EVALUATING ELK HABITAT INTERACTIONSWITH GPS COLLARS

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ABSTRACT

Global positioning systems (GPS) are likely to revolutionize animal telemetry studies. GPS collars allow biologists to collect systematically scheduled data when VHF telemetry data is difficult or impossible to collect. Past studies have shown that the success of GPS telemetry is greater when animals are standing, or in open habitats. To make effective use of GPS telemetry, biologists need to understand its advantages and disadvantages. Our objectives are to compare data from GPS and VHF telemetry, present data on the use of activity sensors for estimating behavior and show that unsuccessful GPS fix attempts can provide insights into the biology of elk. We placed two GPS telemetry collars, capable of remote transmission of data to a command unit, and 44 VHF telemetry collars on adult female (cow) elk *(Cervus elaphus)*.The GPS collars were programmed to take three fixes, three days each week. These GPS collars did not operate properly. In February 2000, we placed four store-on-board GPS collars from a different manufacturer on cow elk. These collars were programmed to collect 6 - 12 locations each day, with drop-off mechanisms set for December 1, 2000. The average success in acquiring fixes was 88%, with 70 % 3D locations. Each GPS collar collected more locations of elk than were obtained by three technicians working >2 yr using VHF telemetry. Tilt-switch activity sensors suggested that elk were feeding in 40% of locations. The data indicated that feeding and bedding occurred in all habitats. As expected, elk appeared to spend more time feeding than bedded in grasslands during both daytime and night-time hours. Disparity between the number of feeding and bedding locations in grasslands was less during night-time. Unsuccessful GPS fix attempts occurred more often when elk were bedded ($P < 0.01$) and more often during daytime than night-time or the crepuscular periods ($P <0.01$. Unsuccessful GPS fix attempts increased in frequency from spring through July and for some animals during the hunting seasons. GPS telemetry was an efficient and effective tool for studying elk habitat.

INTRODUCTION

Global positioning systems (GPS) have created new opportunities. Biologists 10.63 easily meet the sample size requirements for assessing habitat selection of animals (e.g., Alldredge and Ratti 1986), track animals during night-time or periods of poor weather, receive data by remote transfer, and collect considerable information about animals without disturbing them.

Success rates for obtaining GPS locations may be as high as 90% (Dussault et al. 1999), but vary among animals depending on habitat (Rempel et al. 1995, Moen et al. 1996 Rempel and Rodgers 1997) and behavior (Bowman et al. 2000). Because there is some bias associated with GPS telemetry, biologists need to understand the character and magnitude of the bias before deciding if GPS telemetry is useful for a study (e.g., Rumble and Lindzey 1997, Gamo et al. in press). Our objectives were to compare the quantity of data from GPS telemetry to VHF telemetry on free ranging elk *(Cervus elaphus)*, compare elk behavior among habitats during days and nights, and present the usefulness of unsuccessful GPS location attempts to provide insight into elk biology.

STUDY AREA AND METHODS

Our study was conducted in the limestone plateau of the central Black Hills. Elevations range from approximately 915 m to 2207 m. Annual precipitation ranges from 46 to 66 cm (Orr 1959). January is the coldest month with mean daily temperatures from 1.8 to -11° C; July and August are the warmest months with mean daily temperatures from 15 to 29°C. The Black Hills is mostly forested with interspersed grasslands. Ponderosa pine *(Pinus ponderosa)* is the dominant vegetation type but white spruce *(Picea glauca* and quaking aspen *(Populus tremuloides)* also occur (Hoffman and Alexander 1987).

In August 1998 and January 1999, we captured 46 adult female (cow) elk. Forty-four were equipped with VHF telemetry collars and two were equipped with GPS telemetry collars. Three technicians located elk using VHF telemetry and hand-held yagi antennae year-round from sunrise to just after sunset. When snow was absent, technicians spent three days each week locating animals, resulting in about two locations per month per animal. During winter, we located animals using snowmobiles and an airplane, resulting in approximately one location per animal per month. The GPS collars were programmed to collect three locations each day (two at night and one during day), three days each week (Mon., Wed., Fri.). Data from the GPS collars were stored on the collar until they were transmitted to a remote command unit, after which data were removed from the collar memory. We conducted remote downloads from collar at irregular intervals. One GPS collar was retrieved in October 1999 from an animal harvested during the hunting season.

In February 2000, we recaptured the elk with a GPS collar and three additional cow elk. These elk were equipped with store-on-board GPS telemetry units in sealed canisters. Each collar had an electronic release mechanism which, when activated on 1 December 2000, caused the collar to fall off the animal. These collars were programmed to obtain six locations each day from February through to August 20, 12 locations each day (2 hr intervals) from August 21 to November 10, and six locations each day from November 11 to December 1. Locations outside the 2-hr intervals varied each month to ensure that one location occurred during each of the two crepuscular periods and two occurred during each nighttime and daytime. Each collar also had a tilt-switch. During the 10-minute interval following each location attempt, the tilt-switch was queried at one-second intervals and head-down occurrences were tallied. These were stored in the collar as percent head-down time associated with each GPS location attempt.

We constructed histograms of relative frequency for percent head-down time to assign feeding or non-feeding bedding behavior to elk. Our observations suggest that when elk are not feeding, they are usually bedded. Therefore, we assigned non-feeding behavior as bedded. We used chi square homogeneity tests to evaluate (1) whether unsuccessful GPS location attempts were independent of activity (feeding or bedding), (2) whether unsuccessful location attempts were independent of daily periods (day, night, or crepuscular), and (3) whether feeding and bedding GPS locations were similar among habitats. Elk locations were assigned to habitats using inventory data (Buttery and Gillam 1983) for the Black Hills National Forest in a geographic information system. We determined significant deviations from the expected distributions in the chi square tests by comparing the adjusted standardized residuals with the critical values of a Z-statistic after making a Bonferroni correction to a level (Mosteller and Paranuk 1985). All tests were considered significant at $\alpha = 0.10$.

RESULTS AND DISCUSSION

The first two GPS telemetry collars deployed on elk did not operate correctly. The collars were programmed to collect 36 locations each month (three each day, three days each week), but the number of locations varied from 0 to 153 per month (Table 1). One collar did not obtain a GPS location for more than two months after it was placed on an elk. We cannot explain these apparent malfunctions. During winter, the rate of successful locations for both **collars** was poor. We suspect that moisture in the collars and freezing temperatures caused the poor success of these GPS collars during winter. Temperature was not related to success of obtaining GPS locations on moose *(Alces alces)* in Canada (Dussault et al. 1999). We found it difficult to accomplish remote downloads of data from the collars. We believe the signal was blocked when animals walked behind large trees causing the communication link to be broken. The four store-on-board GPS collars we deployed operated correctly. These GPS collars obtained locations on 88% of attempts, with 70% 3D locations (Fig. 1). Biggs et al. (in press) recorded 70% location rates using an earlier version of GPS units from the same manufacturer.

We obtained 1,811 locations of elk from VHF telemetry from August 1998 to December 2000; 967 of which were visual observations of collared elk, or elk in the same herd as collared animals. There was no way to estimate accuracy of the latter visual observations, but we believe it was equivalent to a differentiallycorrected 2D or 3D location with dilution of precision < 7 (approx. ±20 m, Rempel and Rodgers 1977). The accuracy of 844 VHF locations was only sufficient for a skilled technician to confidently place the animals in a 4 - 32 ha land unit through the combined use of the telemetry system and topographic features.

Collar#	Deployment Dates	Number of locations by month[1]											
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
910		3	0	5	27	24	19	14	31	23	10	34	43
920	8/98 - 10/99	16	48	153	51	23	18	7	15	13	2	14	1
340	2/00 - 11/00		167	178	171	168	154	156	226	330	288	203	1
350	2/00 - 11/00		165	174	157	152	146	153	201	314	338	221	1
370	2/00 - 11/00		174	181	170	160	155	155	231	323	343	229	1
380	2/00 - 11/00		169	177	174	172	149	149	221	327	322	206	1
VHF	8/98- 01.01	149	170	165	82	122	163	102	77	143	242	239	157

Table I. Number of locations obtained from GPS and VHF telemetry collars placed on elk in the Black Hills.

[1] Collars 910 and 920 were programmed to collect 3 locations a day for 3 days each week. Collars 340,350,370, and 380 were programmed to collect 7locations a day in February, 6 locations a dayfrom March - August 20,12 locations a day August 21 to November 20, and 6 locations a day from November 21 to December 1.

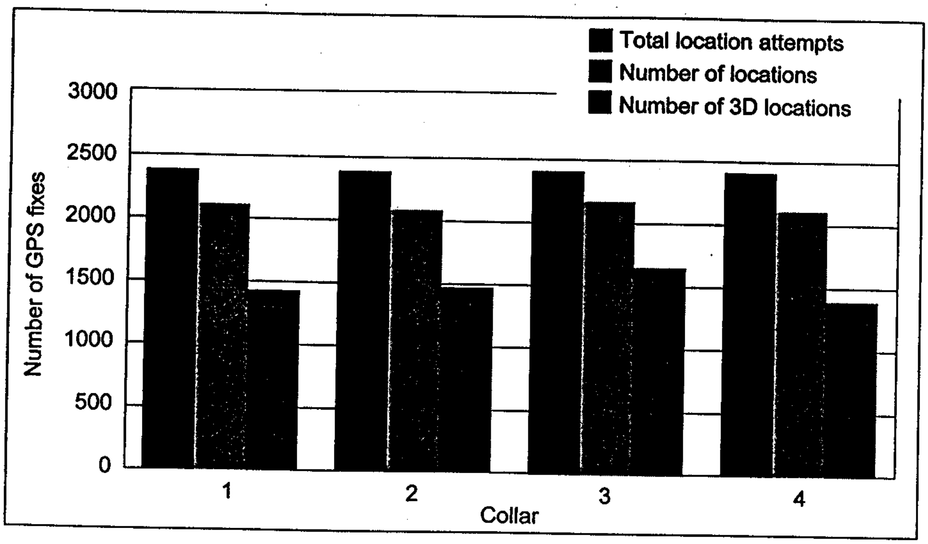

Figure 1. Number of location attempts, total locations, and 3D locations of four store-on-board GPS collars deployed on elk in the Black Hills, South Dakota.

We considered elk to be feeding if the activity sensor recorded >10% head-down position during the 10-minute time interval following GPS location attempts (Fig. 2). The most likely error in our behavior assessments would be browsing by elk at or above head-level. However, our observations indicate that when browsing, elk frequently select low plants also. If estimates of activity made from telemetry are compiled over time and include relative duration, activity of animals can be estimated with >90% accuracy (Gillingham and Bunnell 1985, Hansen et al. 1992).

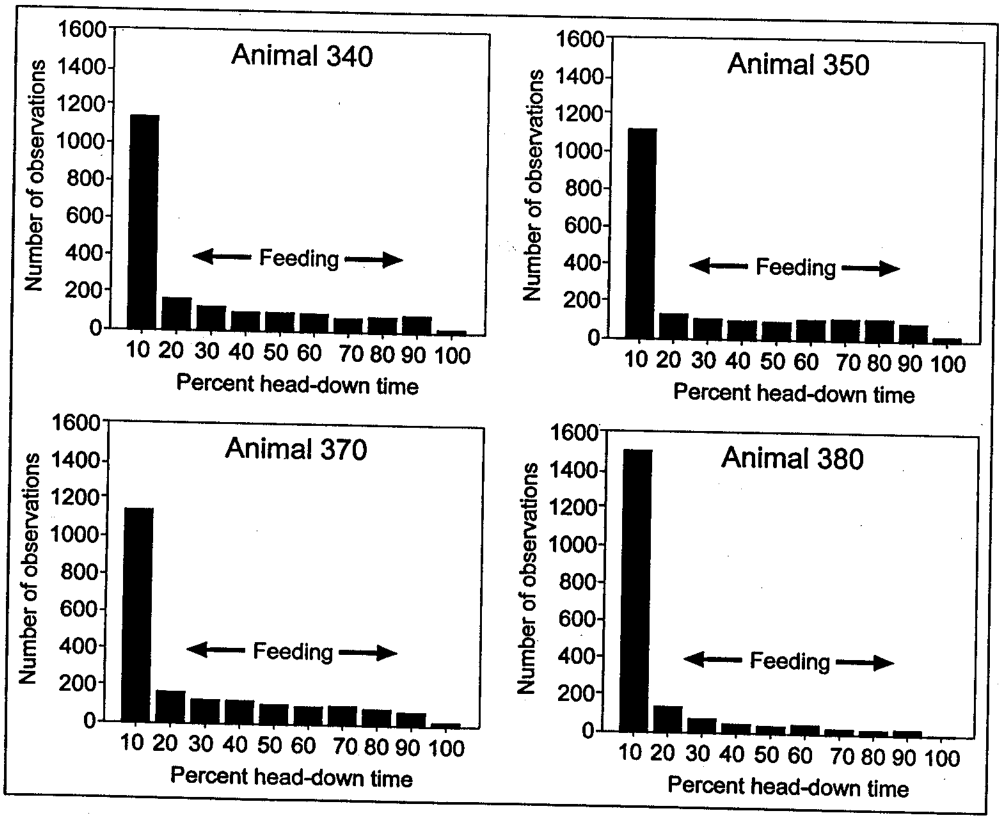

Figure 2. Frequency histograms of percent of time in head-down position on elk fitted with GPS collars in the Black Hills, South Dakota.

During the day, 37% of GPS elk locations were feeding. At night, 42% of GPS elk locations were feeding. Our daytime observations from VHF telemetry frequently included elk feeding while others in the herd were bedded. Our estimates of feeding and bedding behavior obtained from GPS collars contrast estimates of optimal spatial allocation of forage (60%) and cover (40%) for elk (Thomas et al. 1979).

Habitat	Standardized residual[1] for feeding during day	Standardized residual for feeding during night
Grasslands	4.6	2.3
Private (mostly grassland)	8.3	4.9
Open canopy aspen	2.4	-0.7
Moderate canopy aspen	-0.9	-0.7
Dense canopy aspen	-0.8	0.2
Shrublands	-1.1	-3.2
Open canopy ponderosa pine	-0.9	-1.2
Moderate canopy ponderosa pine	-5.9	-3.6
Dense canopy ponderosa pine	-2.0	-1.9
Open canopy white spruce	1.1	1.5
Moderate canopy white spruce	2.3	0.1
Dense canopy white spruce	-1.2	0.3

Table 2. ***Adjusted standardized residuals for feeding activity from chi-square homogeneity test of activity of elk with GPS collars among habitats for days and nights.***

[1]Standardized residuals for bedding are not shown because they are the same value with an opposite sign. A negative standardized residual indicates elk used habitats more for bedding than feeding and a positive sign indicates elk used habitats more for feeding than bedding. Standardized residuals =*2.38* are significant at a 0.10 from a Bonferroni correction to the Z-statistic (Mosteller and Parunak 1985).

Elk used all habitats for feeding and bedding during days and nights (Table 2). When in grasslands, elk were usually feeding. During daytime, the disparity between feeding and bedding in grasslands was greater than at night-time. When elk used moderate or dense ponderosa pine, they were bedded more than feeding during both daytime and night-time. Unsuccessful GPS locations occurred more ($P < 0.01$) frequently when elk were bedded (833) than when they were feeding (212). GPS location attempts failed more frequently when white-tailed deer *(Odocoileus virginianus)* were bedded (Bowman et al. 2000). Unsuccessful GPS location attempts also occurred more frequently ($P < 0.01$) during the day (731) than during night (126) or crepuscular (161) periods. We suspect the decline in successful GPS locations was caused more by dense forest vegetation frequently used by elk for bedding than the bedding activity itself. We frequently observed elk bedded in patches of white spruce and ponderosa pine with high basal area and high overstory canopy cover during summer. Unsuccessful GPS location attempts increased ($P < 0.01$) from February through July (Fig. 3). Greater frequency of unsuccessful GPS location attempts during daytime and through July may have been a thermoregulatory response by elk utilizing dense cover for shade (e.g., Merrill 1991, Millspaugh et al. 1998). GPS location attempts failed more frequently during daytime, when temperatures were higher, and moose used closed canopy vegetation types in Alaska (Moen et al 1996). Because the temperature sensors were not activated, relations between bedding and temperature in our study are speculative. Two animals showed increased frequency of unsuccessful GPS locations in October. We observed elk using dense cover, possibly as security cover during the hunting season.

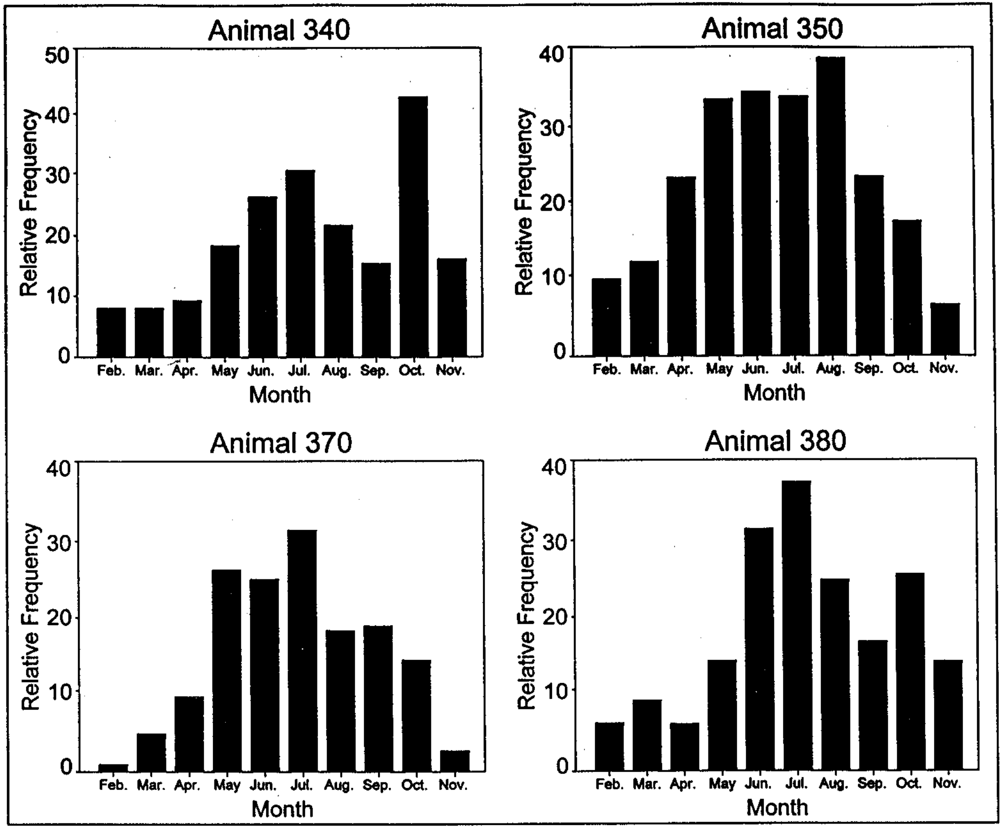

Figure 3. Histograms of relative frequency for unsuccessful GPS location attempts by month, in the Black Hills, South Dakota.

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