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SUMMER ACTIVITY PATTERNS OF BIGHORN EWES IN THE NORTHERN GREAT PLAINS

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Abstract: Eight bighorn ewes (*Ovis canadensis californiana*) were captured and fitted with motion-sensitive transmitters in early 1992. Their activity patterns were monitored with a telemetry/data recording system during the summers of 1992 and 1993. Concurrent behavioral observations indicated that the system recorded activity/inactivity with $\geq$ 95% accuracy. The ewes were more active during the daytime and PM twilight than during the night or AM twilight ($P < 0.01$). Peak activity periods occurred in the morning soon after sunrise, and in the afternoon/evening, which tended to be the most active time of the day ($P < 0.05$). Activity levels did not differ on days when temperature was > 23 C, compared with days $\leq$ 23 C ($P > 0.05$). However, the ewes tended to be more active on wet days than on dry days ($P < 0.01$ in 1992).

Knowledge of activity patterns can yield important information about the ecology and behavior of ungulates. However, data are difficult to obtain. Long hours of observations are required, study animals may move out of view, and the presence of observers may affect the behavior of the animals. Moreover, data on 24 hr activity budgets, including nocturnal patterns, of bighorn sheep are lacking. Radio telemetry has facilitated research of activity patterns, and new advances with automated telemetry allows workers to collect activity data continuously over extended periods. Previously, the data were collected on strip chart recorders (e.g.., Merrill 1985, Hamr and Czakert 1986, Kufeld et al. 1988), but these require intensive monitoring. Computerized data recording devices interfaced with telemetry equipment have been used on mule deer (Kie et al. 1991, MacDonald 1990, Peterson and MacDonald In Prep.) but not on bighorn sheep. Use of this technology could help increase knowledge of ungulate ecology in a variety of regions and environmental conditions.

Relatively few ecological studies of bighorn sheep have been conducted in the Great Plains region (Brundige and McCabe 1986, Fairbanks et al. 1987, Berger 1991). Fairaizl (1978, 1980) provided the only previous reports on the reintroduced population of bighorns in the badlands of North Dakota, and his research focused on population estimates and food habits. Behavioral studies of these sheep in their new environment have not been conducted.

The objectives of this study were: (1) implement and validate an automated telemetry monitoring system to evaluate 24-hr activity patterns of bighorn ewes in northern Great Plains; (2) determine summer activity patterns of ewes during the different periods of the day; and (3) analyze the influence of temperature and precipitation on activity patterns.

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STUDY AREA AND BIGHORN SHEEP POPULATION

The research was conducted at the 14 km^2 Magpie Creek study area, 1.5 km east of the confluence of Magpie Creek and the Little Missouri River in McKenzie County of western North Dakota. Elevation ranges from 646-803 m. The area is rugged and dissected by steep coulees which were formed due to erosion of the soft silt and clay since the Pleistocene. The plant communities are a complex mosaic that reflect the varied terrain. Plateau tops and gentle side slopes (<50%) are dominated by threadleaf sedge (*Carex filifolia*), needle and thread (*Stipa comata*), western wheat grass (*Agropyron smithii*), and blue grama (*Bouteloua gracilis*). The steep southerly facing slopes ($\geq$ 50%) are either non-vegetated or dominated by xerophytic shrubs such as sagebrush (*Artemisia tridentata* and *A. cana*), and rabbitbrush (*Chrysothamnus* spp.). North facing slopes are dominated by Rocky Mountain juniper (*Juniperus scopulorum*). Complexes of shrub communities, including chokecherry (*Prunus virginiana*), snowberry (*Symphoricarpos occidentalis*), and skunkbrush (*Rhus trilobata*), are interspersed within the primary habitats. During most of the past century, livestock grazing was the primary land use and it continues in the Magpie Creek area. During the past 15-20 years, oil development has become increasingly widespread in the Little Missouri badlands, and the current density of active oil wells within the study area is 1.6 wells/km^2.

Audubon's bighorn (*O. c. auduboni*) previously occupied the badlands, but they were extirpated by the early 1900s (Fairaizl 1978, Knue 1991). Eighteen California bighorns were introduced to the Magpie Creek area in 1956 (Fairaizl 1978, Knue 1991), and by 1975, the area was inhabited by at least 30 sheep (Fairaizl 1978). The herd count totalled > 40 sheep as recently as 1990 (W. Jensen, North Dakota Game & Fish Dept. pers. comm.); however, only 18 individuals have been observed within the Magpie Creek study area since our research commenced in 1992.

METHODS

Eight ewes and 1 ram were captured using a net gun fired from a helicopter during March of 1992. Each ewe was ear-tagged and fitted with a radio-collar that was equipped with a motion-sensitive tip switch (Telonics Inc., Mesa, Arizona). The ram was ear-tagged and released. Radio signals from each ewe were recorded for 30 sec, every 5 min, 24 hr/day by a telemetry/data recording system. The signals were received by an omnidirectional antenna that was connected to a Telonics TR-2 receiver/scanner and Telonics TDP-2 data processor. The telemetry equipment was interfaced with a Campbell Scientific CR10 data-logger (Campbell Scientific, Logan, Utah) (MacDonald 1990, Peterson and MacDonald In Prep.). The system was powered by a 12 V battery that was recharged with a 5 w solar panel. Data were stored and periodically down-loaded onto a personal computer.

The telemetry system recorded whether an animal was active or inactive. Active behaviors included feeding, walking, running, and social activities. Inactive behaviors included bedding and standing still. To validate accuracy, 5 of the radio-collared ewes were observed directly while the system was operating, and the recording was compared with observed activity. Activity analysis was conducted by compiling data from randomly selected 24 hr periods during June, July, and August of 1992 (n = 10) and 1993 (n = 14). Missing data were discarded from the analysis. Temperature and precipitation data were collected at Fairfield weather station, located 37 km southeast of the study area.

Activity data for the ewes were combined because field observations indicated that the radio-collared ewes usually remained in the same group (Sayre unpublished data), thus their activity patterns were not independent. The proportion of time ewes were active were averaged for each hour and for different periods of the day. The 24 hour cycle was categorized into 4 periods based on civil twilight (Anonymous 1992, 1993): AM twilight (beginning when the sun was 6° below the horizon; daytime (sunrise to sunset); PM twilight (sunset until the sun was 6° below the horizon); and night (between the end of PM twilight and the beginning of AM twilight). Daytime was subsequently divided into 3 periods: morning (the first 4 hours following sunrise), mid-day (from > 4 hours after sunrise until 4 hours before nightfall), and evening (4 hours prior to nightfall). Times were recorded at Mountain Daylight Time. Two levels were analyzed to evaluate relationships between activity patterns and ambient temperature: $\leq$ 23 and > 23 C. This temperature was used because it is the best available estimate for upper critical temperature (UCT) of a bighorn ewe. Information on UCT for northern bighorn sheep are lacking, and 23 C was used as a threshold because it has been reported as the average UCT for mule deer (Parker and Robbins 1984, Parker and Gillingham 1990), a ruminant that is approximately the same size and body shape as a bighorn sheep. In addition, 2 levels for precipitation were used: wet and dry. We analyzed this variable because the bentonite clay ridges, used as the primary escape terrain by the sheep, become extremely slippery when wet. We hypothesized that the behavior patterns could be different on wet days because field observations indicated that the sheep had difficulty negotiating the steep slopes. Wet days were defined by field observations, and/or when $\geq$ 0.5 cm was recorded during the 24 hr period that activity data were recorded, or when $\geq$ 1.0 cm of precipitation was recorded during the previous day (the bentonite remains slippery for > 24 hr after substantial rainfall).

The data were subjected to repeated measures ANOVA, with activity as the dependent variable, and year, temperature, and precipitation as the independent variables. Paired t-tests with the Bonferroni inequality (Snedecor and Cochran 1989) were used to compare activity levels during different periods of the day. Influence of weather variables on activity levels were compared with the two sample t-test. Statistical analyses were conducted with SAS computer programs (SAS 1985).

RESULTS

When compared with visual observations, the telemetry monitoring system correctly recorded active behavior 93 of 95 times (97.9%), and inactive behavior 109 of 114 times (95.6%). However, preliminary analysis of the data indicated that the radio-transmitter from 1 ewe malfunctioned. Therefore, data from this animal were excluded from further analysis.

Hourly activity patterns indicate that the ewes followed a diurnal activity schedule during summer (Fig. 1). Ewes were relatively inactive at night and displayed peaks of activity at about 0600-0700 and about 1400-1800. During a mid-morning lull (0900-1100), activity levels were reduced by at least 50% when compared to peak times. The ewes typically had 3- 4 activity bouts/day.

Statistical analysis of the activity patterns indicated that the ewes were significantly less active ($P < 0.001$) in 1992 than in 1993. Thus the data were analyzed separately by year, even though daily trends between years were similar. During both summers, the ewes were less active at night and AM twilight, and more active during the day and PM twilight ($P < 0.01$) (Table 1). Analysis of data from different daytime periods, indicated a slight decrease of activity from morning to mid-day ($P > 0.30$) in 1992, but revealed significantly greater activity during the evening period ($P \leq 0.01$). In 1993, the ewes were more active in the evening than in the morning ($P < 0.05$) but the other comparisons were not different ($P > 0.15$).

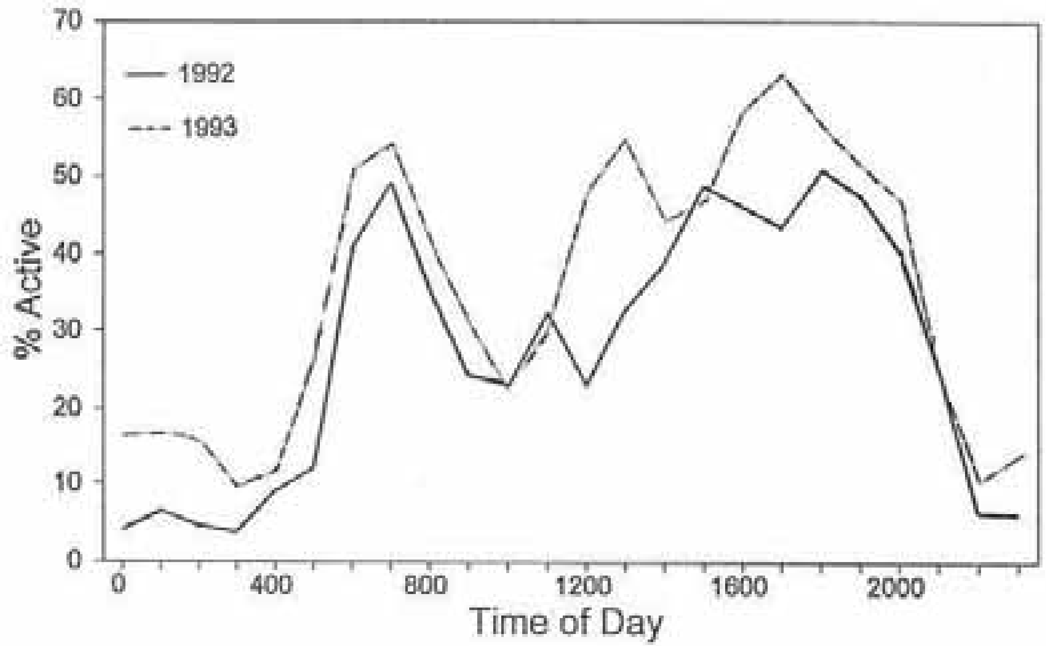

Figure 1. Average 24 hour activity patterns of 7 bighorn ewes during summers of 1992 (n = 10 days) and 1993 (n = 14 days) at Magpie Creek, North Dakota.

Table 1. Proportion of time (%) bighorn ewes were active during segments of 24 hour cycle and during daytime at Magpie Creek study area[a].

	1992		1993	
Period	Mean	SE	Mean	SE
AM twilight	10.2A[b]	2.7	13.5A	2.6
Daytime	35.2B	1.4	44.7B	1.3
PM twilight	34.4B	5.5	39.2B	5.8
Night	5.7A	0.5	12.5A	1.5
Morning	33.9A	2.1	45.9A	2.5
Mid-day	31.8A	1.4	41.2B	2.4
Evening	42.6B	2.8	52.5B	3.1

[a] Ewes (n = 7) were monitored for 10 days in 1992 and 14 days in 1993.

[b] Means within columns with different letters are statistically different ($P \leq 0.05$, adjusted for Bonferroni inequality).

The average summer temperature was 16.7 C in 1992 and 16.2 C in 1993. These were relatively cool compared to the average seasonal temperature of 19.7 C (National Weather Service). Temperatures on days that activity data were recorded did not deviate from the average of each year ($P > 0.30$). Daytime activity levels did not differ when the temperature was ≤ 23 C compared to > 23 C ($P \geq 0.19$) (Table 2). However, the ewes tended to be more active on wet days in 1992 ($P < 0.01$) (Table 2). During 1993 the activity levels during the wet daytime periods were slightly higher than on dry days, but the differences were not significant ($P > 0.20$).

DISCUSSION

The telemetry recording system provided accurate recordings of general activity patterns. Although Kie et al. (1991) reported high r^2 values (≥ 0.91) for mule deer at the level of walking, foraging, and resting, we did not quantify behavior at this resolution because the sheep frequently fed on steep hillsides with their head up, and we were not able to differentiate feeding from other activities. Inaccurate recordings occurred either when the animals were bedded and they moved their head up and down during the 30 sec scan period, or when the animals were standing or foraging without moving enough to tip the mercury switch.

Nocturnal behavior patterns of bighorn sheep are poorly understood. Data obtained in this study indicated that during the summer, bighorn ewes were relatively inactive at night. Although nocturnal observations were not conducted, field observations indicated that the ewes stayed within the same area once they bedded down for the night (Sayre, unpubl.

Table 2. Daytime activity levels of bighorn ewes in relation to temperature and wet weather (wet days had ≥ 0.5 cm precipitation, and/or ≥ 1.0 cm on previous day; explanation and rationale in text), at Magpie Creek, North Dakota.

Year &	[≤ 23 C][a]		[> 23 C][b]			Dry[c]		Wet[d]		
Period	*x*	SE	*x*	SE	*P*	*x*	SE	*x*	SE	*P*
1992										
Daytime	35.6	1.8	35.1	2.1	0.93	31.5	1.0	38.9	1.4	0.004
Morning	34.4	4.1	33.7	2.8	0.89	30.2	2.5	37.6	2.8	0.090
Mid-day	34.1	1.2	30.9	1.9	0.19	28.4	1.5	35.3	1.0	0.009
Evening	39.3	4.8	43.9	3.7	0.49	38.9	3.5	46.5	4.3	0.200
1993										
Daytime 43.9	1.6	46.8	1.8	0.29	43.3	1.6	45.6	2.4	0.290	
Morning	43.8	3.5	50.4	3.6	0.22	43.2	4.2	49.1	3.0	0.270
Mid-day	41.1	2.7	40.6	5.3	0.90	38.6	3.0	44.3	3.5	0.250
Evening	52.6	3.5	51.3	5.7	0.86	51.6	5.2	53.1	1.3	0.790

[a] n = 3 days in 1992 and 10 days in 1993.

[b] n = 7 days in 1992 and 4 days in 1993.

[c] n = 5 days in 1992 and 8 days in 1993.

[d] n = 5 days in 1992 and 6 days in 1993.

data). The activity that did occur probably represents repositioning and movement among bed sites during the night. Diurnal observations indicated that, during bedding periods, the animals stand and reposition themselves every 30-120 min. Additional research on nocturnal behavior patterns of bighorn sheep is needed.

Circadian activity levels increased > 2 hours/day from 1992 to 1993. A number of factors may have contributed to this increase, including weather, lambing success, predator activity, forage availability and quality, or other disturbances. The activity data in 1993 were collected on relatively more wet and cool days than in 1992 (Table 2). Furthermore, 3 ewes successfully reared lambs in 1992, but no lambs were alive after 1 June 1993. In 1992 the ewes tended to stay closer to their primary lambing terrain than in 1993 (Sayre, unpubl. data), thus their travel time may have been less. Disturbances by coyotes also were observed more frequently in 1993 than in 1992 (Sayre, unpubl. data), which may have contributed to the increased level of activity. Likewise, sightings of rams and ram harassment of the ewes was greater in 1993 than in 1992 (Sayre, unpubl. data). Data on the availability and quality of forage were not collected. However, the timing and stocking rate of cattle grazing did not differ between the 2 years, (Bruce Rogers, U.S. Forest Service, pers. comm.). The effects of other disturbances, such as oil development or interactions of ewes with cattle are yet to be analyzed.

Although activity levels did not vary in relation to the hypothesized threshold of 23 C, field observations have indicated that the ewes sometimes increased daytime bedding intervals on hot and sunny days by resting on the shady side of the ridges (Sayre, unpubl. data). A higher temperature threshold may exist, and research is continuing to determine whether the ewes alter activity patterns when the temperature is high. It is not clear why ewes tended to increase activity levels during wet days. Energetically, they may be less stressed because the cloud-cover would substantially reduce the operative temperature (Parker and Gillingham 1990). In addition, travel by bighorns on steep bentonite-clay ridges appears to be more difficult on wet days, therefore, ewes may be spending more time foraging on less slippery grass and shrub habitats resulting in overall increased activity levels. Data collection is continuing so that telemetry activity recordings can be corroborated with observed behavior and habitat use under varying environmental conditions.

Eccles (1983) reported that semi-captive bighorns in British Columbia averaged 5 diurnal activity peaks during the summer, while Davis (1938), and Van Dyke (1978) reported only 2 or 3 daily peaks for wild sheep in Wyoming and Oregon, respectively, which is closer to the telemetry recordings of ewes at Magpie Creek. The higher number of activity peaks reported by Eccles (1983) may be an artifact due to semicaptivity.

Finally, the data presented in this report are representative of a sample of data from only 1 herd during the summer. Extrapolation of the Magpie Creek data to other populations, or to other seasons should be viewed with caution.

MANAGEMENT RECOMMENDATIONS

Human activities should be scheduled at times that are least disruptive to bighorn sheep. Therefore, we recommend that vehicle traffic within sensitive areas, such as lambing habitat, should be limited to times when the sheep are more likely to be inactive and secure on escape terrain. Specifically, based on the information presented in this report, the early morning prior to 0400, or mid-morning from 0900-1100 would be the best times to allow human activity in close proximity to the sheep.

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