1985

Lungworm Infections, Reproduction and Summer Habitat Use of Bighorn Sheep in Custer State Park, South Dakota

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LUNGWORM INFECTIONS, REPRODUCTION, AND SUMMER HABITAT USE OF BIGHORN SHEEP IN CUSTER STATE PARK, SOUTH DAKOTA

BY

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A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science
Major in Wildlife and Fisheries Sciences (Wildlife Option)
South Dakota State University
1985

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This thesis is approved as a creditable and independent investigation by the candidate for the degree Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ACKNOWLEDGEMENTS

I would especially like to thank Dr. T. R. McCabe for all his patience and encouragement during this study, and H. Shave for her assistance and labratory work.

I am grateful to L. Layne for his valuable assistance in the field and all the graduate and undergraduate students who provided assistance with trapping.

My thanks go to T. R. McCabe, L. D. Flake, C. G. Scalet, H. L. Hutcheson and R. Foreman for editing the manuscript. They provided many helpful insights.

I thank my parents, Edward and Betty, for all the love and support they have provided. Without their support this would not have been possible.

Funding was provided by a grant from the Foundation for North American Wild Sheep, Custer State Park, and Federal Aid administered by South Dakota Department of Game Fish and Parks.

PREFACE

This thesis was written in 3 chapters, each dealing with a separate phase of the study. Each chapter was written in the format of the Journal for which it is intended to be submitted for publication. Chapter 1 will be submitted to the Journal of Wildlife Diseases, Chapter 2 to the Journal of Mammalogy, and Chapter 3 to the Journal of Wildlife Management.

Preparation of the thesis in journal formatted chapters will facilitate expedient publication of the material presented. In addition, invaluable experience in presenting material in an acceptable manner for publication was gained.

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INTRODUCTION

Bighorn sheep (*Ovis canadensis*) were once indigenous to the Black Hills and Badlands of South Dakota. When European settlers moved into this region during the late 1800's, market hunting, loss of habitat, and introduction of animal diseases and parasites caused the subspecies of the region, the Audubon's bighorn sheep (*O. c. auduboni*), to become extinct by 1916 (Buechner 1960).

To reestablish bighorn sheep in the Black Hills, 8 Rocky Mountain bighorn sheep (*O. c. canadensis*) were introduced into the former range of the Audubon's sheep in 1922. Finding the habitat to be very suitable, this small population increased to about 150 animals. A suspected waterborn disease (leptospirosis?) decimated this population, causing it to decline to 1 animal by 1959 (W. Winter, Custer State Park, pers. comm.). A second reintroduction of Rocky Mountain bighorn sheep was made in Custer State Park in 1964. Again the population increased, reaching a level of 100-150 animals by 1975 (Trefethen 1975).

The population in the park has failed to increase above this 1975 level, having at present an estimated population of 120 animals. Two possible factors are limiting the expansion of the herd: 1) mortality induced by a lungworm-pneumonia complex (Spraker 1981, Hibler et al. 1972, Forrester 1971), and/or 2) carrying capacity restricted by some habitat factor.

Previous studies have indicated that the Custer State Park bighorn herd is infected with the lungworm *Muellerius capillaris* (Pybus and Shave 1984). However, very little is known of the reproductive success of the herd or of the behavior and habitat use of the sheep. To ascertain whether parasitic influence and/or habitat availability are instrumental in negating population growth, close examination of the level of lungworm infection, reproductive success, and habitat use of the bighorn sheep in the park was necessary. Only with this information can Custer State Park meet the management objective of maintaining a healthy bighorn sheep herd for both the viewing and sporting public.

CHAPTER 1: REPRODUCTIVE SUCCESS AND LUNGWORM INFECTIONS OF BIGHORN SHEEP IN CUSTER STATE PARK, SOUTH DAKOTA

INTRODUCTION

Recruitment of bighorn sheep (*Ovis canadensis*) lambs at Custer State Park (CSP), a 29,150 ha park situated in the southeast corner of the Black Hills, South Dakota, is thought to be at best only enough to maintain the herd at the present level of about 120 animals. The population has failed to increase above this level for the last 10 years. A suspected cause of the failure to increase is a fatal lungworm-induced pneumonia. In CSP, lungworm (*Muellerius capillarius*) is found to be ubiquitous among adult sheep (Pybus and Shave 1984).

Mortality that is disease related is responsible for a decline in the growth or size of many bighorn herds. Epidemics attributed to the lungworm-pneumonia complex (Forrester 1971, Hibler et al. 1972) are particularly severe on the juvenile cohort. Because natural mortality in yearlings and subadults is minimal (Geist 1971), changes in the structure of the population are directly related to reproductive success and juvenile survival. Lungworms predispose bighorn sheep to pneumonia caused by *Pasteurella* spp., which is highly pathogenic (Forrester 1971, Hibler et al. 1972, Post 1971).

Although numerous stress factors have been associated with fatal pneumonia in bighorn sheep (Foreyt and Jessup 1982), nutritional and physiological stress caused by lungworms is well documented (Forrester et al. 1966). Of particular importance is the effect of lungworm infection on the reproductive potential of bighorn sheep. Lamb survival is adversely affected both directly and indirectly by lungworms.

Nutritional loss in pregnant dams debilitated by lungworm infection will result in lower nutrition for the lamb both pre- and post-parturition. The ability of lambs to survive the first months of life is dependent upon maternal nutritional input (Cowen and Geist 1971). Gestation occurs during a season when climate-induced energy costs are maximum and forage quality is minimal. Increased energy demand associated with lungworm infection during gestation will aggravate the potential of lamb loss shortly after parturition. Probability of lamb mortality due to hypothermia (Alexander 1961) and other physiological and behavioral dysfuntion (Geist 1971) is increased when ewes have lost weight during gestation.

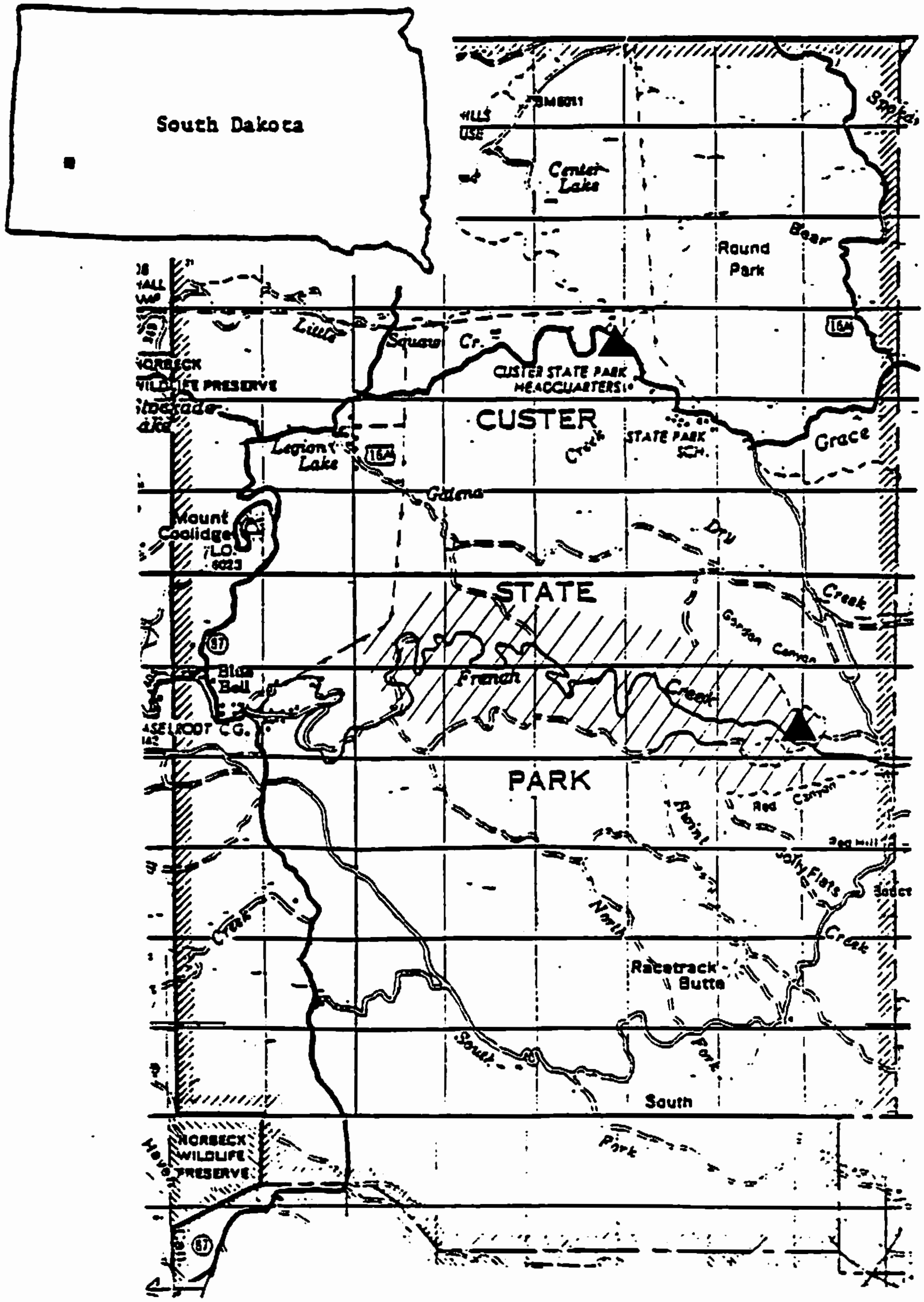
Direct impact of lungworms on lambs involves the presence of the parasite in the lambs at birth (Pilmore 1959, Gates and Samuel 1977, Kistner and Wyse 1979, Hibler et al. 1974). Transplacental migration occurs with the third stage larval form, which implants in the liver of the fetus. Just prior to birth, the lungworms migrate to the lungs of the fetus to complete the life cycle (Schmidt et al. 1979). The immediate stress on lambs caused by lungworms may be a major factor in lamb mortality (Woodard et al. 1974). Schmidt et al. (1979) reported that lamb survival was greater in a herd of bighorn sheep when pregnant ewes were treated with antihelmenthic drugs, indicating a causal relationship between lamb mortality and parasitic infection in ewes.

Objectives of this study were to determine lungworm infection levels and reproductive success. Monitoring sheep allowed estimates of lamb mortality.

STUDY AREA

Research was conducted during 1983 and 1984 in the French Creek Natural Area, located in the central portion of CSP, and Grace Coolidge Canyon (Fig. 1). French Creek Natural Area encompasses French Creek Canyon, which is approximately 19 km long, 800 m wide, and from 140 to 270 m in depth, and which represents the primary sheep range.

Figure 1. French Creek Canyon study area in Custer State Park, South Dakota, and bighorn sheep trap sites(▲).



METHODS

LAMBING SUCCESS

Initial investigation of lambing success and lungworm infection levels required locating the sheep to determine the number of lambs, yearlings, and ewes composing groups to calculate lamb:ewe and yearling:ewe ratios. Fecal samples were collected for determination of larval lungworm output. French Creek and Grace Coolidge canyons were searched daily during the 1983 and 1984 summer field seasons for ewes and lambs. Identifying and monitoring individual ewes was necessary in order to determine reproductive success in relation to lungworm loads.

Radio-telemetered, color-coded collars were attached to breeding age ewes to facilitate locating and monitoring ewes. Bighorn sheep were trapped at 2 locations in February 1984 (Fig. 1). Sheep were baited, using apple pomace and alfalfa hay, under a 20 X 20 m drop net for capture.

Numbered, livestock ear tags were placed in the left ear of all 14 female sheep trapped. In addition, 10 adult females were radio collared. Male bighorn sheep were not marked and were released as soon as they were extricated from the net.

Radio-collared and tagged ewes were then monitored throughout the summer of 1984 to determine which of these ewes produced lambs and to ascertain the locations and dates of their lambing.

FECAL ANALYSIS

Fecal samples were collected whenever fresh bighorn sheep pellet groups were found. These included samples from unmarked and marked individuals (tagged and collared sheep). An effort was made to observe tagged sheep long enough to collect a fresh sample. Fecal samples were frozen and delivered to the Veterinary Diagnostic Center at South Dakota State University (SDSU) for analysis. Larval lungworm (Baermann 1917). Lungworm sample counts were then extrapolated to the average number of larvae per gram feces.

RESULTS AND DISCUSSION

LUNGWORM LARVAE COUNTS

Uhazy et al. (1973) reported a significant change in the number of lungworm (Protostrongylus) larvae found in bighorn sheep feces from winter to summer months. They also reported a direct relationship between the number of larvae/g of dry feces and the area of lung surface covered by lungworm lesions, with fecal counts over 1400 larvae/g representing heavy infections. The life cycle of

Muellerius is the same as *Protostrongylus*; therefore fecal larvae output and infection levels should be comparable.

A total of 843 fecal samples were collected between January 1980 and January 1985, including samples collected from the CSP bighorn sheep prior to the commencement of this study. Mean lungworm loads were calculated for the summer and winter seasons from 1980 to 1984 (Table 1). An increasing trend in mean lungworm levels has developed since nematocide (Fenbendazole and Cambendazole) treatments were administered orally to the sheep during the winters of 1980 and 1981 (H. Shave, unpublished data). Increasing infection levels, along with reductions in the number of fecal samples containing no larvae (Table 1), indicated that reinfection had occurred.

Lungworm fecal counts showed a significant decrease ($P<.05$) from winter to summer in treated years. A 90-94% reduction in the number of lungworms counted was observed in post-treatment summers 1980 and 1981, as compared to a 15-33% reduction from winter to summer in untreated years 1982 and 1983 (Table 2). The mild winter of 1982-83 allowed lungworm infections to remain high. Lungworm loads decreased only slightly (15%) the summer following this mild winter.

Table 1. Mean seasonal fecal lungworm counts for Custer State Park bighorn sheep, 1979-1985, and the number of uninfected samples.

Season/Date	Mean lungworm count (larvae/gram)	Number of uninfected samples
Winter 1979-80	1646 (pretreatment)	22
Summer 1980	93	5
Winter 1980-81	1378	3
Summer 1981	140	1
Winter 1981-82	1544	1
Summer 1982	1028	0
Winter 1982-83	2818	0
Summer 1983	2382	3
Winter 1983-84	3106	0
Summer 1984	895	8
Winter 1984-85	1952	0

Table 2. Mean lungworm load by season and percent reduction from winter to summer counts for Custer State Park bighorn sheep.

Year	Winter Mean	Summer Mean	% reduction	
79-80	1646	93	94%	*
80-81	1378	140	90%	*
81-82	1544	1028	33%	
82-83	2818	2382	15%	
83-84	3106	895	71%	*

* = significant at P < .05, ANOVA LSD.

The influence weather exerts on infection levels from season to season may be via the snail intermediate host (Forrester and Senger 1964) rather than larval survival in the environment. Uhazy et al. (1973) reported 73% and 61% larval survival for 77 and 156 days, respectively, in fecal pellets frozen in Alberta during winter. E. Huggins and H. Shave (South Dakota State University, pers. comm.) have demonstrated that larvae can be frozen at -40° C for several months and still remain viable. Extreme cold temperatures recorded in November 1983 (Fig. 2) may have reduced the snail population, thereby reducing the reinfection of animals the following summer and leading to the lower lungworm loads.

A total of 30 lamb fecal samples were collected and analyzed (Table 3). Two of these samples were collected from fetuses of sacrificed ewes post-treatment, 1980. Evidence of possible lungworm larvae was discovered in 1, indicating possible of transplacental infection. The other lamb samples were all from fecal pellets collected after June. Only 8 of the 28 fecal samples showed no lungworm larvae in the feces. Nine of 17 lamb samples collected prior to the end of August in each year have shown some degree of infection, ranging up to 944 larvae/g. All 7 fecal samples collected from lambs having reached 6 months

Figure 2. Monthly temperature summary for Custer State Park area 1979-1984. Included are mean (x), average maximum and minimum (o), and range.

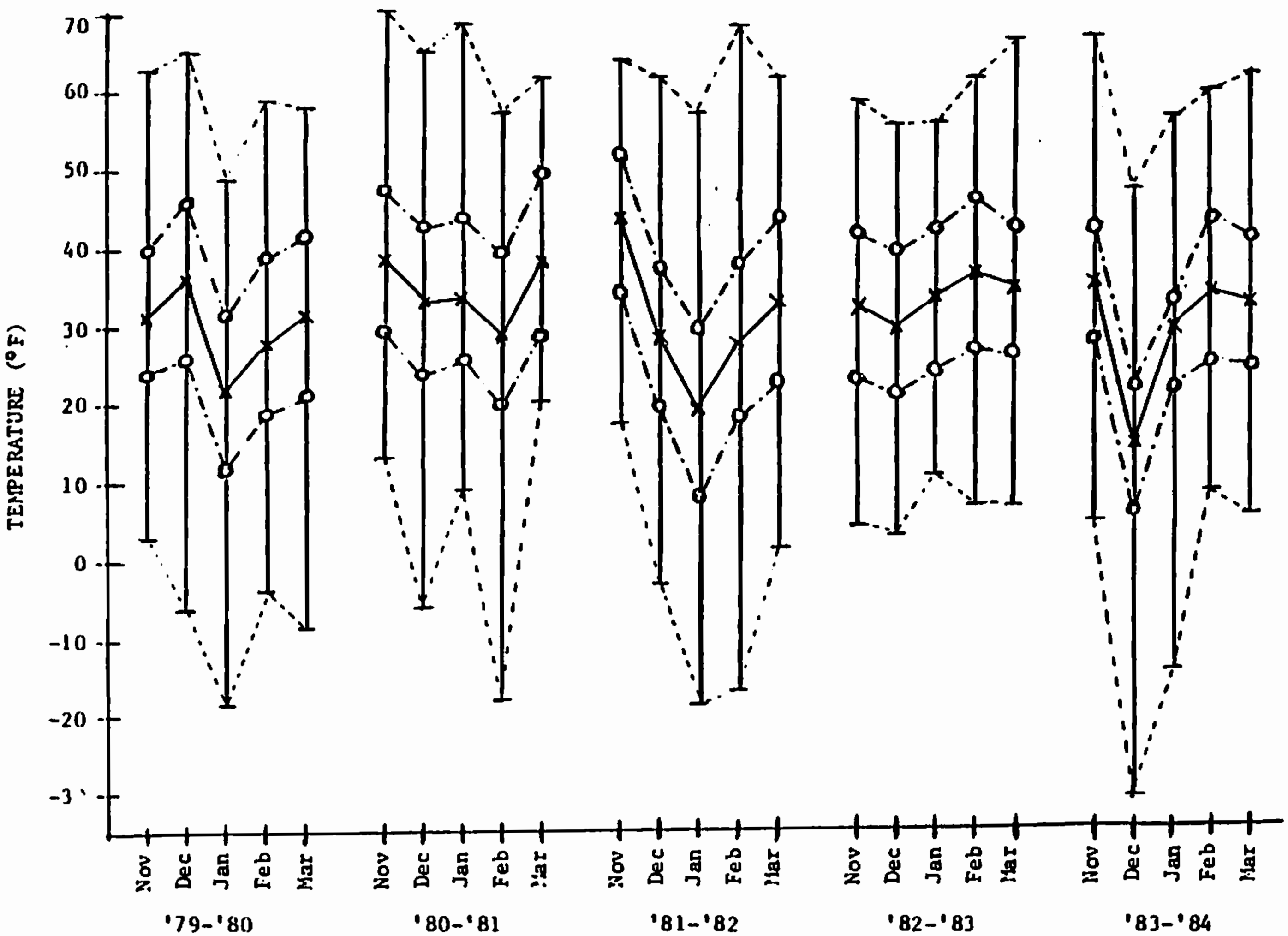


Table 3. Bighorn lamb lungworm fecal counts collected in Custer State Park, 1980-1984.

Year	Month	Fecal count (approximate age, months)
1980	2	1 (? fetal)
		1 (? fetal)
1980	7	7.5 (2)
		0.5 (2)
		0 (2)
		0 (2)
		1.5 (2)
		2.0 (2)
		0 (2)
1980	9	0.3 (4)
		2.2 (4)
1981	1	367.9 (8)
		3455.5 (8)
1983	8	0 (3)
		484.0 (3)
1984	7	128.9 (2)
		0 (2)
		944.3 (2)
		0 (2)
		2.6 (2)
1984	8	0 (3)
		0 (3)
		812.0 (3)
1984	11	870.0 (6)
		289.0 (6)
1984	12	4153.0 (7)
		3428.0 (7)
		639.0 (7)
		2345.0 (7)
		1010.0 (7)

of age were infected, with larval estimates ranging from 368 to 4153 larvae/g. Four of 7 were classified as having a heavy load (Uhazy et al. 1973). Lungworm larvae in the feces of a lamb of 1 - 3 months age is evidence of transplacental infection (Hibler et al. 1972). Transplacental migration and an infection rate approaching 100% by winter could be contributing to the high lamb loss encountered in CSP.

LAMBING SUCCESS

Lamb:ewe ratios were calculated from observed counts of groups over 10-day intervals from 28 June to 26 November 1983 and 8 June to 12 November 1984 (Table 4). Lamb:ewe ratios over the summer period of 1983 ranged from 75:100 to 50:100. The ratio dropped over the 1983 summer season from 63.2:100 to 50.0:100. This drop was more evident when the ratio from mid-July, after the conclusion of lambing, of 75.0:100 is compared to the mid-August ratio of 50.0:100.

A count made 28 September to 4 October showed a lamb:ewe ratio of 76.9:100. However, this count was determined from sightings of only 3 groups, reducing the reliability of this estimate. A ratio determined for 25-26 November of 45.4:100 (determined from 6 group counts) again showed the downward trend of the summer period.

Table 4. Lamb:ewe ratios obtained for Custer State Park bighorn sheep on 10 day intervals, June 28 to November 26, 1983 and June 8 to November 12, 1984.

Date	Lamb:ewe ratio (n) 1983	Lamb:ewe ratio (n) 1984
June 8-17		32.3:100 (27)
June 18-27		29.0:100 (24)
June 28-July 7	63.2:100 (6)	4.9:100 (18)
July 8-17	72.7:100 (6)	25.3:100 (35)
July 18-27	75.0:100 (14)	48.8:100 (17)
July 28-Aug 6	56.1:100 (14)	40.5:100 (51)
Aug 7-16	56.2:100 (8)	33.3:100 (33)
Aug 17-26	50.0:100 (5)	20.0:100 (8)
Sept 28-Oct 4	76.9:100 (3)	27.8:100 (3)
Nov 4-12		36.4:100 (8)
Nov 25-26	45.4:100 (6)	

In 1984, no lambs were observed prior to 8 June. The 1984 lamb:ewe ratios ranged from a low of 4.9:100 in late June, early July to a high of 48.8:100 in mid-July. The lamb:ewe ratios for 1984 were lower than the lamb:ewe ratios for the summer of 1983. Temperatures were much colder during the winter of 1983-84 than during the winter of 1982-83 (Fig. 2). Increased stress imposed on the ewes during the cold winter together with high lungworm infections could have resulted in a higher mortality of the lambs during the summer of 1984 (Alexander 1961, Geist 1971) leading to the lower lamb:ewe ratios.

The fate of lambs produced by radio-tagged ewes was considered indicative of the fate of lambs for the entire CSP bighorn sheep population. Mortality of lambs that were produced by radio-tagged ewes was high. Of the 8 lambs produced, 6 had died within 2 weeks of parturition. The lamb:ewe ratio for radio-tagged animals dropped from 80:100 to 20:100, indicating high lamb mortality. The latter ratio was equivalent to 1984 ratios, but was lower than those from 1983.

Plotting 1984 lamb:ewe ratios produced a bimodal distribution with the peaks approximately 1 month apart (Fig. 3). High lamb loss within the first few weeks of life would cause lamb:ewe ratio peaks on dates when high

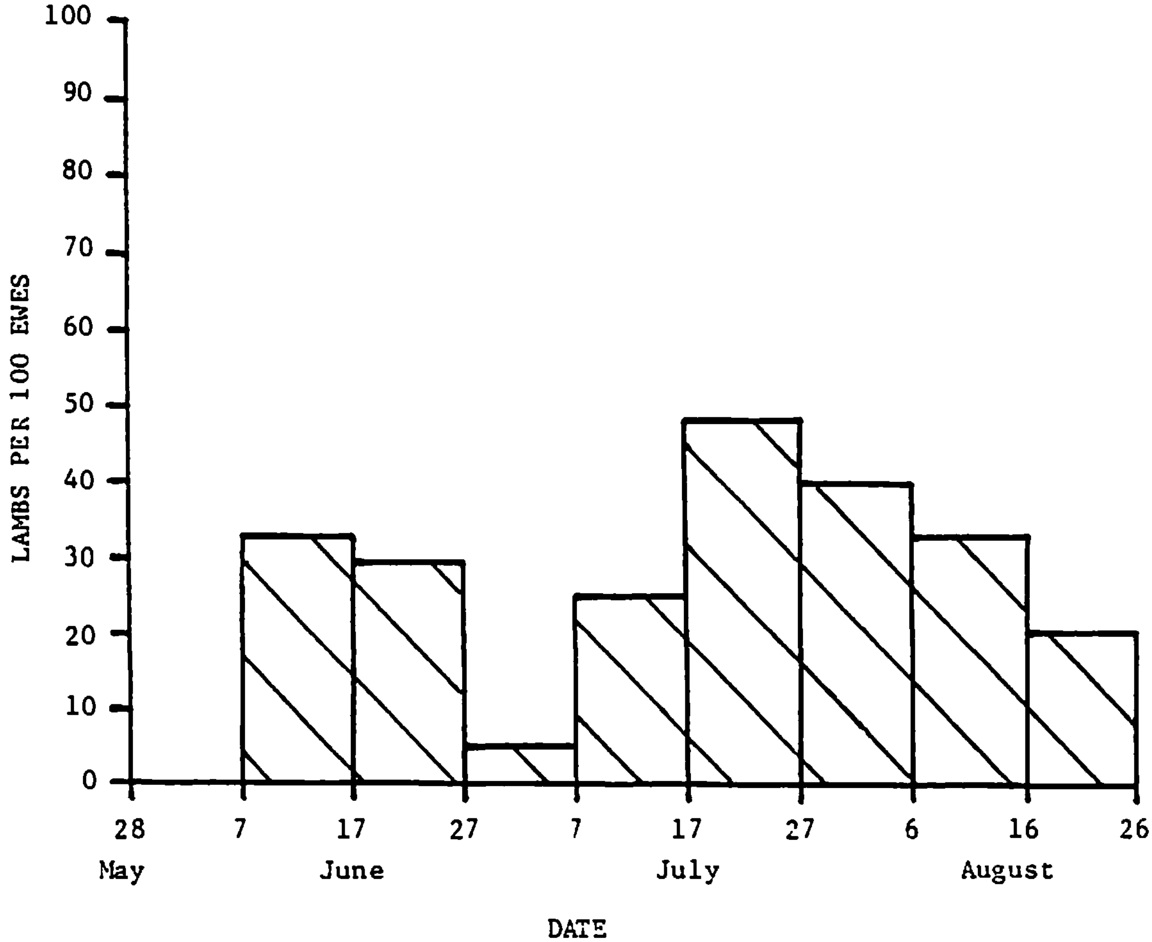


Figure 3. Distribution of lamb:ewe ratios for Custer State Park bighorn sheep over the period 28 May to 26 August, 1984 on 10 day intervals.

numbers of lambs were being produced. The bimodal distribution suggests several ewes were not bred until their second estrous. Late lambing dates of CSP ewes supported this conclusion. One collared ewe (152) lambed 1 August; therefore, she must have conceived during the first week in February, since gestation for bighorn sheep is 174 days (Shackleton et al. 1984). The effect of lungworm infection levels on late breeding is unknown.

YEARLING:EWE RATIOS

Yearlings generally associate with lamb-ewe groups (Geist 1971). Yearling:ewe ratios can be used as an indication of lambing rates the previous year together with the survival of those lambs over their first winter. The highest yearling:ewe ratio obtained during the summer of 1983 was 54.5:100 (Table 5). Calculated yearling:ewe ratios fluctuated throughout the observation periods. Yearlings were not closely associated with lamb-ewe groups, because they tended to range more widely (Geist 1971). This produced varying yearling:ewe ratios throughout the summer. Because yearling mortality is minimal (Geist 1971), summing all sightings made during a given period gives the best estimate of yearlings to ewes. Ratios of 18.8:100 and 23.2:100 were obtained when observations were summed over summer, 1983, and the entire 1983 season, respectively.

Table 5. Yearling:ewe ratios obtained for Custer State Park bighorn sheep on 10 day intervals, June 28 to November 26, 1983 and April 18 to November 12, 1984.

Date	Yearling:ewe ratio (n) 1983	1984
April 18-19		56.5:100 (4)
May 19-28		14.1:100 (31)
May 29-June 7		24.1:100 (15)
June 8-17		12.3:100 (27)
June 18-27		12.9:100 (24)
June 28-July 7	10.5:100 (6)	29.3:100 (18)
July 8-17	54.5:100 (6)	38.0:100 (35)
July 18-27	40.6:100 (14)	27.9:100 (17)
July 28-Aug 6	4.9:100 (14)	22.3:100 (51)
Aug 7-16	12.5:100 (8)	16.7:100 (33)
Aug 17-26	0.0:100 (5)	30.0:100 (8)
Summer compilation	18.8:100 (53)	21.1:100 (263)
Sept 28-Oct 4	15.4:100 (3)	22.2:100 (3)
Nov 4-12		25.0:100 (8)
Nov 25-26	54.5:100 (6)	
year compilation	23.2:100 (62)	21.3:100 (274)

Yearling:ewe ratios were consistently lower than lamb:ewe ratios, further indicating first year mortality of lambs.

Yearling:ewe ratios for CSP in 1984 ranged from a high of 56.5:100 in April to a low of 12.3:100 in June (Table 5). The summer ratio compiled from observations 19 May to 26 August 1984, was 21.1:100, nearly equal to the yearling:ewe ratio for 1983 of 23.2:100. However, the yearling:ewe ratio for 1984 is noticeably less (~50%) than the final lamb:ewe ratio for 1983 (Table 4). This decline also indicated a relatively high mortality rate of lambs over their first winter.

Yearling:ewe ratios calculated for 30 September to 1 October and 4 and 12 November 1984 are 22.2:100 and 25:100, respectively. These ratios were consistent with the summer compilation, indicating that lambs surviving to the yearling stage are subject to lower rates of mortality.

CONCLUSIONS

Bighorn sheep reproduction in CSP is comparable to that observed in other expanding sheep populations (Woodgerd 1964), with approximately 80% of the adult ewes producing lambs. However, the number of lambs surviving their first year was low as evidenced by the low lamb:ewe ratios of winter and the yearling:ewe ratios the following year. This high lamb mortality results in the CSP herds failure to increase in number.

Mean lungworm loads in CSP exceed the heavy infection level assigned by Uhazy et al. (1973). With infection rates approaching 100% and evidence of transplacental migration, lungworm infection will remain ubiquitous within the herd.

Treatment of the bighorn sheep herd in CSP with antihelmenthic drugs did lead to a significant decrease in the mean lungworm load. However, lungworm infections returned to pre-treatment level. In order to reduce lungworm infection levels in CSP and maintain these lower levels, nematocide treatments need to be administered over a period of several years. Treatment should occur during winter when environmental stress is high and maintenance of ewe condition is essential to reproduction.

A lower infection in the ewe should increase the survival of lambs by 1) reducing transplacental infection of the lamb, 2) improving the ewes health during gestation, thereby leading to higher maternal nutritional input pre-parturition for the lambs, 3) reducing reinfection of the ewe, providing her with more energy for lactation, and 4) delaying initial infection of the lamb and improving its chances of survival.

Effective treatment with antihelmenthic drugs would lead to a reduction in lungworm infections in CSP bighorn sheep, resulting in improved survival of lambs. This would result in an increase in herd size, producing a surplus of animals. These surplus animals would be available both as a reservoir of animals for reintroduction to other former bighorn sheep ranges and for an increased harvest.

CHAPTER 2: PREGNANCY DETERMINATION USING SERUM PROGESTERONE CONCENTRATION IN BIGHORN SHEEP

INTRODUCTION

Chronically low recruitment has been apparent in the bighorn sheep (Ovis canadensis) population in Custer State Park (CSP), South Dakota. Severe lungworm infection is considered to be an additive or causative factor in lamb mortality. In order to determine the extent of this mortality, accurate assessment of reproduction was necessary. Visual counts of lamb-ewe groups are not entirely reliable, since bighorn ewes are secretive when lambing and have a potential for early lamb loss (Geist 1971, Alexander 1961). In addition, these counts may take place after a substantial early postnatal mortality has occurred, and count data does not include pre-natal mortality.

To accurately determine reproductive rates, prediction of pregnancy early in gestation is required. Several techniques are used in pregnancy determination of domestic animals, with some having been successfully used in studies of wild animals. These techniques include rectal palpation (Greer and Hawkins 1967, Follis and Spillet 1974), laparotomy (Zwank 1981), ultrasound (Smith and Lindzey

1982, Harper and Cohen 1985), and hormonal assay (Ramsey and Sadleir 1979, Whitehead and McEwan 1980).

Rectal palpation requires no laboratory analysis or collection of samples. It has proven successful in predicting pregnancy (Greer and Hawkins 1967) and predicting fall cow/calf ratios (Follis ans Spillet 1974) in elk (Cervis elaphas).

Zwank (1981) used laparotomy techniques, developed by Hulet and Foote (1968) for domestic ewes, on mule deer (Odocoileus hemionis). He had a high degree of accuracy in predicting pregnancy and fetus numbers.

Ultrasound is a technique which has proven extremely accurate in studies on white tailed deer (Odocoileus virginiana) (Smith and Lindzey 1982) and bighorn sheep (Harper and Cohen 1985). However, ultrasound was accurate only during a certain part of gestation.

Blood progesterone concentrations have been shown to be accurate indicators of pregnancy in both domestic ewes (Bassett et al. 1969) and bighorn ewes (Ramsey and Sadleir 1979, Whitehead and McEwan 1980). Progesterone determination has the advantage of relatively simple sample collection and relatively inexpensive analysis.

This study was designed to determine if, and how early in pregnancy, progesterone serum concentrations could reliably indicate pregnancy in bighorn sheep in CSP.

METHODS

Bighorn sheep were trapped using a baited drop or cannon net during February 1984 and January 1985. Captured ewes of breeding age were equipped with radio telemetry collars to facilitate observation during lambing and the lamb rearing period. Blood was drawn from the jugular vein into 10 cc serum separator tubes (SST). Blood samples were centrifuged to separate serum and plasma, then frozen until delivery to the Animal Science Department at South Dakota State University, where the serum was assayed for progesterone concentration.

Radio-collared ewes were monitored throughout the 1984 and 1985 summers to verify which ewes produced lambs and the approximate date of lambing.

RESULTS

A total of 10 breeding age ewes were sampled and radio collared in 1984. Fifteen ewes were sampled and marked in 1985, 11 of which were equipped with radio collars. Trapping and sampling occurred 24-25 February 1984 and 18-21 January 1985.

Progesterone concentrations of 2.44 ng/ml (Gadsby et al. 1972) and 1.48 ng/ml (Weigl et al. 1975) have been proposed as threshold levels for pregnancy in domestic ewes and levels between 2 and 3 ng/ml for pregnancy in bighorn sheep

(Ramsey and Sadleir 1979). Progesterone levels were generally lower in CSP ewes (Table 1) than those measured by either Whitehead and McEwan (1980) or Ramsey and Sadleir (1979), who both found levels in excess of 10 ng/ml. Based on the low progesterone levels measured in CSP, the lower level proposed by Ramsey and Sadleir (1979) of 2.0 ng/ml was used as the threshold for predicting pregnancy.

In 1984, 8 ewes tested positive for pregnancy (1 ewe with a questionable level of 1.82 ng/ml). Two sheep tested negative with progesterone levels of 0.33 and 0.82 ng/ml. The 8 sheep predicted to be pregnant lambed on approximately the dates indicated in Table 1.

The date of conception was calculated by subtracting 174 days, the gestation period of bighorn sheep (Shackleton et al. 1984), from the estimated lambing date (Table 1). The ewe which had the lowest positive progesterone level lambed on 1 August, indicating she conceived approximately 16 days prior to sampling (Table 1). Lambing began in early June in 1983; therefore, a lamb produced in early August indicated late lambing and represented conception at the end of the breeding period.

In 1985 trapping occurred approximately 1 month earlier than in 1984. The progesterone levels were higher than in 1984, but were still lower than those measured by Whitehead

Table 1. Progesterone concentration for Custer State Park Bighorn sheep including approximate lambing date, calculated conception date, trapping date, and the number of days into gestation when sampled.

Ear Tag Number	Progest (ng/ml)	Lamb Date	Concept Date	Trap Date	Days of Gestation
			1984		
1	2.48 *	July 28	Feb 4	Feb 24	20
7	4.05 *	June 11	Dec 19	Feb 24	67
9	3.81 *	July 9	Jan 16	Feb 24	39
10	3.14 *	June 3	Dec 11	Feb 24	75
19	0.33	no lamb		Feb 24	
21	1.82 ?	Aug 1	Feb 8	Feb 24	16
23	2.35 *	June 24	Jan 1	Feb 24	54
51	3.94 *	July 1	Jan 8	Feb 25	48
63	6.91 *	June 13	Dec 21	Feb 25	66
73	0.85	no lamb		Feb 25	
			1985		
1	4.51 *	June 25	Jan 2	Jan 19	17
20	4.45 *	no lamb		Jan 19	
23	6.46 *	June 12	Dec 20	Jan 19	30
25	5.29 *	no lamb		Jan 20	
28	7.40 *	?		Jan 20	
31	1.34	no lamb		Jan 20	
45	4.79 *	June 10	Dec 18	Jan 19	32
48	5.93 *	June 15	Dec 23	Jan 19	27
50	6.32 *	lactating Aug 10		Jan 20	
56	7.32 *	?		Jan 20	
78	4.10 *	July 9	Jan 16	Jan 18	2
80	5.75 *	June 9	Dec 17	Jan 20	34
81	5.86 *	June 29	Jan 6	Jan 19	13
84	4.26 *	June 10	Dec 18	Jan 18	31
85	3.80 *	June 8	Dec 16	Jan 20	35

* indicates positive for pregnancy

and McEwan (1980) and Ramsey and Sadleir (1979). Again using the 2.0 ng/ml threshold for pregnancy, 14 of the 15 ewes sampled indicated pregnancy (Table 1).

Four of the 14 ewes predicted to be pregnant in 1985 failed to produce lambs. Breeding activity was apparent at the time sampling occurred and several of these ewes may have been estrous cycling and in breeding condition rather than pregnant. Lambing occurred during approximately the same time period in 1985 as in 1984, so breeding periods were similar. This, together with the calculated conception dates, indicates breeding was still in progress when sampling occurred in 1985.

DISCUSSION

Although several techniques have been used successfully in predicting pregnancy in wild animals, most present problems when applied to wild populations of bighorn sheep. Rectal palpation is not possible in this small a mammal. Laporatomy requires surgery and anesthetizing the animals. The possibility of complications and mortality exclude this technique from many studies of bighorn sheep. Ultrasound is very accurate, but only during the last trimester in sheep (Harper and Cohen 1985), a time when sheep are not easily baited to trap.

However, progesterone determination is possible very early in gestation when bighorn are easily baited and trapped. This is important in bighorn sheep which are susceptible to capture myopathy when immobilized with capture drugs (Dalton et al. 1978), a technique often necessary for capture of bighorn sheep in late gestation.

During female breeding receptivity and ovulation, the estrous cycle, several blood hormone levels increase. However, anestrous females do not show these increases. If conception occurs, some of these hormones remain elevated in the blood through pregnancy. Thornburn et al. (1969) demonstrated that during estrous cycling, progesterone levels increase to the same levels attained in early pregnancy. This elevated level then rapidly drops to almost zero if conception does not occur. Prediction of pregnancy in the domestic ewe is possible 16-20 days after mating (Bassett et al. 1969).

Accuracy in predicting pregnant and non-pregnant ewes in CSP was 100% in 1984. In 1984 no ewe conceived less than 16 days prior to sampling. However, 2 ewes conceived less than 16 days prior to sampling in 1985 and 1 ewe was apparently lactating on August 10, indicating conception occurred after the sampling period (Table 1). The elevated progesterone level of these 3 ewes was a reflection of estrous cycling and breeding condition, rather than pregnancy. Seven additional ewes were correctly predicted pregnant and lambed in 1985, and 1 was correctly predicted non-pregnant. Of the additional 4 ewes sampled in 1985, 2 (#28,#56) were rarely sighted during the summer and reliable field verification of lambing was not possible. These 2 ewes were not included. Two ewes misdiagnosed in 1985 (#20,#25) were predicted pregnant but failed to produce lambs. Since breeding was still in progress, their elevated progesterone levels apparently indicated estrus but not pregnancy.

This study has shown that the use of blood serum progesterone concentration can be used to predict pregnancy when sampling occurs at least 16 days past the conception date of the animal. Since the actual date of breeding of a specific ewe in a wild population is generally not available, sampling of the population should not be conducted until at least 16 days after the conclusion of all breeding activity. This will allow sampling by late February in most bighorn populations, when baiting and trapping of large numbers of animals is still possible. An early estimate of reproduction can then be obtained. Summer observation would then provide an estimate of both pre-natal and early post-natal mortality.

CHAPTER 3: SUMMER HABITAT USE BY BIGHORN EWES AND LAMBS

INTRODUCTION

The Black Hills and Badlands of South Dakota were traditional range for Audubon's bighorn sheep (*Ovis canadensis auduboni*), a subspecies extinct by 1916 (Buechner 1960). The present population of Rocky Mountain bighorn sheep (*O. c. canadensis*) was introduced to the Black Hills in Custer State Park (CSP), a 29,150 ha park, in 1964. The population had increased to 100-150 animals by 1975 (Trefethen 1975), but has failed to increase above this level with a population estimated at 120 animals at present.

Most studies on Rocky Mountain bighorn sheep report distinct summer and winter ranges with traditional migration routes. Migration is often an elevational shift, with the animals using alpine and subalpine zones until snow forces them to lower elevations in winter (Martin 1981, Erickson 1972). Deming (1964) and Bradley (1964) noted that seasonal shifts by bighorn sheep were to different plant communities. However, introduced bighorn sheep populations often fail to establish traditional migration patterns and remain restricted to the site of introduction (Geist 1971).

Several researchers have demonstrated the importance of steep, rocky terrain to bighorn sheep. Ewes and subadults preferred a steep and rocky terrain in the spring (Morgantini and Hudson 1981, Geist and Petocz 1977). Welch (1969) reported that lambs and ewes used only extremely rugged areas until the lambs were 2-3 months old. These areas provided increased protection from predators during lambing and lamb rearing (Irvine 1968).

Graham (1968) found that summer activity centers of bighorn sheep consisted of precipitous terrain with forage and water nearby. Hinkes (1978) reported that bighorn sheep stayed within 2 mi. (3.2 km) of water in the summer and that carrying capacity was determined by forage within this distance. Irvine (1968) also reported that sheep were dependent on water, remaining close to permanent water during dry periods, but utilizing their entire range during wet periods.

This study was designed to determine which specific habitats were selected by bighorn ewes and lambs in CSP during summer, based on observed use and proportional availability of these habitats to the sheep.

STUDY AREA

This study was conducted in CSP, which is situated in the southeast corner of the Black Hills of South Dakota (Fig. 1). Bighorn sheep are resident in the French Creek Natural Area, which is located in the central portion of the park. French Creek Natural Area encompasses French Creek Canyon, which is approximately 19 km long, 800 m wide, and ranges from 140 to 270 m in depth. French Creek Canyon represents a typical canyon in the southern Black Hills.

METHODS

Radio-telemetry was used to monitor bighorn sheep movements from early May through August, 1984. Bighorn sheep were baited with alfalfa hay and apple pomace, and trapped with a drop net (Schmidt et al. 1978). A total of 14 ewes were marked, 10 of which were equipped with color-coded radio-transmittered collars (Advanced Telemetry Systems Inc., Bethel, MN). Radio-collared ewes were tracked until visual verification of location could be established.

To insure random location sampling throughout the diurnal period, fixes were taken during 8, 2-hour time periods starting at 0500 h and ending at 2100 h. Telemetered sheep were assigned a number 0 through 9.

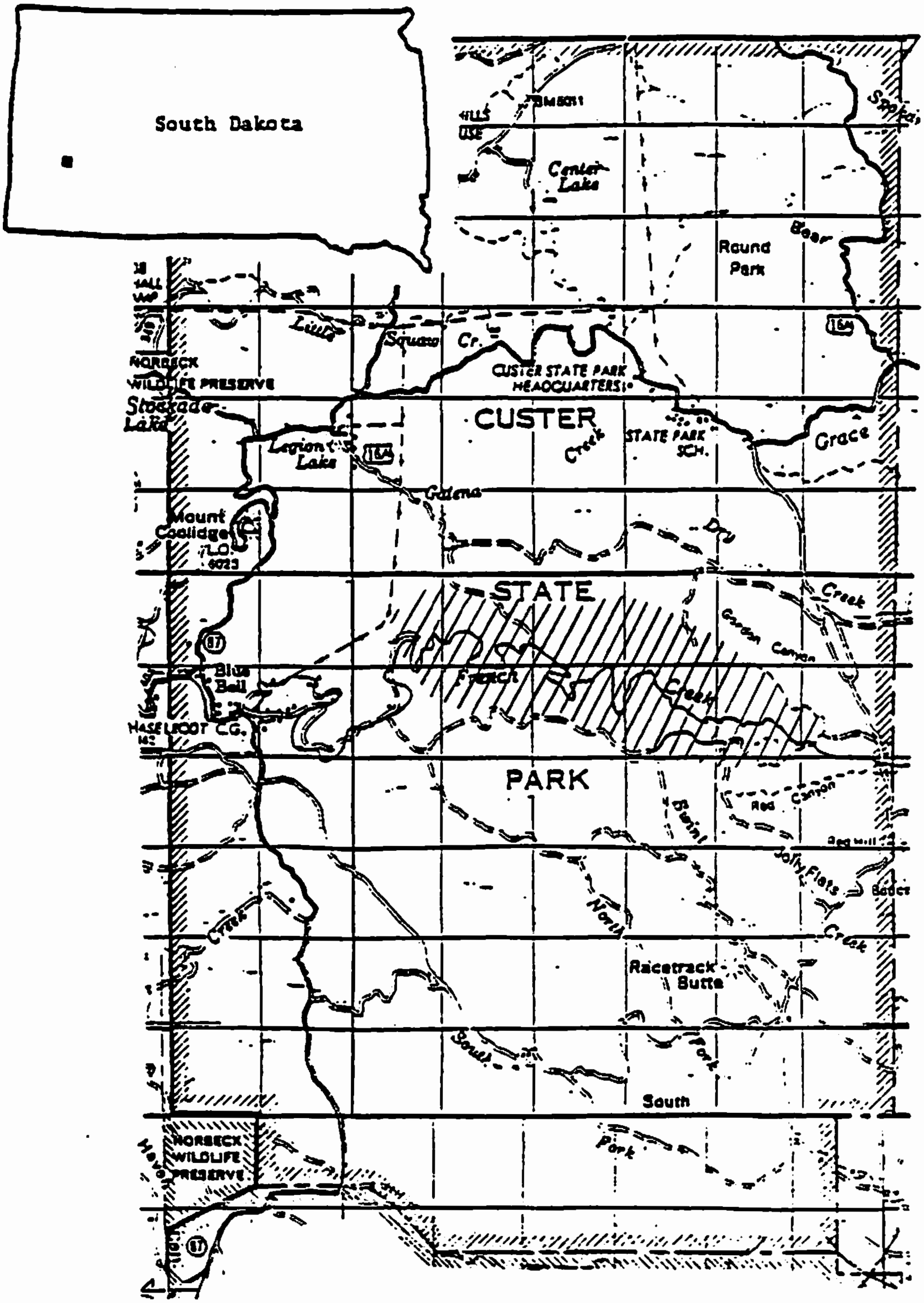


Figure 1. French Creek Canyon study area in Custer State Park, South Dakota.

Numbers were randomly selected for each of the 8 time periods and the corresponding sheep was located during that time frame. No sheep was located twice in the same time period until all sheep had been located in all time periods.

Information recorded during each observation included time, location (UTM longitude and latitude), percent slope, exposure, position on slope, distance to escape cover, and habitat type.

Habitat Sampling

Six habitat types, based on a combination of topography and vegetative cover were classified within the sheep range. These habitats were characterized as mixed grass-forb meadows with no overstory (mxgr/forb), riparian with several deciduous overstory species (ripr), ponderosa pine (*Pinus ponderosa*) stands with a grass-forb ground cover (pipo/grfb), steep rocky canyon sides with a grass-forb understory and a ponderosa pine overstory (stro/pipo), steep rocky canyon sides with a grass-forb understory but no overstory (stro/grfb), and dense stands of ponderosa pine (doghair).

Habitat understory characteristics were sampled using a 20cm X 50cm frame to define a sample plot (Daubenmire 1959). Four sites were randomly selected within each habitat type for placement of a 30 m transect which was aligned parallel to the contour within the habitat to be sampled. At 1.5 m intervals along the transect a random direction was selected (coin toss) and the plot was placed at 1 of 6 randomly chosen (die roll) increment marks spaced at 0.25 m intervals in the direction from the transect selected.

Overstory characteristics were sampled using 10, 0.01-ha sampling sites randomly located in each type. All trees greater than 2 m in height were counted and diameter at breast height (dbh) measured. Canopy cover was estimated from 4 readings of a spherical densiometer (Lemmon 1956, 1957) placed on the site center, 1 in each compass quarter. Horizontal obstruction was determined from 4 readings at 10 m of a density checker board, 1.5 m X 1.5 m, placed in the center of the site. One reading was taken from each compass direction.

Habitat Availability and Selection

To determine habitat availability, sheep locations were plotted and group home range was determined using the modified minimum polygon method (Harvey and Barbour 1965). The maximum distance sheep traveled between areas of use, as determined from plotted locations on a topographic map, was determined and used as the maximum distance between home range polygon perimeter points. This same distance was added around the home range perimeter, and habitats within were considered total available habitats (TAH). Habitat availability within the home range only was considered home range available habitat (HRAH).

Habitat availability within these areas was determined by stereoscopy using color photographs (1:24000 scale) and a point grid overlay. TAH and HRAH frequencies were recorded from 3,958 point observations.

Habitat selection and avoidance by bighorn sheep were calculated from the proportion of observations of sheep in each habitat and the proportional availability of each habitat type (Neu et al. 1974, Byers et al. 1984). Preference ratios were calculated from percent use and percent availability (Risenhoover and Bailey 1985).

RESULTS

Habitat

Habitat understories were analyzed using discriminant analysis of species composing at least 4% total cover in any 1 habitat. Understory vegetation of all types were different with the exception of the 2 steep, rocky habitats. Steep rocky habitats showed some overlap and had the same 2 dominant species, little bluestem (*Andropogon scoparius*) and side-oats grama (*Bouteloua curtipendula*)

(Table 1). However, stro/grfb had greater total ground cover than stro/pipo (32% vs 19%). In addition, these 2 habitats differed in overstory, 1 with a dominantly ponderosa pine overstory and the other without any overstory.

Overstory characteristics were analyzed using analysis of variance. Overstory characteristics were not significantly different (P<.05) in all habitats except doghair stands (Fig. 2). These doghair stands were composed of ponderosa pine trees with an average dbh of 7.5 cm and mean number of stems/ha of 14,340 as compared to average dbh of 19.9 cm to 23.4 cm and average stem densities of 840 to 880 stems/ha in all other types of overstories. Riparian habitat, although very similar to other habitats in overstory structural characteristics, was composed of deciduous trees with very few ponderosa pine trees encountered. All other overstories were composed almost exclusively of ponderosa pine. Burr oak (*Quercus macrocarpa*) was the only other tree species encountered in any habitat but riparian.

Doghair also showed a significantly (P<.05) greater canopy cover (74.3%) than any other habitat (40.2% to 56.6%). Horizontal density was significantly (P<.05) higher in doghair stands at 52.4% than the other habitats (18.3% to 23.0%)

Table 1. Percent ground cover composition in each of 6 habitats in Custer State Park bighorn sheep range (standard deviation).

Habitat type	Andropogon gerardi	Andropogon scoparius	Bouteloua curtipendula	Bouteloua gracilis	Poa species	Psorelea tenuflora	Rhus radicans	Scirpus atrovirens	Non-vegetation
Ponderosa pine/ grass forb	1.3 (1.4)	2.3 (3.0)	5.4 (5.1)	1.6 (1.9)	9.2 (6.9)	0	0	0	55.7 (13.2)
Steep rocky/ ponderosa pine	1.9 (1.7)	5.9 (4.5)	4.0 (3.9)	0	0	0.1 (0.2)	1.3 (1.8)	0	81.0 (5.3)
Steep rocky/ grass forb	3.5 (2.5)	9.3 (5.7)	7.4 (6.0)	1.6 (2.0)	0	0.1 (0.2)	0.5 (0.9)	0	67.9 (10.6)
Doghair	0	0	0	0	0	0	0	0	97.5 (0.0)
Riparian	0	0	0.2 (0.4)	0	1.8 (2.1)	0	14.1 (7.6)	16.3 (5.6)	24.8 (11.9)
Mixed grass/ forb	6.2 (2.8)	5.0 (5.4)	2.1 (4.0)	8.3 (8.2)	12.7 (5.3)	4.0 (5.4)	0	0	11.6 (10.4)

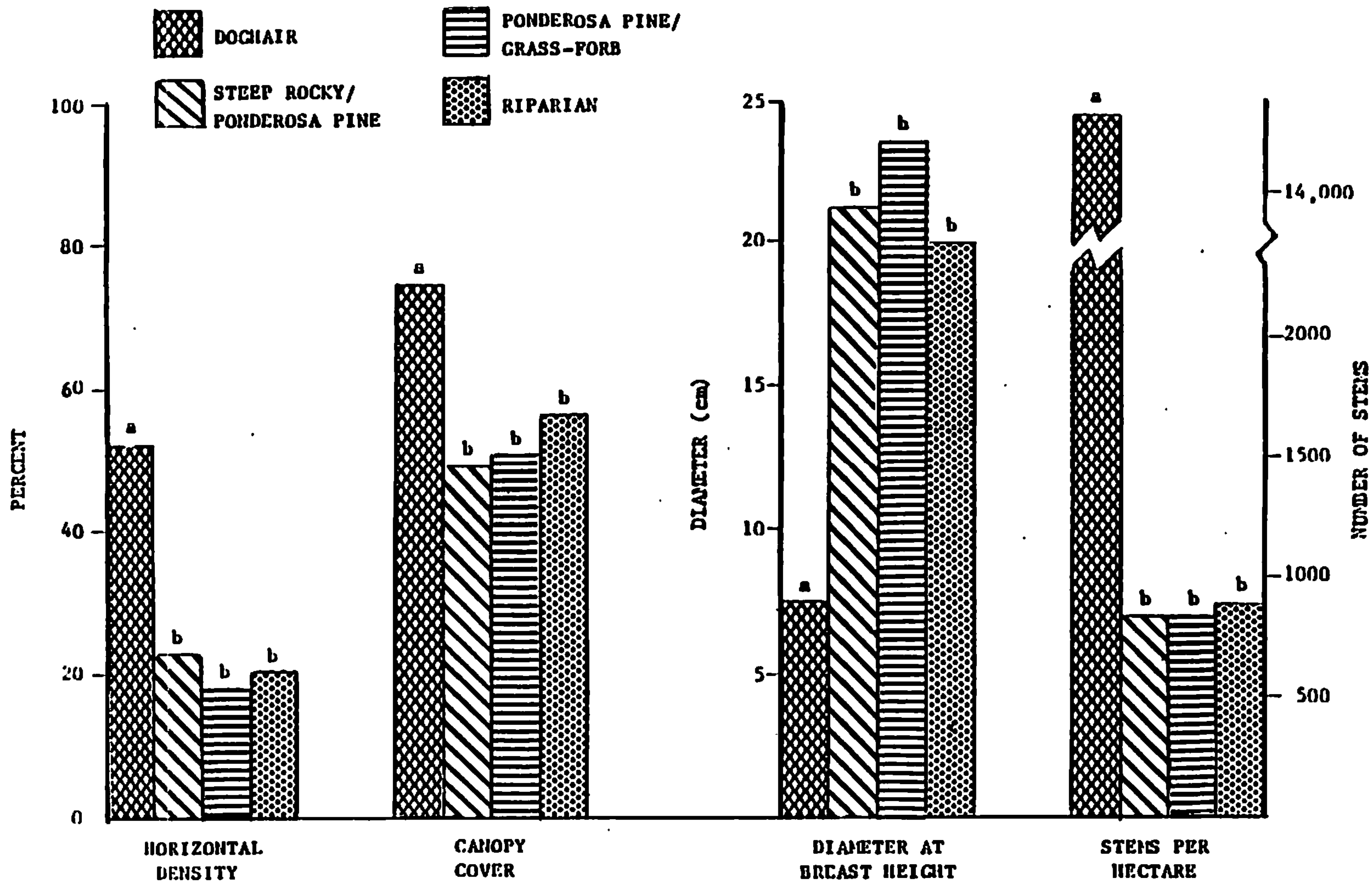


Figure 2. Characteristics of habitat overstories in Custer State Park bighorn sheep range (characteristics with the same letter are not significantly different P<.05).

To ascertain whether HRAH was characteristic of TAH, proportions of habitats within home range were tested against proportions of habitats overall using contingency table analysis. HRAH was significantly different from TAH (X^2=133.14, df=5, p<.001). The most available habitat, pipo/grfb, occurred less than expected in the home range (Table 2). Other habitats which occurred less than expected in the home range were doghair and mxgr/forb. However, both steep rocky habitats and ripr habitat were more abundant than expected within the home range.

Habitat Selection

Bighorn sheep used habitats in different proportions than TAH (X^2=16.7, df=5, p<.01). Sheep selected stro/pipo and avoided doghair and pipo/grfb (Table 3). Other habitats were used in proportion to their availability. Selection of HRAH was similar to selection of TAH. However, bighorn sheep used pipo/grfb in proportion to its availability within HRAH. The sheep still selected stro/pipo but used stro/grfb slightly less than available within HRAH.

Bighorn sheep were never located farther than 80 m from escape terrain (greater than 100% slope with large rock outcrops). Locations occurred on an average slope of 57%. Almost half (44%) of the observations of sheep were on the middle third of the slope and only 27% were off the slope

Table 2. Availability of 6 habitats within the modified minimum home range compared with total habitat availability.

Habitat Type	Total Availability	H. R. Availability	
Ponderosa pine/ grass forb	39.4%	30.8%	*
Steep rocky/ ponderosa pine	20.1%	34.2%	*
Steep rocky/ grass forb	4.0%	8.7%	*
Doghair	23.2%	17.6%	*
Riparian	2.2%	3.8%	*
Mixed grass/ forb	11.2%	4.8%	*

* indicates significant at $P<.05$

Table 3. Habitat selection by Custer State Park bighorn ewe-lamb groups, May-August 1984.

Habitat Type	Proportion availability (total)	Proportion availability (home range)	Proportion observations (p_i)	Preference ratio*	Confidence interval for proportion of use p_i
Ponderosa pine/ grass forb	.394	.308	.273	0.69	$.174 \le p_1 \le .371$ [a]
Steep rocky/ ponderosa pine	.201	.342	.545	2.75	$.443 \le p_2 \le .662$ [ab]
Steep rocky/ grass forb	.040	.087	.042	1.06	$0 \le p_3 \le .086$ [b]
Doghair	.232	.176	.000	0.00	$0 \le p_4 \le 0$ [ab]
Riparian	.022	.038	.042	1.95	$0 \le p_5 \le .086$
Mixed grass/ forb	.112	.048	.091	0.81	$.027 \le p_6 \le .154$

* preference ratio=use divided by total availability

[a] indicates significantly different use than total availability at $P<.05$

[b] indicates significantly different use than home range availability at $P<.05$

on top or bottom. No sheep was ever located farther than 1 km from water. Over 90% of the locations were within 0.5 km of water.

DISCUSSION

Risenhoover (1981, in Risenhoover and Bailey 1985) reported that bighorn sheep avoided areas with tall, dense vegetation but would use these areas when visibility was increased through thinning. Peek et al. (1979) and Riggs and Peek (1980) also reported that bighorn sheep will move into ranges that were recently burned to clear vegetation. Once a threshold of visibility has been exceeded, forage density becomes more important in determining habitat selection (Risenhoover and Bailey 1985). This is the case in CSP. There was a slight negative correlation (r=-0.46) between preference ratio and horizontal density. Sheep used areas with horizontal densities less than 25%, but totally avoided doghair with a horizontal density of over 50%.

MacArthur et al. (1979, 1982) have reported that heart rates increase when sheep enter forested areas with reduced visibility. Heart rate is a sensitive indicator of arousal, the first stage of an alarm reaction to stress (Jenkins and Kruger 1975). The added cost of excessive arousal may interfere with health, growth, and reproductive fitness (Geist 1979). Sheep in CSP may avoid doghair stands because of the stress involved and the very limited forage available.

Foraging efficiency of bighorn sheep was negatively associated to distance from escape cover and positively associated to habitat visibility (Risenhoover and Bailey 1985). Bighorn ewes and lambs in CSP have restricted their activity to steep, rugged canyons with permanent water supplies. Forage density was higher in some habitats available than the stro/pipo selected by the sheep. However, this study was concerned with ewes and lambs during lambing and lamb rearing. The added security of close proximity to escape terrain and its associated reduction in heart rate (MacArthur et al. 1982), together with an acceptable forage density and close proximity to water in this habitat could have led to this selection.

Habitat selection is related to the home range, which is determined the movements of an animal or group of animals. Thus, home range must reflect habitat use. This is indicated by the differences in availability of habitats within the home range of the sheep compared to the total habitat availability.

Selection for stro/pipo and the close proximity to both water and escape terrain indicated that CSP bighorn ewes and lambs required rugged slopes or canyons near permanent water supplies. The forage available within these areas determine the carrying capacity of that particular range.

Doghair stands in these areas should be thinned or burned. Clearing these areas would increase available range to the sheep by opening areas which would otherwise remain unused. Carrying capacity would also be increased due to increased forage production stimulated by opening the canopy.

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