is then automatically created for data on location, date, slope, aspect, vegetation type, ambient temperature, and activity of the caribou. Slope, aspect, and vegetation data are obtained from LANDSAT imagery while temperature and animal activity are provided by sensors in the PTT. The data are in the process of being analyzed.

Information on locational accuracy, sensors, duty cycles, and reliability of the satellite tracking system was published in October 1985. That publication is included as Appendix A.

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Appendix A.

PERFORMANCE OF A PROTOTYPE SATELLITE TRACKING SYSTEM FOR CARIBOU

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ABSTRACT

The study confirmed the utility of a satellite tracking system to monitor caribou location, activity, mortality, and environmental temperature. Performance of the system (2.1 kg transmitter package, TIROS-N polar orbiting satellites and French ARGOS signal processing) was evaluated during bench, enclosure, and field trials. Mean locational error ranged from 0.5 to 2.5 km. Temperature tolerance of the transmitters spanned from -20 to 70C. The motion sensor provided relative measures of activity and identified mortality if it occurred. During the field trials, the system fixed the location of an adult cow in the Porcupine Caribou Herd (PCH) 114 times during a 2.5-month period. The system successfully tracked this cow during the fall migration as she moved over 1,000 km. Transmitter size, weight, oscillator stability, temperature tolerance, sensitivity of the activity sensor, and life were improved in the production units. Production units deployed on 8 PCH and 2 Central Arctic Herd cows have successfully monitored the spring, summer, and fall movements and continued to perform without problems.

INTRODUCTION

The use of conventional radio-tracking gear to systematically monitor the movements, activity, and fate of barren-ground caribou (*Rangifer tarandus granti*) in the subarctic is hindered by (1) extensive migrations, (2) international and territorial boundaries, (3) remote and harsh environment, (4) prolonged darkness, and (5) researcher's safety. A prototype satellite tracking system offered the potential of overcoming most of the deficiencies associated with conventional tracking gear. Major components of the system included the TIROS-N series satellites in orbit, the ARGOS (Center National d'Etudes Spatiales, France) Data Collection and Location System (DCLS), and Platform Terminal Transmitters (PTT) developed by Telonics, Inc. Bench, enclosure, and field trials were conducted to assess reliability, accuracy, logistics, and operational utility of the system. Two functional NOAA/TIROS satellites launched by the National Aeronautics and Space Administration and managed by the National Environmental Satellite and Data Information Service were in near polar (98.7° inclination from equator) orbits. Orbit period was approximately 102 min at an altitude of 830-850 km. Coverage of the earth was completed every 24 hr by each satellite as the earth rotated (25° each period) within the sun synchronous orbit (stationary orbital plane relative to the sun).

Receivers located on each satellite and linked with the DCLS covered a 5,000-km wide swath on the surface of the earth during each orbit. The frequency that satellites received signals from a point on the earth was a function of latitude. Polar areas were in view of the satellites approximately 28 times per day in contrast to 6 times per day at the equator. A PTT-collared caribou at 65° latitude was in view of a satellite for a total of 246 minutes during 22 orbits each day (ARGOS User's Guide, Service ARGOS, Toulouse, Cedex, France).

The PTT's transmit both a 160 milliseconds (ms) of unmodulated carrier (401.650 MHz) and a phase modulated signal containing additional data every 40-60 sec. A radiated output of 1 watt was desired to assure noise-free reception by the satellite. The frequency shift of the unmodulated carrier due to the doppler effect was measured as the satellite passed over and provided the basis for fixing latitude and longitude coordinates of the PTT. Oscillator stability was therefore critical to the operation and locational accuracy of the DCLS. ARGOS certifies all PTT designs to ensure compatibility with the system. Short (100 ms), mid (20 min), and long (100 min) term oscillator (Δf/f) of 10^{-8}, 2.10^{-7}, and 10^{-6}, respectively, were required by the DCLS for processing.

Data transmitted via the modulated signal included error correcting code, synchronization and format information, an identification code unique to each PTT, and 32-256 bits of data from various sensors that may be incorporated in the PTT (manual, Sensor Data Processing, Service ARGOS, Toulouse, Cedex, France).

The prototype (first generation) and production (second generation) PTT's tested during this study were designed to rectify the size, weight, attachment, and reliability problems identified during earlier attempts at tracking wildlife with satellite systems (Craighead et al. 1972, 1982; Kuechle et al. 1979; Jennings and Gandy 1980; Kolz et al. 1980; Schweinsburg and Lee 1982; Timco and Kolz 1982). Unique power pack, microprocessor, and antennae designs resulted in a package that was compatible with the successful collar attachment for conventional transmitters on caribou (Miller et al. 1977).

METHODS AND MATERIALS

Platform Terminal Transmitters

The first generation PTT was the first to be specifically developed for deployment on caribou (Fig. 1). The electronics circuitry measured 2.5" x 4.0" x 3/4" and weighed 150 g. The electronics were powered by 3 lithium "D" size batteries. The transmitter and batteries were housed in an external magnetically transparent metal canister which measured 3.325" x 4.410" x 2.825". The completed hermetic canister, transmitter, and power supply weighed 1,400 g. This package was mounted on a butyl collar approximately 4" in width. The flexible whip antenna was housed within the collar itself with only a small portion exposed. Total weight of the antenna configuration was 10 g. Current was minimized by cycling the microprocessor and, thus, the electronics circuitry through various states with varying current requirements to extend the life of the battery system. Duty cycles were developed so that the microprocessor could turn on the transmitter at optimum periods of time for reception by available satellites. These optimum periods were established by examination and analysis of computer generated pass prediction schedules for the available satellites in the given region where the PTT's were to be deployed (Fig. 2).

Ultimately, a system was developed which was capable of providing an operational life of 1 year, using an 8-hr per day "on" period, 3 days per week, or alternatively 4 hr per day every day. The completed package weighed 2.2 kg, including a VHF location beacon acting as a backup to the PTT, and was certified to meet ARGOS specifications over the temperature range of -20C to +60C. In addition to providing information necessary to calculate a position, the PTT monitored sensors and transferred data to the satellite's Data Collection System (DCS). The PTT monitored the temperature of the internal electronics package with a high precision oscillator. Additionally, 2 levels of animal activity were monitored via a short-term activity counter and long-term activity counter. Sharing a common sensor (single mercury switch), the microprocessor determined if a switch activation occurred during the past minute. This information was accumulated in a counter register. The total count for the previous 0.5 hr for the short-term counter, and every 6 hr for the long-term counter, was transmitted. These data were contained within the minimum ARGOS transmission message format and therefore did not increase message length or power requirements of the system. This configuration offered a successful experimental approach to the problem of tracking animals with satellite systems. The information obtained from these initial experimental first generation units was subsequently utilized in the development of a second and more sophisticated generation of satellite PTT's.

The second generation PTT's were applicable to a wide range of wildlife species and demonstrated a further reduction in current consumption, an increased flexibility in microprocessor control, as well as an overall increase in system performance.

The second generation satellite transmitters represented a major step over first generation systems in terms of package size and weight. These units featured electronics which measured 2.2" x 3.75" x 5/8" and a total weight of 100 g. The most recent advances in lithium electrochemical systems led to the development of a new power source which exhibited increased energy density and operating voltage and, thus, allowed the transmitter to operate for a 12-mo period when employing a duty cycle of 6 hr on, 18 hr off each day at temperatures down to -40C. Once again, computer pass prediction schedules of the satellite availability in a given region were employed to optimize the "on" times for the system. The second generation units were certified by ARGOS over a temperature range of -40 to +70C. Several new and sophisticated approaches in compensated circuit technology allowed a substantial increase in performance characteristics for the second generation units.

These improvements increased oscillator frequency stability and, thus, the number of location fixes obtained per unit time. The final second generation unit configuration had a substantial reduction in the overall packaged weight of the transmitter and power supply. The hermetic canister measured 2.7" x 4.25 x 2.32". The completed weight of the entire configuration, including electronics, power supply, and canister, was 800 g, or 57% of the first generation package. This unit, when attached to the caribou collar, resulted in a total weight of 1,600 g or 72% of the weight of the first generation completed unit. The data format of the second generation units was similar to the first generation unit; however, the activity sensors were monitored once per second, rather than once per minute. Activity information was held in memory for the next transmission. The short-term activity counter reflected the number of seconds in which switch closures occurred during the previous 60-sec interval with a maximum of 60. The long-term activity counter reflected the number of seconds in which closures occurred during the previous 24 hours.

Calibration curves for the internal temperature sensor were generated for each PTT during the oscillator stability trials in a temperature controlled environment. The relationships between ambient air temperature and internal PTT temperature both on and off caribou were measured during enclosure trials at the Institute of Arctic Biology's Large Animal Research Station, Fairbanks, Alaska.

Continuous activity scans of PTT-collared caribou within the enclosures were conducted to determine if sensor counts were related to gross behavioral classes.

Data Processing and Dissemination

PTT signals were preprocessed by the satellite and down linked to the NESDIS Gilmore Tracking Station located near Fairbanks, Alaska. Data were then relayed via the Data Processing Services Subsystem in Suitland, Maryland to Service ARGOS, Toulouse, France for processing. Processed data were accessed daily via telecommunication and saved on microcomputer floppy disc for near real-time reference. Hard copy and a 9-track computer compatible tape were also acquired from ARGOS at biweekly and monthly intervals, respectively. Processed data for 1 satellite overpass of 1 PTT is exhibited in Table 1. Consult the ARGOS Data Dissemination Manual (Detailed Technical Document) for a more complete description of the data output.

RESULTS

Field Development

Three first generation PTT's were deployed on caribou during summer 1984. One adult female in the Central Arctic Herd (CAH) was collared in early June. This PTT had a daily duty cycle of 18 hours on and 6 hours off. The objective was to observe diel movement patterns of a caribou in the Kuparuk Oilfield during the insect season (Curatolo, in press). Two PTT's were placed on adult cows in the Porcupine Caribou Herd (PCH) during June. One PTT monitored movement for 7 days and then indicated mortality had occurred (zero activity in the activity sensor). Field examination indicated probable grizzly bear (Ursus arctos) predation. The second PTT functioned from 19 June to 24 August and fixed location of the caribou 114 times as it traveled over 1,000 km (Fig. 3). This cow died on 24 August and bear predation was indicated.

The PTT's may have predisposed caribou to predation. Hair loss due to rubbing of the collar and natural hair shedding resulted in the PTT collar fitting loosely around the neck. The loose fit allowed the PTT to swing like a pendulum and strike the chest and lower jaw when the caribou ran. This bumping appeared to disrupt the natural gait of the caribou and could have reduced its ability to escape from predators.

Eight female caribou in the PCH and 2 in the CAH were collared with PTT's in early April 1985. Ages of the caribou ranged from 10 months to 10 years. The objectives were to monitor spring migration, summer movement corridors, and location of winter ranges. Fidelity to specific calving areas and winter ranges will also be assessed. To date, the PCH animals have been monitored daily since 11 April 1985 as they traveled over 950 km. One mortality occurred in late June due to grizzly bear predation. The bear killed the cow's calf, and subsequently killed the cow. The second generation PTT's were attached more tightly around the necks of caribou than the first generation. This tighter attachment and the lighter transmitter package kept the PTT from swinging when the caribou ran and their gait did not appear to be affected. Any problems of predisposing the collared caribou to predation appear to be solved with the tighter attachment.

Location Efficiency and Accuracy of the System

Eighty to 90% of the signals sent by the PTT's were received by the DCLS when it passed over the PTT. The transmission reception was best when the PTT was off the animal and dropped about 15% when the PTT was on the caribou (Table 3). The second generation PTT's had a slightly lower efficiency of reception than the first generation. This adversely affects the acquisition of sensor data. When the PTT's were on the caribou, the first generation fixed location on 38% of the overpasses, while the second generation fixed location on 45% of the overpasses (Table 2). The improved oscillator stability in the second generation lead to the 7% increase in location efficiency.

The second generation PTT's reduced location error from an average of 2,472 m to 571 m (Table 3). The greater accuracy is the result of greater oscillator stability.

Sensor Data

Activity sensors were incorporated into the PTT to provide information on mortality and an index of caribou behavior. Mortality was readily identified by the sensor, but knowledge of death was delayed because predators and/or scavengers often moved the collar after death had occurred.

Preliminary data on activity sensors indicated that the system can differentiate between behavior classes of caribou. The 30-min and 6-hr activity counts in the first generation PTT's were not correlated with behavior. In contrast, the 60-sec and 24-hr activity counts in the second generation showed good correlations (Fig. 4). Lying and standing periods can be readily distinguished from walking and running. With additional calibration, the activity sensor has the potential of providing data on 24-hr behavior patterns and daily energy expenditure during different seasons.

Correlation analysis indicated that ambient air temperature could not be predicted from PTT temperature (Fig. 5). This is likely due to insolation and warming of the PTT by the caribou. Also, the caribou may be able to select microsites where the temperature is different from the ambient air temperature.

CONCLUSIONS

The satellite tracking system appears to be a cost-effective, reliable, and accurate method of acquiring data on animal location and movements. The second generation trials cost only 40% of acquiring a similar data set obtained with conventional transmitters, and the comparable costs decrease each day the PTT's continue to function. Data were acquired systematically without gaps caused by inclement weather or logistical problems. Locational accuracy equaled or exceeded that obtained by conventional systems in homogeneous habitats and approached the accuracy of conventional systems in heterogeneous habitats. Sensor data can provide indexes of behavior and use of microhabitats by caribou. Additional sensors can be added to the PTT that could monitor abiotic conditions near the animals or the physiological state of the animal.

Disadvantages of the system include its high initial capital investment and the requirement for funding commitments from several government agencies. For example, NOAA could decide to maintain only 1 satellite in polar orbit and the amount of data obtained would be reduced by 50%. Also, the capacity of the system is finite; the DCLS can acquire only 4 messages at the same time, the DCLS cannot handle similar transmissions at the same frequency, and the probability of acquiring location and data messages drops to 0.8 if 75 or more PTT's are concurrently within view of the satellite.

However, the advantages of tracking wildlife with satellites far outweigh the problems. The potential of acquiring sensor data on behavior and habitat selection cannot be accomplished on migratory species without a satellite system. For animals that live in remote locations and travel long distances (i.e., caribou, whales, polar bears), the satellite system provides a research tool that will prove to be invaluable.

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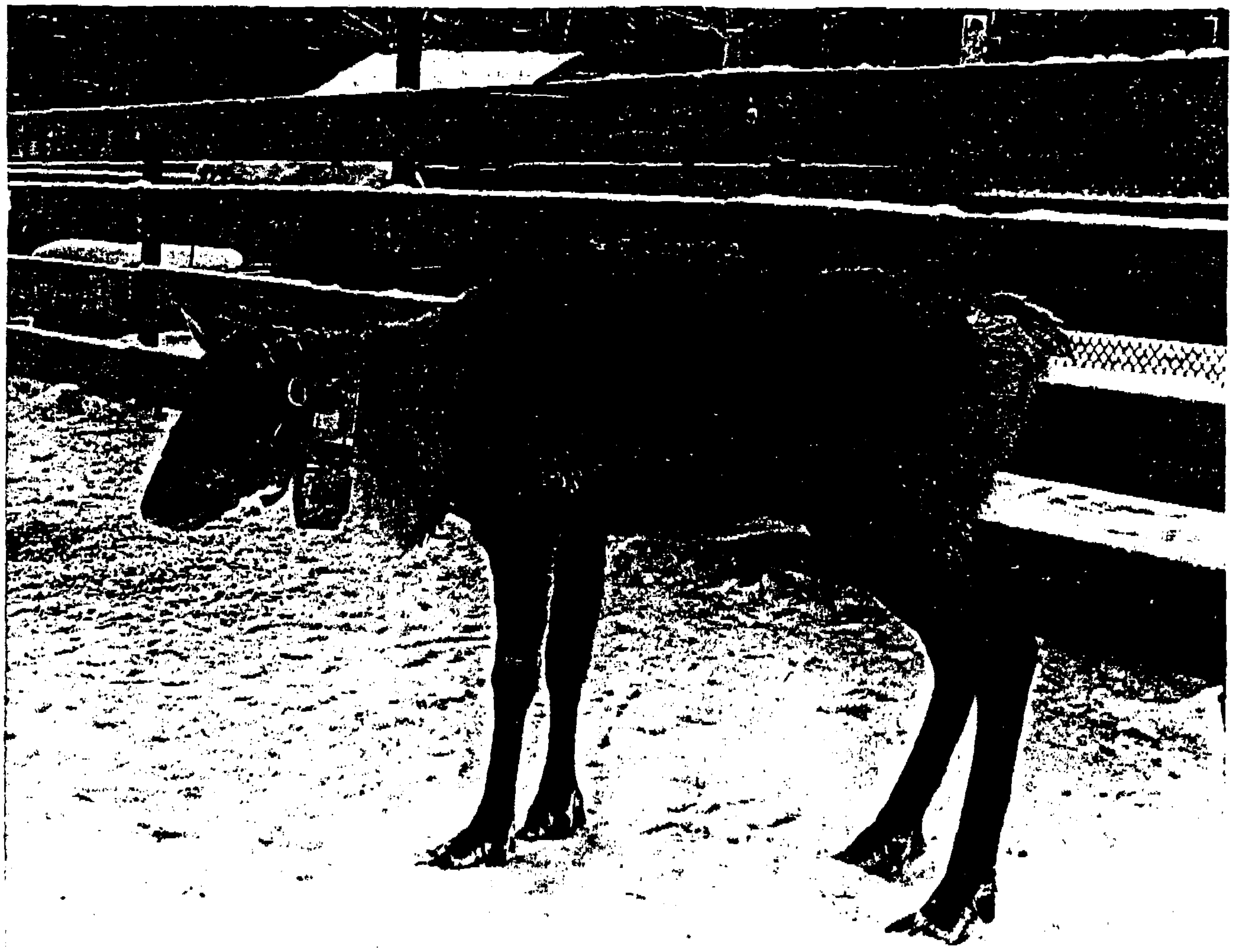

Fig. 1. First generation Platform Terminal Transmitter on a 2-year-old female caribou at the Large Animal Research Station, Institute of Arctic Biology, University of Alaska, Fairbanks.

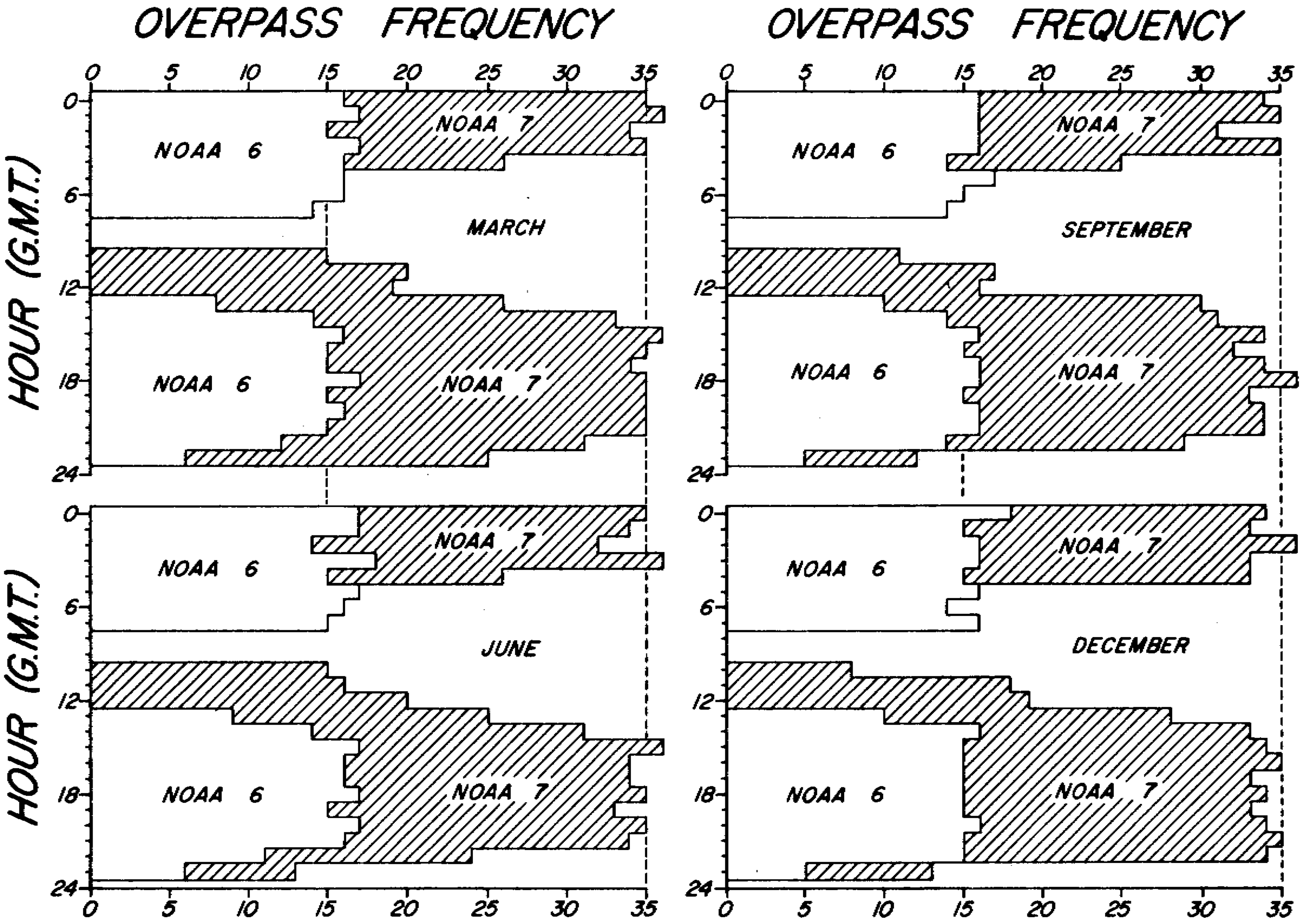

Fig. 2. Diel distribution of the cumulative number of satellite (NOAA 6, 7) overpasses in northern Alaska during March, June, September, and December 1984.

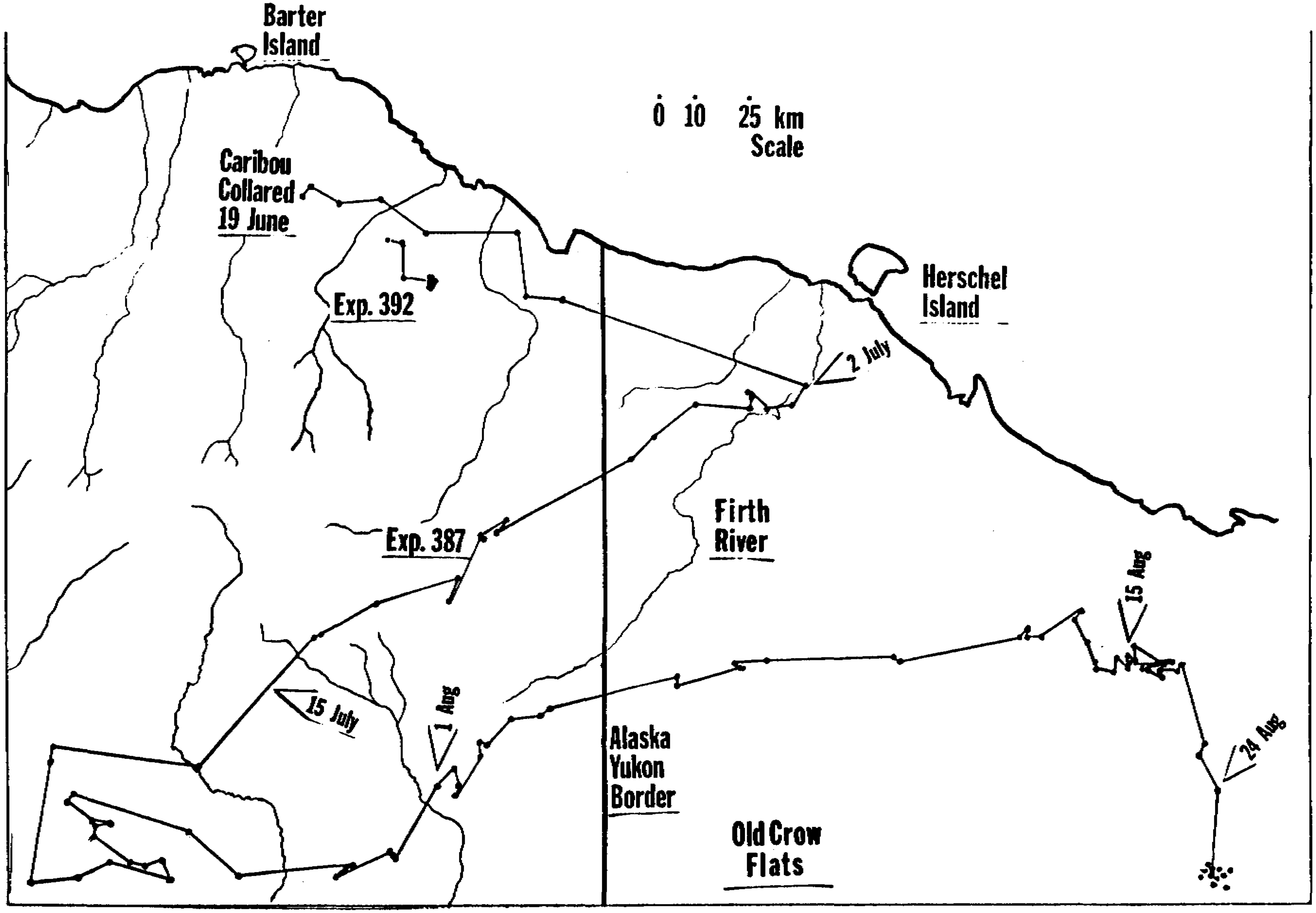

Fig. 3. Movements of a caribou over a 67-day period as determined by a first generation Platform Terminal Transmitter and the ARGOS Data Collection and Location System. Each dot represents 1 satellite fix.

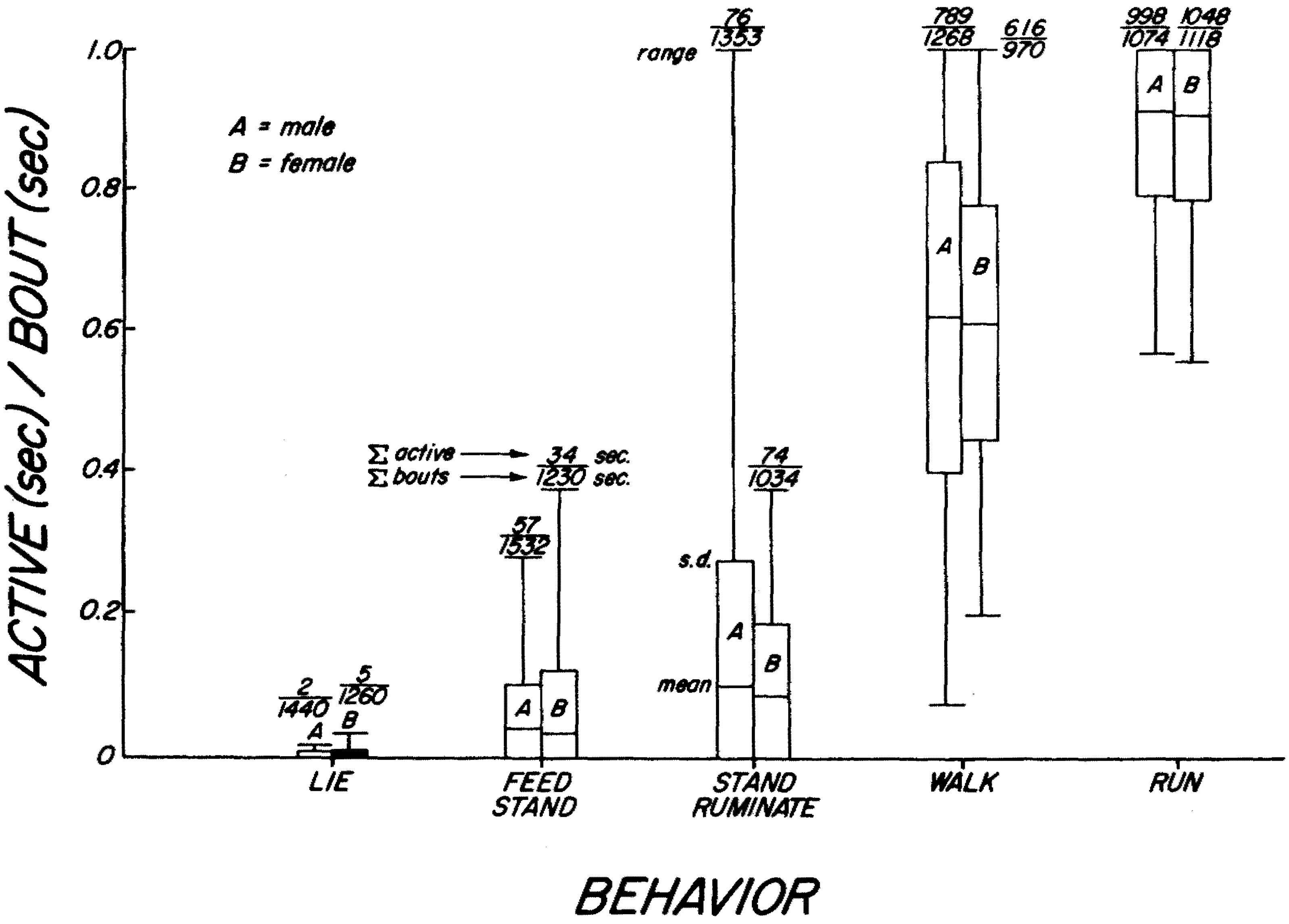

Fig. 4. Relationship between caribou behavior and activity sensor counts during discrete bouts of 5 behavior classes.

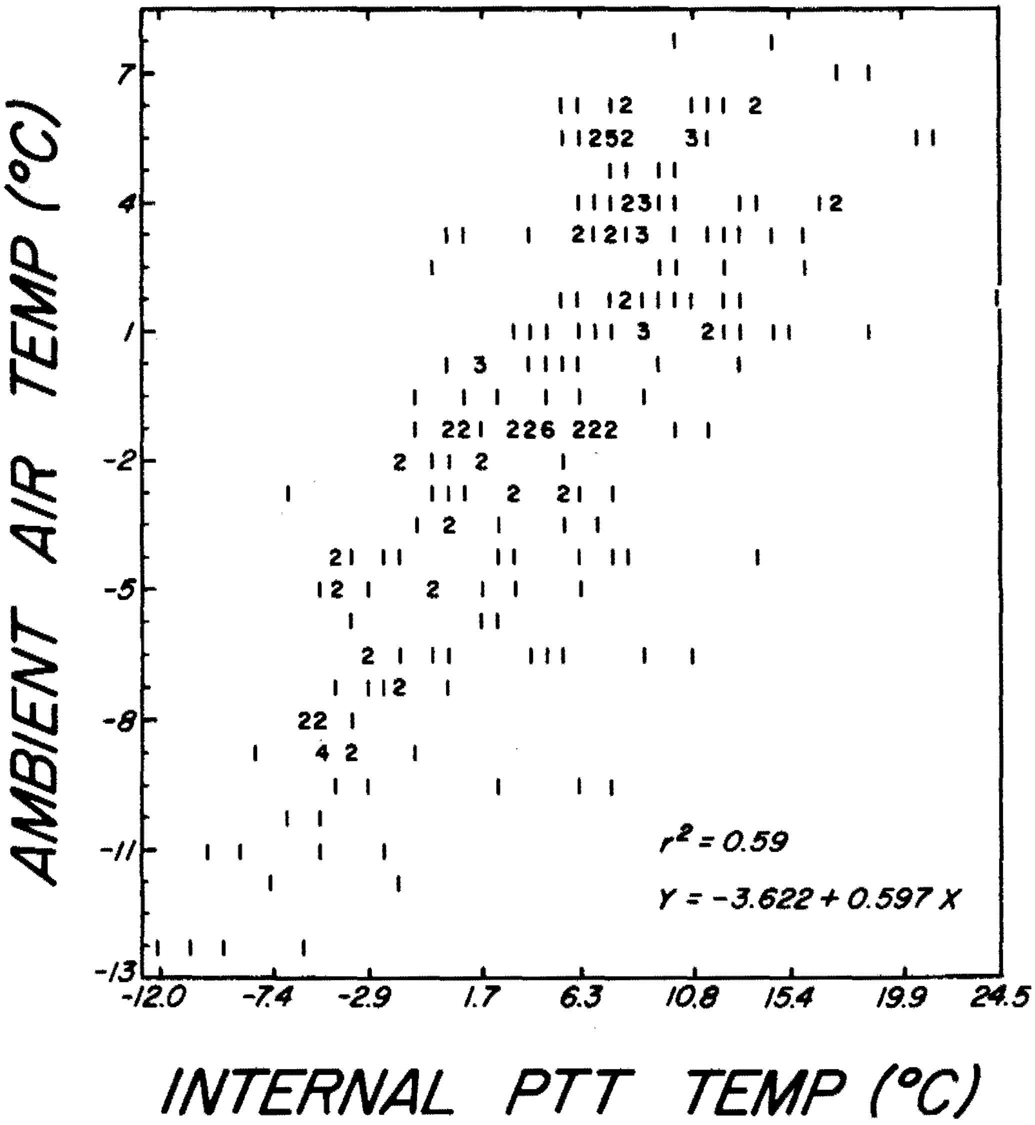

Fig. 5. Concurrent measurement of ambient air temperature and internal temperature of a transmitter on a caribou.

Table 1. Sample output and definitions of ARGOS processed data for one satellite overpass of one PTT.

OUTPUT

```
Line
1      392     9    5871    4 12981    85 198  0 15 42 3  -1 2         0  401650000         001
2      392       -1        68.100      215.303     .544     .351       0  401649693         002
3      392  12981  21    4   37   1    115          066           11         0253         003
4      392  12981  21    5   37   1    115          031           18         0253         004
5      392  12981  21    6   37   1    114          239           38         0253         005
6      392  12981  21    8   37   1    114          124           22         0253         006
7      392  12981  21    9   37   1    114          057           26         0253         007
8      392  12981  21   12   37   1    113          142           21         0253         008
9      392  12981  21   13   37   1    113          113           27         0253         009
```

DEFINITION OF OUTPUT

First line

392 = experiment no.
9 = total no. lines this overpass
5871 = PTT #
4 = no. of sensors
12981 = Julian day
85* = year
198* = day in year
0 15 42 * = hr min sec GMT of last locating fix
3* = location index
-1 = type of PTT
2 = satellite no.
0 = assigned altitude
401650000 = initial frequency
001 = line no. for overpass

Second line

-1 = location quality index
68.100 = latitude
215.303 = longitude
.554 = speed in latitude (in degrees/day)
.351 = speed in longitude (in degrees/day)
0 = altitude (calculated)
401649693 = transmission frequency
002 = line no. for overpass

Lines 3-9** (sensor data)

12981*** = Julian day
21 4 37*** = hr min sec (GMT)
1 = no. identical messages received during this overpass
115 066 = uncorrected temperature sensor
11 = one minute activity index
253 = 24 hour activity index

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* Parameters associated with last location.
** Number of lines is dependent on the number of minutes the PTT is in view of the satellite.
*** Parameters associated with the sensor data.

Table 2. Transmission reception and location efficiency of first and second generation platform terminal transmitters on caribou and when motionless at a fixed point.

Location	PTT generation	n	Satellite overpasses: Transmission recorded No.	%	Location fixed No.	%
Off animal	First	64	63	98	36	56
	Second	90	82	91	59	66
On animal	First	101	85	84	38	38
	Second	99	77	78	45	45

Table 3. Location accuracy of the ARGOS Data Collection and Location System with first and second generation Platform Terminal Transmitters at 5 known locations.

PTT	n	Location error, spherical distance (m): median	mean	SD	minimum	maximum
First generation	10	2996	3134	1950	255	5749
	10	831	961	500	169	2585
	27	3343	3322	1367	1438	6511
Second generation	21	430	518	394	75	1698
	28	360	545	580	75	2837