Evaluation of habitat use by a transplanted bighorn sheep herd in Theodore Roosevelt National Park
by Stephen Thomas Lewis

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University
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Abstract:
Nineteen radio-collared California bighorn sheep (14 ewes/5 rams) were transplanted from British Columbia, Canada to the North Unit of Theodore Roosevelt National Park on 26 January 1996 and monitored over the course of a 2-year ecological study of bighorn sheep habitat use. Since their introduction, the transplanted animals have slowly increased their range inside and outside the park boundaries. Actual habitat use was compared to habitat use predicted by a habitat suitability model (Smith et al. 1991). Field observations during the 2-year study generally validated this model suggesting that it could be a useful tool for bighorn sheep management. Sheep activities were focused in the Agronvron smithii-Stipa comata and Artemisia tridentata-Atriplex confertifolia habitat types. Vegetation analysis suggests utilization of areas used by sheep averaged. 54% before the study animals moved to other feeding sites. Plant species composition at feeding sites was highly variable. The physiographic type most frequently used by the sheep was the River Breaks. Feeding was heaviest during the mid-morning and late evening hours for most sampling seasons. Bighorn sheep interactions with other ungulate species and predators were frequent and rare, respectively. Sheep generally habituated to the presence of humans. Two sheep occupied areas grazed by cattle. Only 2 sheep occupied ranges near oil development areas.

EVALUATION OF HABITAT USE BY A TRANSPLANTED BIGHORN SHEEP HERD IN THEODORE ROOSEVELT NATIONAL PARK

by

Stephen Thomas Lewis

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APPROVAL

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Stephen Thomas Lewis

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Nineteen radio-collared California bighorn sheep (14 ewes/5 rams) were transplanted from British Columbia, Canada to the North Unit of Theodore Roosevelt National Park on 26 January 1996 and monitored over the course of a 2-year ecological study of bighorn sheep habitat use. Since their introduction, the transplanted animals have slowly increased their range inside and outside the park boundaries. Actual habitat use was compared to habitat use predicted by a habitat suitability model (Smith et al. 1991). Field observations during the 2-year study generally validated this model suggesting that it could be a useful tool for bighorn sheep management. Sheep activities were focused in the Agropyron smithii-Stipa comata and Artemisia tridentata-Atriplex confertifolia habitat types. Vegetation analysis suggests utilization of areas used by sheep averaged 54% before the study animals moved to other feeding sites. Plant species composition at feeding sites was highly variable. The physiographic type most frequently used by the sheep was the River Breaks. Feeding was heaviest during the mid-morning and late evening hours for most sampling seasons. Bighorn sheep interactions with other ungulate species and predators were frequent and rare, respectively. Sheep generally habituated to the presence of humans. Two sheep occupied areas grazed by cattle. Only 2 sheep occupied ranges near oil development areas.

INTRODUCTION

Audubon bighorn sheep (Ovis canadensis auduboni) were widespread and thriving along the Little Missouri River breaks of North Dakota in the early 19th century. Overhunting, improper land management practices, and introduced diseases extirpated most populations in the state by the end of the 1800's (Buechner 1960, Lawson and Johnson 1982, Dunbar 1992). The Killdeer Mountains, located in the western portion of North Dakota, were the home of the last documented Audubon bighorn which was killed in 1905 (Buechner 1960). A series of bighorn sheep transplants were initiated during the early 1950s to restore sheep populations to the Little Missouri Breaks but have resulted in limited success. Two subspecies of bighorn sheep, Rocky Mountain (O. c. canadensis) and California (O. c. californiana), have been released in North Dakota. Releases involving the California subspecies have been the most successful, and 200-300 individuals currently are present in various herds located along the Little Missouri River of western North Dakota. However, continued transplant efforts may be needed to maintain sheep populations at viable levels (Roy and Irby 1994).

Two of the most important management goals for Theodore Roosevelt National Park (TRNP) are the reintroduction of extirpated species and management of resident species (Andrascik 1996). California bighorn sheep were transplanted into the South Unit of TRNP during the 1960's and 1970's, but the transplants were considered unsuccessful due to poor recruitment (Sayer 1996, Lawson and Johnson 1982). One sheep that originated from a North Dakota Game and Fish Department transplant (Lone

Butte herd) was resident in the North Unit of TRNP at the beginning of this study. California bighorn sheep (14 ewes and 5 rams) were released into the North Unit in January of 1996. A 2-year ecological study of this transplanted herd was initiated in 1996 to evaluate this transplant.

Many biologists perceive sheep as responding poorly to management strategies that have worked successfully in reintroduction of deer (Odocoileus hemionus and virginianus) and elk (Cervus elaphus) into former habitat (Jensen 1988 and1992). Release of elk and deer in adequate habitat (as defined by field biologists) and reasonable protection from excess harvest have produced a large number of successful, expanding populations. These populations may decline following periods of overharvest or unfavorable weather or forage conditions, but they seem to respond quickly and positively when favorable conditions return (Jensen 1988). If these differences in response to management are true, they are likely related to high habitat specificity and the social organization of sheep (Geist 1971, Roy and Irby 1994). Preferred habitat for bighorn sheep can be simplistically defined as open grassland associated with steep terrain (Lawson and Johnson 1982). This type of habitat is apparently more limited, more fragmented, and/or more susceptible to changes imposed by human land use patterns than that preferred by native cervids (Geist 1971). The gregariousness of bighorns concentrates them in habitat islands and may discourage colonization (Geist 1971). Living in herds may increase the potential for local over utilization of forage and the impacts of epizootics when pathogens enter a population. This could be especially evident if behavioral patterns encourage animals to remain in a habitat island long enough to

reduce food quality to the extent that individual physical condition of animals declines and compromises immune responses (Forrester 1971, Stelfox 1976, Dunbar 1992).

Additional factors could also play a crucial role in the dynamics of bighorn sheep populations. Domestic livestock, other native ungulates, and the systems under which they are managed can result in major impacts on bighorn sheep. Disease transmission from domestic animals (especially domestic sheep) to bighorn sheep has been reported and may be a major factor in bighorn survival in some areas (Goodson 1982). Forage competition between bighorns and other ungulates has frequently been cited as a possible reason for herd declines (Buechner 1960, Picton and Picton 1975, Stelfox 1976).

Utilization of forage by other ungulates could also operate indirectly. Grazing-induced declines in forage quality could decrease bighorn productivity and/or resistance to mortality factors as diverse as parasites, predators, and abnormal weather conditions (Dunbar 1992). Human land management systems which promote long term overuse of vegetation, long term fire suppression, and changes in predator mixes can make preferred habitat less desirable for sheep or more desirable for other ungulate species (Etchberger et al. 1989). These changes would reduce the carrying capacity for bighorns or force them to seek food in less desirable habitats.

Other ungulate species and associated management activities could also have beneficial impacts. Predator control could reduce bighorn losses as well as losses to livestock. Grazing by elk and cattle may increase forage quality in grasses or convert vegetation to seral communities more desirable to sheep (Coughenour 1991; Frank and McNaughton 1992; Wamboldt, unpublished). Intentional and unintentional fires set by

humans can eliminate tree cover and open habitat for sheep as effectively as wild fires. Parasite and disease control efforts on behalf of livestock may reduce the incidence of parasites and diseases in bighorns (Hobbs 1996).

The release of California bighorn sheep in the North Unit of TRNP provided an opportunity not only to restore a native species but to use the introduction to test a habitat suitability model developed by Smith et al. (1991) and modified by Gudorf (1994) for TRNP. This habitat model is unique in that it was designed specifically for the California bighorn sheep species in a Badlands type of habitat. It also incorporates a process of elimination, where land area is systematically removed from consideration if it does not meet specific habitat constraints. These types of models appear to be very useful in predicting suitable habitat for various animal species (Verner, et al.1984). Mosher et al. (1984) and Lancia et al. (1981, 1982) showed that "habitat suitability" can be predicted on an acceptable level for raptor and mammal species, respectively. Smith and Flinders (1992) have also demonstrated that habitat evaluation methodology and GIS technology can be used effectively in determining optimum habitat for bighorn sheep where minimum viable populations are a necessity. However, Laymon and Barrett (1986) explain that Habitat Suitability Indexes (HSI) lend no credible support to habitat management without sound research management involving clear objectives.

Comparison of actual sheep use of habitat in the North Unit of TRNP with the predictions of the modified Smith et al. (1991) model was used to determine how well we, as biologists, can identify sheep habitat at the landscape level. The Smith et al. (1991) habitat model represents one of the more systematic strategies to defining

suitability of release sites and the potential for a population to occupy habitat at a landscape level that is currently available. Modifications of the model suggested by Gudorf (1994) and ground surveys were incorporated into maps predicting suitable habitat in the North Unit of TRNP on the basis of evaluations presented by Gudorf (1994) and Sweanor et al. (1994). Close monitoring of released sheep allowed me to determine the fit of this map to habitat choices actually made by sheep in the North Unit of TRNP and thus refine habitat assessment procedures.

The transplant also enabled me to learn more about how sheep make habitat use decisions in a new environment. If they are to be successful, translocated sheep must: 1) locate adequate forage, water sources, and escape terrain; 2) successfully produce lambs and recruit individuals to reproductively active age classes; 3) reach population levels that minimize small population demographic effects and stochastic catastrophes; and 4) pioneer new habitat as populations increase to minimize overutilization of preferred sites and exposure to pathogens.

Several objectives were addressed in this study. These can be broken down into two categories:

1.) Test the fit of the modified Smith et al. (1991) habitat suitability model by examining critical variables such as escape terrain, horizontal visibility, water sources, natural barriers and land management constraints (i.e human-use areas).

2.) Describe bighorn sheep seasonal habitat use, movement patterns, food habits and interactions with other animal species during the first two years following the release.

STUDY AREA

Geology

The 3,494 km² study area was located in McKenzie and Billings counties of western North Dakota. The North and South Units, and the historic Elkhorn Ranch of TRNP, and portions of the Little Missouri National Grasslands are included in this area (Figure 1). The changing course of the Little Missouri, which bisects the study area, has shaped the Badlands topography over geologic time through erosion of sedimentary rock present in the Great Plains upland prairie. Highly erosive siltstones, bentonite clay, shale, and sandstone along with less erosive caprocks of lignite and scoria contribute to the complex landforms of the study area. Badlands topography occurs from 19-32 km on both sides of the current course of the Little Missouri River. Elevations in the study area vary from 600 m to 1,050 m.

Vegetation

A large portion of the Badlands consists of mixed-grass prairie situated on the flat tops of plateaus and buttes. The prairie regions support a wide array of grass species including western wheatgrass (Agropyron smithii), needle grasses (Stipa comata., Stipa viridula), blue grama (Bouteloua gracilis), and big bluestem (Andropogon scoparius). The rugged topography of the area has created several microhabitats where juniper (Juniperus scopularum and J. horizontalis), ash (Fraxinus pennsylanica), and aspen (Populus tremuloides) stands occur in coulees and along moderate slopes ranging from 15-40%. Silver sage (Artemisia cana) and big sagebrush (A. tridentata) are the predominate species in shrublands.

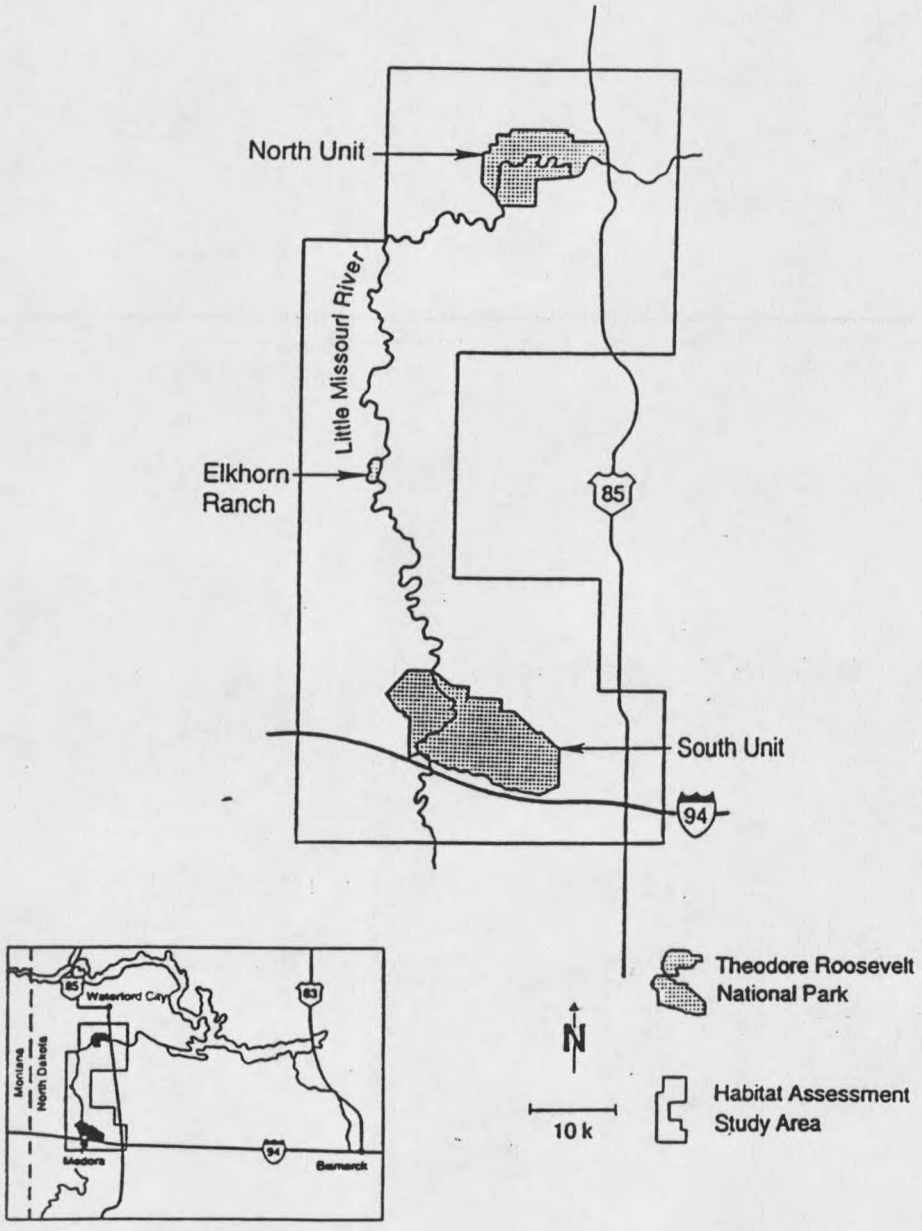


Figure 1. The study area included the North and South Units of the Theodore Roosevelt National Park and a portion of the Little Missouri National Grasslands that surround the park. The study animals dispersed throughout the designated habitat assessment area.

Climate

The climate in western North Dakota is continental in that the winters are typically long and harsh while the summers are brief in duration and hot. Annual precipitation averages 35.5 cm. July and January are usually the warmest and coldest months of the year, respectively. The average temperature is 30 C for the former and -18 C for the latter. Snow fall ranges from 23 cm to 28 cm (Jensen 1972).

Landuse

The study area consists of a matrix of private, National Park Service, Bureau of Land Management, Forest Service, and state land ownership. The North Unit, Elkhorn Ranch Historic Site, and South Unit of the Theodore Roosevelt National Park are relatively undisturbed areas with the exception of visitor support facilities. Oil and gas development has become a very important source of economic income in the Little Missouri River Grasslands. The study area is situated within the Williston Basin, which is one of the most productive basins for oil and gas development in the United States. This area encompasses a majority of western North Dakota, northwest South Dakota, eastern Montana, and southern Saskatchewan, Canada. TRNP and Little Missouri National Grasslands include abundant oil and gas reserves. The number of active oil wells in the Little Missouri National Grasslands is increasing and encroaching on potential bighorn sheep habitat. Presently, there are approximately 1,500 functional wells in this region (excluding North Unit, South Unit, and Elkhorn Ranch of TRNP) while several hundred wells are in the planning stages and will likely be drilled within the next 10 years.

Oil and gas extraction and livestock grazing have been the dominant land use practices in the study area outside TRNP. Recreational activities include hunting, hiking, scenic viewing, horseback riding, mountain biking, and snowmobiling. Sport hunting, along with scenic viewing, account for the greatest proportion of Recreation Visitor Days (USFS 1995).

Associated Animal Species

Domestic cattle, mule deer (Odocoileus hemionus), white-tailed deer (O. virginianus), antelope (Antilocarpa americana), and occasional elk (Cervus elaphus) occurred within the range of the transplanted bighorn sheep herd. Potential predators of sheep included the coyote (Canis latrans), bobcat (Felis rufus), and golden eagle (Aquila chrysaetos).

METHODS

Capture and Transplant of Study Animals

Nineteen California bighorn sheep, 14 adult females and 5 adult rams, were captured with the use of helicopters and netguns in Kamloops, British Columbia during late January of 1996. Eighteen of these sheep were fitted with radio-collars. One collar malfunctioned; therefore, 1 ewe in the transplanted herd was not equipped with a collar. All individuals were marked with numbered ear tags. Sheep were taken from 4 different herds near the Fraser and South Thompson Rivers. The sheep were transported via horsetrailer from British Columbia to the North Unit of TRNP where they were released on 31 January 1996. One ewe died from capture myopathy during the trip from British Columbia to the North Unit of TRNP.

Sheep Observation

Each radio-collared bighorn sheep was located and observed at 2-3 day intervals with the aide of a Lotek telemetry receiver (Kamloops, British Columbia) and directional H-antenna. Observation schedules for individual sheep were randomized and divided into 3 categories, early morning (sunrise-1100 hours), mid-day (1100 hours to 1600 hours), and evening (1600 hours to sunset). The point locations were plotted on United States Geological Survey (U.S.G.S.) 1:24,000 topographic maps to the nearest 20 m using the Universal Transverse Mercator (UTM) grid system. The data used to test the Smith et al. (1991) model were limited to visual observations of the animals from the ground and aerial locations. Triangulation techniques were not used to pinpoint precise locations

of the study animals because significant errors can be frequently attributed to signal bouncing caused by the topographic features of the terrain in the Badlands within the North Unit and surrounding areas (Jensen 1988, Fox 1989, Wollenburg 1990). Aerial locations were limited to instances when the sheep could not be located on the ground due to movements of the animals. UTM coordinates of animals located from the air were identified using the Loran/GPS navigation instrumentation.

Habitat configurations used by individual study animals were noted, and use was compared with availability for locations within TRNP. Availability was determined from GIS layers created for the habitat suitability model (Smith et al.1991).

Home Range Analysis

Home ranges for the study animals were determined by entering UTM coordinates into the CalHome home range software package (Kie 1986). Home ranges were calculated for ewes and rams inside the study area as well as the Burnt Creek drainage where rams from the transplanted herd intermingled with rams from other herds during the summers of 1996 and 1997. The 95% minimum convex polygon (MCP) and adaptive kernel methods were used to calculate home ranges. Mann-Whitney U-tests (Sokal and Rohlf 1995) were used to determine if differences existed in home range sizes on a seasonal basis. Ewes 1,4, 8, 13, and 14 were excluded from home range analysis due to small point location sample size as a result of mortality or lack of access to observation areas. Rams 18 and 19 were also excluded from this analysis since the radio-collar malfunctioned on ram 18 and ram 19 died due to complications from liver disease.

Test of the Modified Smith et al. (1991) Model Predictions and Habitat Use

Parameters considered in the Smith et al. (1991) model include geophysical, biological, and human management constraints on the availability of optimum bighorn sheep habitat. The values for these parameters were collected from field observations; historical records; aerial photos; USGS digital elevation models (DEMs); USGS land use and cover maps; USGS topographical maps; GeoResearch Inc. oil and gas well development maps, and U.S. Forest Service, private, and federal land use and development maps. Geophysical , biological, and human management variables were then incorporated in a system of GIS layers which identified spatially explicit areas with suitable year-round habitat, escape terrain, summer habitat, winter habitat, and lambing habitat (Figure 2, Appendix A: Table 11 and 12, Appendix B: Figures 7,8,9, and 10). Data I collected from point locations of sheep allowed me to compare actual use by sheep with the areas the model predicted sheep would use for each respective GIS layer. Point locations were evenly distributed among the study animals on a seasonal basis. Variation from predicted use patterns was used as an index of model validity and to identify changes in the model that would improve it. A test of proportions (Devore and Peck 1986) was used to detect significant differences for point locations that were classified as within 25m of the designated GIS habitat layer and greater than 25m away from the designated GIS habitat layer. These locations were then compared with expected availability for each GIS layer in the entire study area. Additional data were not available to conduct more intensive analysis of point locations.

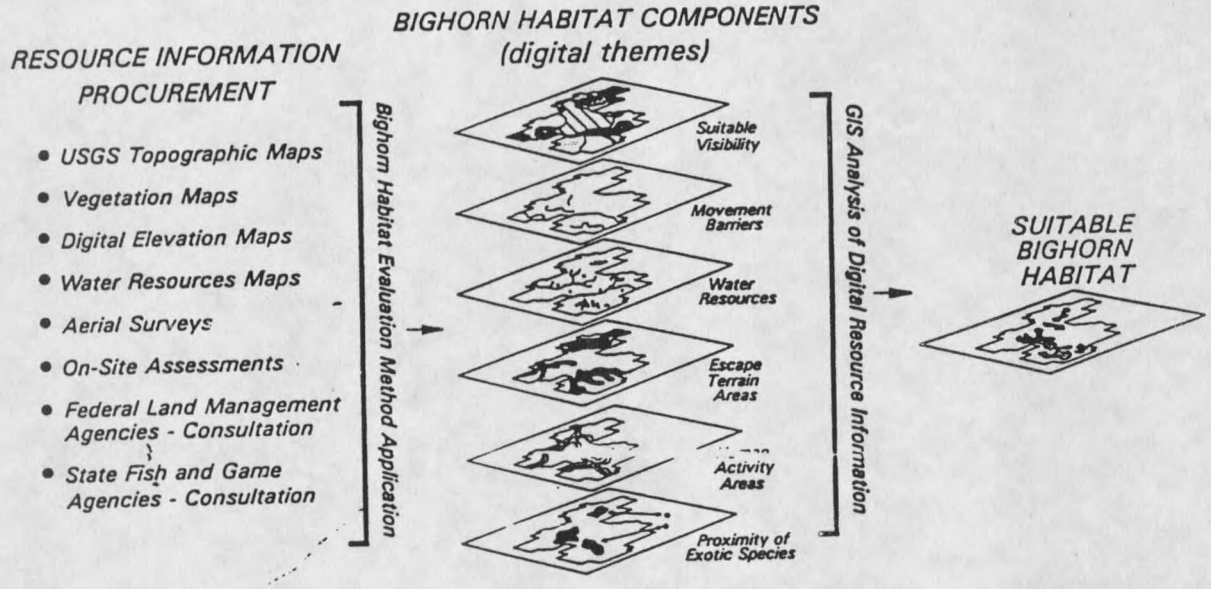


Figure 2. The habitat evaluation process for the GIS habitat suitability model (Smith et al. 1991).

The GIS model was based on very broad vegetative cover and topographic features. I also tested finer habitat classification systems to determine if sheep were selecting at medium scales. Locations in TRNP were identified by habitat types and physiographic types (Marlow et al. 1984). Use versus availability analyses (Neu et al. 1974 and Devore and Peck 1986) were used to differentiate between observed and expected habitat use. Rams and ewes were tested separately. Types used in greater than expected proportions relative to availability were considered "preferred." Those used in less than expected proportions relative to availability were classified as "avoided."

Vegetation Analysis

I examined habitat use at smaller scales by comparing vegetation characteristics at heavily used sites with characteristics at similar non-used sites. Small-scale vegetation measurements (species composition, percent grazed, vegetation coverage, and mean vegetation height) were made during May-August of 1996 and 1997 using Daubenmire plots (Daubenmire 1959). "Percent grazed" was defined as the number of grass, forb, or shrub plants that showed signs of "clippage" by the sheep divided by the total number of grass, forb, or shrub plants within the Daubenmire plot. Vegetation coverage was the amount of canopy area (%) that vegetative matter occupied within each Daubenmire plot. A mean measure of vegetation height for each Daubenmire plot was calculated from 6 height measurements taken in each Daubenmire plot. Eleven paired sites were selected.

Use sites were defined as areas of a single habitat type containing at least 40 point locations of the study animals while non-use sites (sites with no observed use by sheep)

were paired with use sites on the basis of similar habitats. Rugged topography and/or species-specific differences in habitat selection limited access of other ungulate species to these sites. Within the 11 paired areas I identified, data were collected from 20 Daubenmire plots in each use and 20 in each non-use site for a total of 440 plots (220 use versus 220 non-use). Each Daubenmire frame was placed along a transect in an alternating left/right fashion at 0.6 m intervals. Sampling was limited to ground stratum vegetation. Paired t-tests were used to determine significant differences between percent grazed and percentage of vegetative cover on the respective use and non-use sites

Behavior

Bighorn rams and ewes were located and observed with 10 x binoculars or a 15 to 45 x spotting scope. During each bighorn observation, point locations (UTM's) were estimated, the behavior (feeding, resting, running, and rutting behavior) of the focal animal described, and group size and behavior were recorded for a 10-min interval during each observation. The focal animal was defined as a bighorn sheep from the transplanted herd which was randomly selected for observation. Distance to escape terrain as defined by the Smith et al. (1991) model, distance to forested cover, habitat type, interaction with other animal species (i.e. predators or other ungulate species), distance away from human development areas (i.e. oil development and ranching activities), and distance travelled during the 10-min time period were collected during each sheep observation period. One-way analysis of variance (ANOVA)(Sokal and Rohlf 1995) was used to determine significance or lack of significance for distance travelled by study animals situated in

groups of 3 animals or less versus groups of animals greater than 3 during the 10-min interval for each independent observation. This test was used to determine if group size influenced feeding behavior and movement patterns in TRNP as it did in Colorado (Goodson and Bailey 1990). A Friedman's test for a randomized block design (Devore and Peck 1986) was used to detect seasonal and behavioral differences in habitat type use and physiographic type use. This type of analysis was used to detect differences in behavior patterns between rams and ewes in the respective habitat types and physiographic types. Observations of rams and ewes were also combined to display overall differences in habitat use.

RESULTS

Movements and Distribution

During the 2 years following the introduction of 14 ewes and 5 rams into the North Unit of TRNP in January 1996, bighorn sheep slowly increased their range inside and outside the Park boundaries (Table 1). Home range analysis failed to uncover significant seasonal differences in home range size ($z=1.28$, $p>0.05$). Eleven of the sheep stayed near the release site in the western portion of the Park. This area is considered to be some of the best habitat within the North Unit according to the GIS model (Smith et al. 1991). Other sheep dispersed distances ranging from 1.6 to 24 km away from the release site within the first 2 weeks after the transplant (Figure 3). Dispersal in and out of the Park was aided by wildlife walk-unders that are present every ~2 km of Park fence and various openings in the fence that are created by topography. Dispersal occurred along several portions of the boundary. Some of the dispersing animals passed through habitat designated as suitable by the GIS model (Smith et al. 1991) before settling into discrete areas.

All transplanted rams separated from the ewes during June through September of both years of this study. Ewe groups tended to disband in April-June of 1996 and 1997 as ewes sought isolated sites for lambing. Rams from the transplanted herd migrated seasonally from the North Unit to summering grounds outside TRNP in early July 1996 and again in May of 1997 where they joined ram and ewe bands that were introduced into these areas by the North Dakota Fish and Game Department. Transplanted rams returned to the Park in late October during 1996 and 1997 during the rut. Intermingling

of the transplanted sheep with sheep from adjacent herds was frequent during the summer months during both years of this study.

Table 1. Home range estimates (hectares) for transplanted herd using the Adaptive Kernel (AK) method and Minimum Convex Polygon (MCP) method during the 1996 and 1997 field seasons.

Sheep Frequency	Sex	Field Sampling Season[a] 1		2		3		4	
		MCP	AK	MCP	AK	MCP	AK	MCP	AK
164.463	ewe	23	19	33	14				
164.512	ewe	21	13	24	15	14	32	24	51
164.537	ewe	43	14	14	18	102	18		
164.612	ewe	15	13	21	11	101	13	21	14
164.637	ewe	17	12	90	21	51	22	12	14
Ewe #7	ewe			30	11	17	31	42	33
164.712	ewe	13	16	62	52	14	23	56	21
166.737	ewe	165	30	61	21	18	41	83	54
166.762	ewe	25	41	73	18	21	31	40	72
166.788	ewe	41	23	24	17	11	42	47	23
167.162	ewe	19	42	20	51	10	54	44	70
164.437	ram	17	18	33	50	23	51	62	39
164.487	ram	10	15	78	39	187	11	18	33
166.887	ram	16	98	72	37	187	11	33	53

[a]1=late winter/spring 1996 (26 January to 31 May);2=summer 1996 (1 June to 31 August);3=winter 1996 (1 September to 31 December);4=summer 1997 (4 May to 31 August)

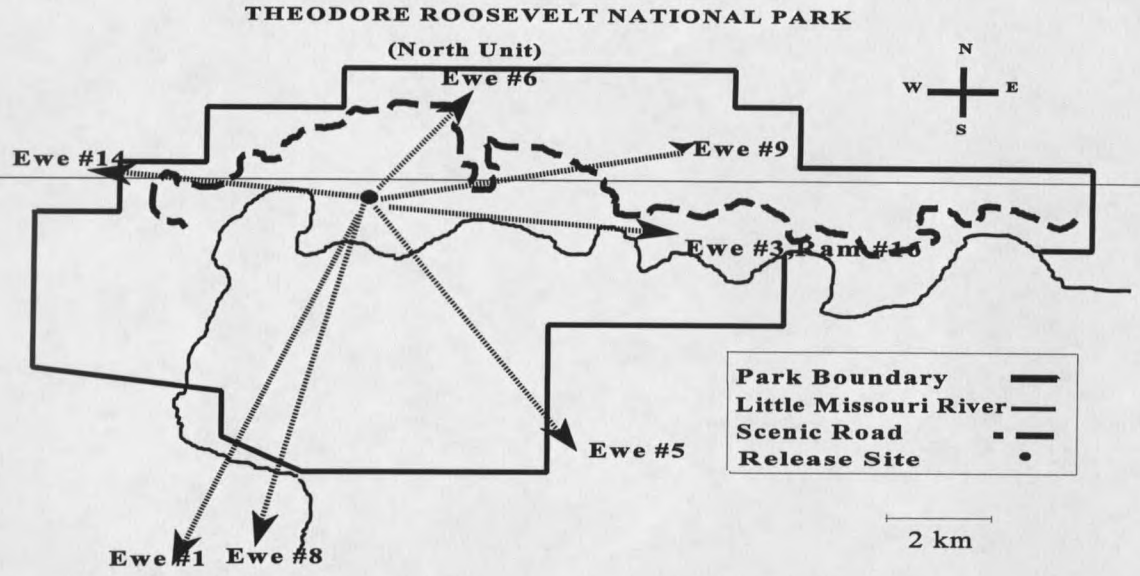


Figure 3. Dispersal of study animals that did not stay within close proximity of the release site for California bighorn sheep in North Unit of Theodore Roosevelt National Park (January 1996).

Efficacy of Smith et al. 1991 Model (Large Scale Selection)

The GIS model was tested against the observed distribution (n=975 point locations) of 19 bighorn sheep. Three of the study animals (rams #16,17, and 20) were excluded from part of this analysis because they migrated from the study area for a portion of both 1996 and 1997. Separate proportion tests were conducted on each layer in the model (lambing habitat, escape terrain, basic suitable habitat, summer habitat, and winter habitat).

The model identified 2.4 km² of steep terrain near water as suitable lambing habitat (LH). Lambing habitat represented 1% of the entire study area. Utilization of these areas by ewes with or without lambs during lambing season (April 15 to June 30)

was low during this time period in 1996. Only 22% of the observations were within 25 m of GIS-designated lambing areas. During the next lambing season (April 15 to June 1997), the proportion of observations within 25 m of lambing habitat increased to 49%. A test of proportions revealed significant differences during 1996 and 1997 for the proportion of locations within 25 m and greater than 25 m away from this type of habitat when compared to expected availability ($p<0.05$). Six of the study animals (ewes #1,#3, #5,#6,#8, and #14) occupied locations during the lambing season that did not come within 500 meters of the predicted use areas. However, only one of these sheep (ewe #6) actually gave birth to a lamb that survived through December.

The model identified 368.5 km^2 as escape terrain (ET) within the study area. This area represented 11% of the study area. This sheep habitat requirement in the GIS model was simply defined as land areas within 300 m of slopes 27° through 85° and did not include all geophysical, biological, and human management land constraints. Therefore, the total area for this layer is greater than the area for basic suitable habitat. The study animals utilized areas >25 m from defined escape terrain in 53% of the observations for January 1996 to May 1996. During the 1996 summer (June 1996-September 1996), 62% of the observations for males and females were within 25 m of escape terrain. The proportion of observations within 25 m of escape terrain decreased during the summer field season of 1997 (1 May to 30 September) to 36%. Analysis with the aid of a test of proportions uncovered significant statistical differences for the 1996 and 1997 field seasons when the proportion of point locations within 25 m and greater than 25 m of escape terrain were compared with expected availability ($p<0.05$).

Individual animals varied widely in their use of escape terrain habitat predicted by the model. Point locations of ewe #6 and ewe #14 were seldom in areas identified as suitable by the model.

The 2 years of field monitoring showed consistent use of basic suitable bighorn sheep habitat (BSH) in the study area. In 1996, 69% of all sheep observations were within 25 m of the 203 km^2 identified in this layer of the model. This habitat layer represented 6% of the study area. During 1997, the study animals were located within or ≤25 m from basic suitable habitat in 71% of observations. Again, a test of proportions showed significant differences ($p<0.05$).

Bighorn sheep use of GIS designated summer habitat (SH) was very consistent for the 2 summers (June to August 1996 and June to August 1997) following the transplant. The model considered 197.6 km^2 to be suitable summer habitat in the study area. Summer habitat represented 6% of the study area. The proportion of observations ≤25m from summer habitat was 84% for both summers and a proportions test did result in significant differences for both 1996 and 1997 ($p<0.05$). Sixty-four percent of winter (January 1996 to March 1996 and September 1996 to December 1996) sheep observations were in areas identified as winter habitat (WH) in the model. The model considered 75.2 km^2 (2% of the study area) available as winter habitat. A test of proportions for the winter habitat layer also resulted in significant statistical differences ($p<0.05$). As with lambing habitat, a few sheep consistently used areas that were not identified as year-round or seasonal habitat by the model. Table 2 shows a more detailed breakdown of point locations by distance category and by gender on a seasonal basis.

Table 2. Distribution of sheep locations (%) relative to the predicted model spatial distribution of GIS designated habitat layers.

	BSH[a]	ET[a]	LH[a]	WH[a]	SH[a]
Total Number of Point Locations	975	368	76	72	168
1996					
Rams (n=)	(78)	(61)	NA	(16)	(22)
≤25 m:	16	25	NA[b]	22	29
≥500m:	0	7	NA	0	0
Ewes (n=)	(412)	(172)	(36)	(56)	(55)
≤25 m:	68	76	42	51	58
≥500m:	16	14	58	26	13
1997					
Rams (n=)	(23)	(11)	NA	NA	(10)
≤25 m:	5	6	NA	NA	10
≥500m:	0	2	NA	NA	1
Ewes (n=)	(467)	(124)	(40)	NA	(81)
≤25 m:	87	77	63	NA	74
≥500m:	9	15	38	NA	15

[a]BSH=basic suitable habitat; ET=escape terrain; LH=lambing habitat; SH=summer habitat; WH=winter habitat

[b]NA=animals occupied areas outside GIS database or data were not collected.

Habitat Use Analysis (Medium Scale Selection)

When bighorn sheep diurnal habitat use was classified by habitat type, sheep were most often observed in Agropyron smithii/Stipa comata and Artemisia tridentata/Atriplex confertifolia habitat types during the summer while heaviest use was focused in the Agropyron smithii/Stipa comata habitat type during the whole year for all field seasons (Table 3 and 4). Use versus availability analyses suggest that bighorn sheep observations did not occur in habitat types in proportion to their availability (X^2=784,

$p<0.05$). Two types (Agropyron smithii-Stipa comata and Andropogon scoparium) were used significantly more than expected, while the Agropyron smithii-Stipa viridula, Artemisia tridentata-Atriplex confertifolia, and Artemisia tridentata-Boutleoua gracilis habitat types were used significantly less than expected (Table 3). Variation in patterns of use of habitat types also varied among seasons (Table 4). Patterns from my 10-min observation periods (Appendix A, Table 12) were similar to point locations.

Overall, bighorn sheep use of physiographic types available in TRNP indicated selection for rugged terrain and open sites. Sheep use of the River Breaks type was significantly higher than expected (Table 5). Ewes and rams utilized physiographic types for different activities. Ewes primarily used the River Breaks type for feeding activities whereas rams used this same type equally for feeding, resting, and other activities. Use of physiographic types varied by season. The type used most frequently (75% of observations) during the late winter/spring of 1996 was the River Breaks type (Table 6). This physiographic type was used for feeding, resting, and escape from danger. A smaller portion of the observations occurred in the Upland Grasslands type during this sample period. In winter, sheep used the Upland Grasslands when the wind blew patches of snow from the upper plateaus thereby revealing additional food resources.

During summer 1996, sheep used the River Breaks heavily but tended to shift some of their activity (i.e. feeding and resting) to the Upland Grasslands. Sheep would migrate from the River Breaks to the Upland Grasslands for feeding bouts when rainfall saturated the surface clay and caused travel to be treacherous.

During fall/winter 1996, the study animals used the River Breaks and Upland

Grasslands extensively. No sheep use was observed in the Scoria Hills complex and Sagebrush Bottoms during this season. The late winter/spring 1997 sampling period showed a similar pattern of physiographic type use. The sheep used the River Breaks during the majority of the observations in this time period. In summer 1997, sheep activity was concentrated in the River Breaks type.

Table 3. Occurrence of sheep point locations in habitat types (Marlow et al. 1984) in North Unit of TRNP from 1996-1997.

Habitat Type (HT)	Total (ha)	Proportion of total area	Observed # point locations	Expected # of point locations	Proportion observed (Pi)	Confidence interval on proportion of occurrence	Selection (+) or Avoidance(-)
HT1[a]	172	0.279	358	192	0.520	$0.470 \leq p1 \leq 0.569$	+
HT2[a]	115	0.187	2	129	0.003	$0.002 \leq p2 \leq 0.008$	-
HT3[a]	97.6	0.158	101	109	0.147	$0.112 \leq p3 \leq 0.182$	
HT4[a]	123.6	0.201	78	138	0.113	$0.082 \leq p4 \leq 0.144$	-
HT5[a]	72.8	0.118	23	81	0.033	$0.015 \leq p5 \leq 0.051$	-
HT6[a]	15.7	0.025	103	17	0.149	$0.114 \leq p6 \leq 0.184$	+
HT7[a]	6.3	0.010	15	7	0.021	$0.007 \leq p7 \leq 0.035$	
HT8[a]	12.8	0.021	9	14	0.013	$0.002 \leq p8 \leq 0.024$	
TOTAL:	615.8		689	689			

[a]HT1=Agropyron smithii-Stipa comata; HT2=Agropyron smithii-Stipa viridula; HT3=Stipa comata-Bouteloua gracilis; HT4=Artemisia tridentata-Atriplex confertifolia;HT5=Artemisia tridentata-Bouteloua gracilis;HT6=Andropogon scoparium;HT7=Hardwood draws;HT8=Steep scoria complex

Table 4. Habitat type use (percentage) for transplanted bighorn sheep in TRNP and adjacent Little Missouri River Grasslands for the field seasons of 1996-1997.

Habitat Type	Field Season[a] 1 (n=162)	2 (n=170)	3 (n=185)	4 (n=193)	5 (n=45)	6 (n=220)
Agropyron smithii-Stipa comata	46	70	44	86	49	37
Agropyron smithii-Stipa viridula	6	1	1	0	0	0
Stipa comata-Bouteloua gracilis	24	14	24	10	27	4
Artemisia tridentata-Atriplex confertifolia	0	4	10	0	24	36
Artemisia tridentata-Bouteloua gracillis	7	0	4	0	0	4
Andropogon scoparium	10	9	17	6	0	13
Hardwood draws	0	0	0	0	0	4
Steep scoria complex	7	1	0	0	0	2

[a]1=Late winter/spring (31 January 1996 to 31 May 1996);2=Summer (1 June 1996 to 31 August 1996);3=Fall (1 September 1996 to 31 October 1996);4=Winter (1 November 1996 to 31 December 1996);5=Late winter/spring (1 January 1997 to 31 May 1997);6=Summer (1 June 1997 to 31 August 1997)

Table 5. Occurrence of sheep point locations in physiographic types (Marlow et al. 1984) in North Unit of TRNP during 1996-1997.

Physiographic Type	Total acreage	Proportion of total Acreage	Observed # Point Locations	Expected # of point locations	Proportion Observed (Pi)	Confidence Interval on Proportion of Occurrence	Selection (+) or Avoidance(-)
River Breaks	2904.1	0.620	524	439	0.740	$0.702 \leq p1 \leq 0.778$	+
Upland Grasslands	419.5	0.090	160	64	0.226	$0.189 \leq p2 \leq 0.263$	+
Sagebrush Bottoms	911.4	0.195	2	138	0.003	$0.002 \leq p3 \leq 0.008$	-
Scoria Hills	77.0	0.016	10	11	0.014	$0.004 \leq p4 \leq 0.024$	
Wooded Draws	373.5	0.080	12	57	0.017	$0.006 \leq p5 \leq 0.028$	-
TOTAL:	4685.5		708	708			

Table 6. Physiographic type use (%) for transplanted bighorn sheep herd in North Unit of Theodore Roosevelt National Park and adjacent Little Missouri River Grasslands for the 1996 and 1997 field seasons.

Physiographic Type	Sample Season[a]				
	1 (n=125)	2 (n=165)	3 (n=173)	4 (n=72)	5 (n=203)
River Breaks	72	76	72	68	81
Upland Grasslands	22	24	28	32	12
Sagebrush Bottoms	2	0	0	0	0
Scoria Complex	5	1	0	0	1
Wooded Draws	0	0	0	0	6

[a]1=Late Winter/Spring 1996(1 January 1996 to 30 May 1996);2=Summer 1996 (1 June 1996 to 31 August 1996);3=Fall/Winter 1996 (1 September 1996 to 30 December 1996);4=Late Winter/Spring 1997(1 January 1997 to 30 May 1997); 5=Summer 1997 (1 June 1997 to 30 August 1997)

Feeding Site Analysis

I examined small scale selection by comparing feeding sites used by sheep with similar sites not used by sheep. Sites used by sheep were, on average, slightly further

away from escape terrain than non-use sites (Figure 4). Analysis of 11 non-use sites (Table 7) showed that an average of 19.7% of grass plants, 32.3% of forbs, and 19.1% of shrubs was grazed in vegetation plots within these sites. On 11 sites used by sheep, I sampled vegetation immediately after they moved to new foraging areas. Frequency of utilization at these 11 used sites (Table 8) averaged 41.8% for dominant grass species, 50.6% for dominant forb species, and 67.5% of dominant shrub species. A paired t-test showed significant differences for percent grazed between the non-use sites and use sites ($\bar{x}$=22.6, SD=38.6, p=0.014). There were also significant differences in percent vegetation coverage between non-use and use sites ($\bar{x}$=15.5, SD=18.9, p=0.001). A paired t-test of the average forage volume (average height x percent vegetation coverage) also indicated significant differences (t=1.80, df=439, p=0.07) between the non-use sites ($\bar{x}$=8.9, SD=10.1) and the use sites ($\bar{x}$= 7.3, SD=8.07) and indicated non-use sites had higher volume.

Plant species composition and diversity were highly variable among the use and non-use sites (Figure 5). Dominant grass, forb, and shrub species for the non-use sites included Carex filifolia, Chrysothamnus nauseosus, and Atriplex confertifolia, respectively. Bouteloua gracilis, Artemisia frigida, and Artemisia tridentata were the dominant grass, forb, and shrub species, respectively, in use sites. The number of plant species on the use sites outnumbered the number of plant species on the non-use sites in 3 pairs, were equal in 3 pairs, and were lower in 5 paired comparisons. The number of plant species did not appear to be a key factor in the foraging behavior of these bighorn sheep.

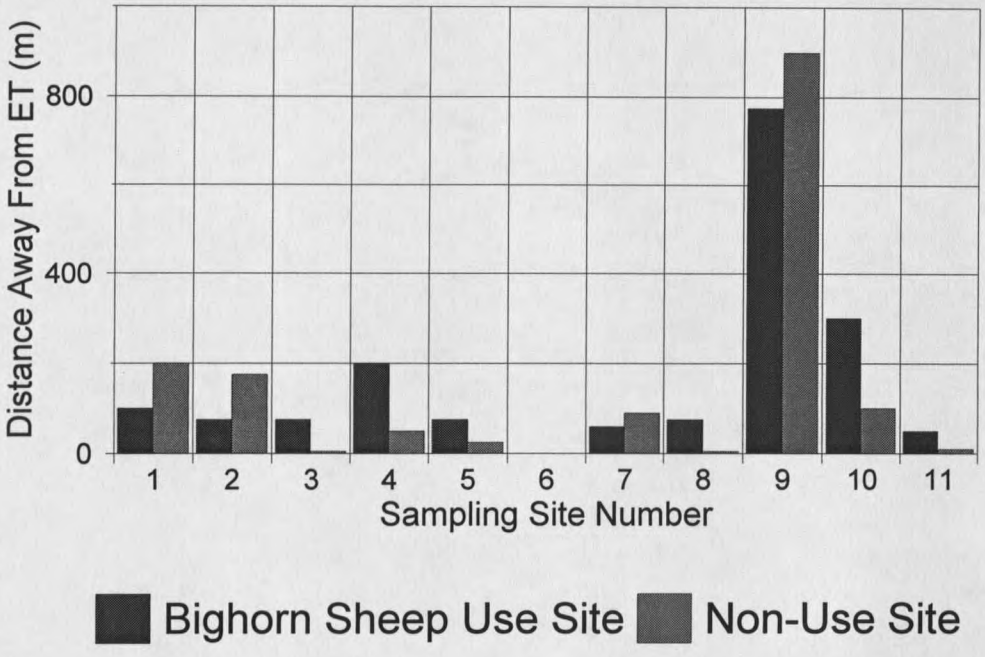


Figure 4. Proximity of vegetation sampling sites to designated "escape terrain" in the North Unit of TRNP and adjacent areas during the summers (1 June 1996 to 31 August 1996 and 1 June 1997) of 1996 and 1997).

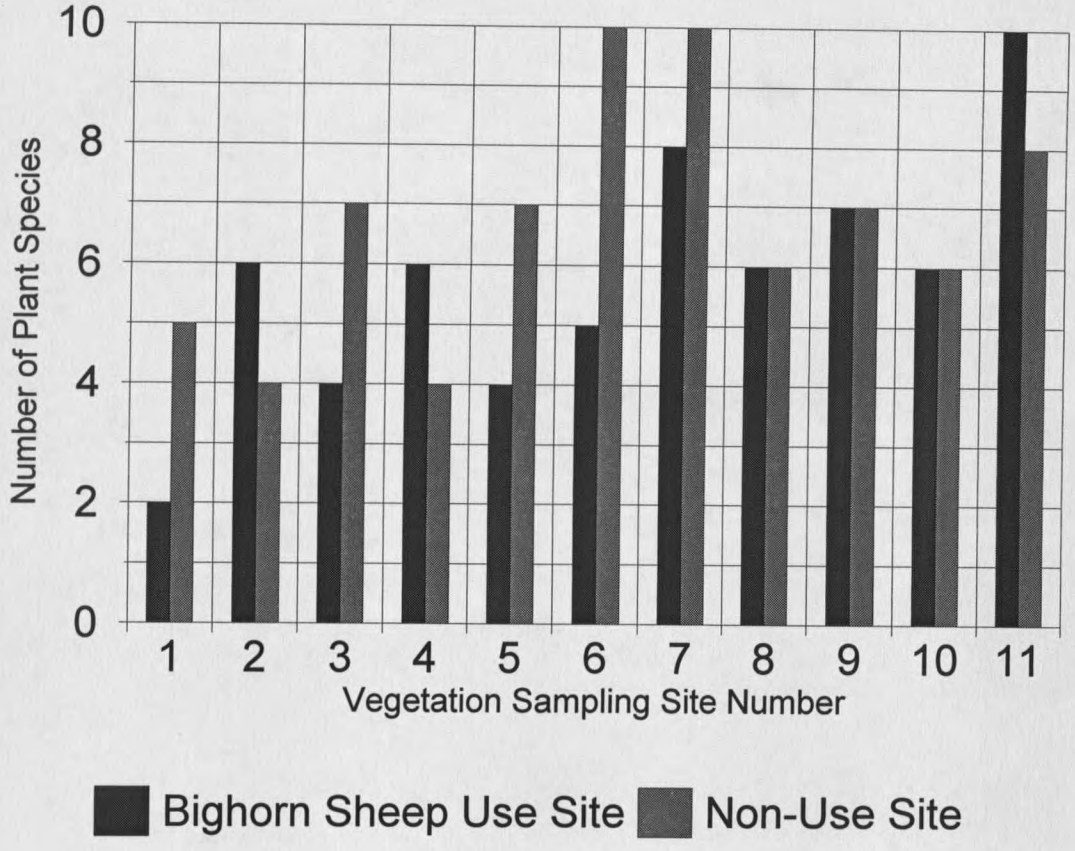


Figure 5. Plant species richness for bighorn sheep use sites and non-use sites in North Unit of TRNP and adjacent Little Missouri River Grasslands.

Table 7. Mean percent grazed and percent vegetation coverage on 11 sites not used by California bighorn sheep in the Theodore Roosevelt National Park during summer 1996 and summer 1997.

DOMINANT PLANT SPECIES	% Grazed	% Vegetation Coverage
Grasses:		
Agropyron smithii	13	38
Andropogon scoparius	21	58
Muhlenbergia Schreberi	24	31
Stipa comata	10	31
Bromus inermis	3	50
Oryzopsis hymenoides	0	20
Stipa viridula	20	38
Stipa spartea	36	70
Panicum virgatum	5	52
Sitanion hystrix	3	10
Agropyron spicatum	0	40
Carex spp.	100	50
MEAN	20	41
Forbs:		
Artemisia frigida	6	26
Artemisia longifolia	29	40
Ceratoides lanata	6	15
Gutierrezia sarothrae	100	20
Atriplex confertifolia	53	39
Opuntia spp.	0	30
MEAN	32	29
Shrubs:		
Artemisia tridentata	7	55
Chrysothamnus nauseosus	0	5
Sarcobatus vermiculatus	50	20
MEAN	19	27

Table 8. Percent grazed and percent vegetation coverage on 11 sites used by California bighorn sheep in the Theodore Roosevelt National Park during summer 1996 and summer 1997.

DOMINANT PLANT SPECIES	% Grazed	% Vegetation Coverage
Grasses:		
Agropyron smithii	58	44
Andropogon scoparius	44	59
Muhlenbergia Schreberi	56	49
Stipa comata	53	42
Bromus inermis	0	80
Stipa viridula	21	28
Panicum virgatum	51	22
Agropyron spicatum	20	75
Agropyron dasystachyum	33	50
Agropyron spp.	46	25
Carex spp.	75	49
Koeleria pyramidata	27	70
Bouteloua gracilis	59	56
MEAN	42	50
Forbs:		
Artemisia frigida	100	80
Ceratoides lanata	53	75
Gutierrezia sarothrae	100	20
Atriplex confertifolia	0	50
Vicia spp.	0	30
MEAN	51	51
Shrubs:		
Artemisia tridentata	64	64
Artemisia longifolia	63	62
Chrysothamnus nauseosus	43	33
Sarcobatus vermiculatus	100	50
MEAN	68	52

Bighorn Sheep Behavior

Feeding was heaviest during the mid-morning and late evening hours for the late winter/spring (January 1996-May 1996) and fall/early winter (September 1996-December 1996) sampling periods (Figure 6). Feeding reached a peak during the mid-day hours for the summer (June-August) of 1996 . When feeding was summed across all diurnal time blocks, it appeared to peak before the lambing season (April-June) and before the breeding season (October-December). Feeding was heaviest during the evening hours for both the late winter/spring 1997 and summer 1997 sampling periods (Figure 6). Within season analysis of bighorn sheep behavior patterns (Friedman's test) uncovered significant differences ($p<0.05$) between ewes ($F=6.8$) and rams ($F=8.11$). Ewes and rams displayed distinct patterns of behavior (i.e. feeding, resting, social activities) during different seasons of the year. Ewes devoted more time to resting on a seasonal basis than rams which spent more time feeding.

Distance travelled per 10-min observation period (Table 9) changed seasonally for sheep groups over the course of the 1996 and 1997 field season. Sheep limited their movements in the winter and increased movements during the summer months. ANOVA indicated no significant differences in movement for groups of ≤ 3 sheep versus groups of >3 sheep ($p>0.10$).

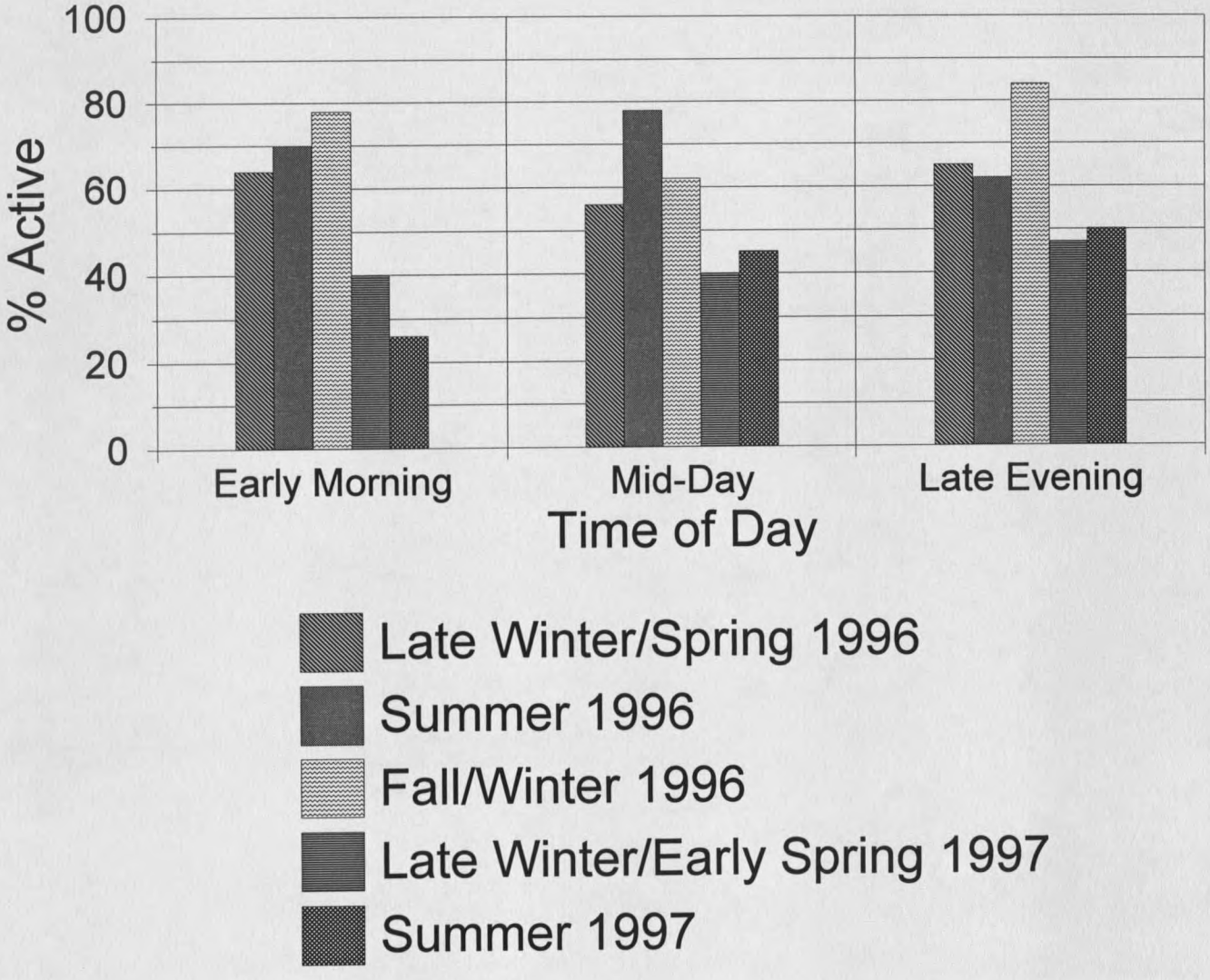


Figure 6. Activity patterns for transplanted California bighorn sheep in North Unit of TRNP.

Table 9. Mean distance travelled for bighorn sheep for 10-min observations collected during the 1996 and 1997 field seasons in the North Unit of Theodore Roosevelt National Park and adjacent areas in the Little Missouri River Grasslands.

Season	MEAN DISTANCE TRAVELLED (m)	
	Large Sheep Groups/SD	Small Sheep Groups/SD
Late Winter/Spring 1996	9/19	5/12
Summer 1996	12/24	10/16
Winter 1996	11/27	5/10
Late Winter/Spring 1997	5/8	7/9
Summer 1997	7/42	13/40

Bighorn Sheep Interactions With Other Ungulates and Predators

Interactions between bighorn sheep and other ungulates were frequent. Mule deer and bighorn sheep habitat use overlapped extensively. White-tailed deer were not observed in habitats used by bighorn sheep. Single mule deer appeared to be startled by the presence of bighorns in the vicinity; however, sheep appeared to be very tolerant of deer. Groups of deer showed no hesitation in feeding in close proximity to bighorn sheep. Six percent of my visual observations in 1996 and 11% in 1997 had either single deer or groups of deer within 500 meters of bighorn sheep. Sixty-two percent of sheep observations within 500 m of deer activity occurred during the mid-day hours of 1100hrs to 1600hrs in 1996. In 1997, bighorn sheep and deer interaction was lower during the early morning hours (sunrise to 1100hrs) and late evening hours (1600hrs to sunset) as compared to the mid-day hours where 54% of these interactions occurred during 1997.

Bison and sheep interacted during several field observations. During 9% of my observation periods in 1996 and 6% in 1997, bison bulls or bison herds (up to 80

animals) came within 500 meters of bighorn sheep. Twenty-three of the 43 instances (53%) where bison came within 500 m of sheep in 1996 were in the mid-day hours of 1100hrs to 1600hrs. During the 1997 field seasons, 57% of bison sightings near observed bighorn sheep fell within the mid-day hours. Bison utilized open plateau habitats where the sheep were occasionally observed feeding and resting; bison rarely utilized the broken habitats that were extensively used by the sheep.

Interactions between predators and bighorn sheep were rare. Only 3 % of sheep observations in 1996 were within 500 m of coyotes. This percentage increased to 5% for the 1997 field season. Single coyotes did not approach large groups of bighorn sheep or single bighorn sheep, but there were a few observations where they attempted to approach ewes with lambs. It appeared that the rugged topography of the badlands protected ewes with lambs during these encounters. Coyotes were generally observed on the perimeter of bighorn sheep habitat. In the summer of 1997, a golden eagle soared for 10 minutes above the newborn lamb nursery group, but no predation was observed.

Bighorn Sheep Interactions With Humans and Human Artifacts

Most of the sheep from the transplant utilized isolated regions of the North Unit rather than areas that offered easy access to tourists. Sheep apparently habituated to humans walking trails in the North Unit. When sheep encountered humans on horseback, the sheep would usually run several meters but would return to their original location the following day. Bighorn sheep habituated to vehicles travelling the North Unit's scenic route during the summer of 1996. However, the percent of sheep within 500 m of either hikers and/or car traffic that I observed decreased from 7% during 1996 to

none in 1997. I was not able to evaluate the impacts of oil development and ranching on the behavior of sheep I observed outside the Park's boundaries. Only 3% and 0% of bighorn sheep observations fell within 500 m of these types of activities during the 1996 and 1997 field season, respectively; 2 of the 14 transplanted ewes lambed in areas within 1 kilometer of oil wells. Seven sheep (4 ewes/3 rams) from the transplanted herd occupied ranges adjacent to areas grazed by livestock. There was 1 instance where deer hunters elicited flight of 1 of the transplanted ewes.

Population Dynamics

Of 19 sheep introduced, 4 died between January 1996 and August 1997. Ram #19 died of apparent liver failure in the second week after the release. Ewe #4 was found dead in a sinkhole in early February 1996. Ewe #1 was apparently ambushed and killed by coyotes during late August 1996. The exact cause of death of ewe #1 was not determined due to the poor condition of the carcass.

Fourteen adult ewes from the transplanted herd produced 8 lambs in 1996 (Table 10, Appendix A Table 14). Three of the lambs died of undetermined causes. At the end of 1996, the population numbered 23 animals. This tally does not include one of the ewes (#51) that moved into the North Unit from a North Dakota Fish and Game introduction near Theodore Roosevelt National Park in the summer of 1992. The total population remained at 23 animals at the end of the final field season (August 1997)(Table 10, Appendix Table 15). Seven of the sheep from the 1996 transplant in the North Unit were currently living outside the Park boundaries at the conclusion of 1997 field season. Migration by the study animals into and out of the North Unit has changed these totals.

Table 10. Population dynamics of transplanted herd after lambing seasons of 1996 and 1997.

Year	Number of lambs produced	Number of surviving lambs through December	Total transplant population in North Unit	Transplant population outside North Unit	Transplant herd mortalities	Population structure of entire herd
1996	8 lambs	4 lambs	19 sheep	4 sheep	1 ram 1 ewe 3 lambs	14 ewes 5 rams 4 lambs
1997	3 lambs	3 lambs	16 sheep	7 sheep	2 ewes	11 ewes 3 rams 4 yearlings 3 lambs

DISCUSSION

GIS Model Suitability

Field observations indicated that the GIS model (Smith et al. 1991, Gudorf 1994) was useful in predicting bighorn sheep habitat use but may be too conservative in identifying lambing areas and water availability. Ewe #6 deviated more from predicted habitat use than any other sheep. The core area inhabited by this ewe and her offspring featured the essential elements of the model with 1 exception, water sources. Her home range was located greater than 3,000 m from a perennial water source suggesting that California bighorn sheep can supplement perennial water resources with water from vegetative materials and/or runoff from seasonal snowstorms or rainstorms which accumulate in isolated pools or stock reservoirs. Clearer documentation of secondary water sources (i.e seasonal streams and/or stockwater ponds) is needed to gain a better understanding of this matter.

The constraints built into the GIS designated lambing habitat also seem too restrictive. Six of the 15 transplanted ewes made extensive use of areas outside the lambing habitat indicated by the model during the lambing seasons. Ewe #6 successfully produced a lamb in a site 900 m from escape terrain, an adjacent water resource, and the non-south facing slopes used to designate lambing habitat.

Laymon and Barrett (1986) suggest that models such as the Smith et al. (1991) along with other Habitat Suitability Indexes (HSI) need several years of testing in order to gain credibility. Schamberger and O'Neil (1986) note that most habitat models are based

on assumed relationships between species and their environment and attempts to validate habitat models have had confusing results. The Smith et al. (1991) model will require several more years of testing in other areas to determine its reliability.

Success of Bighorn Sheep Introduction

Habitat in TRNP appeared to be suitable for California bighorn sheep. The habitat use patterns of the transplanted herd were driven by seasonal variation in weather patterns, preparation for reproduction, and security needs. In winter and early spring, the study animals seemed to avoid the deep snow on the upper plateaus by moving to river breaks and ridges where snow cover tended to be lower and more forage was available. During the late spring, when snowmelt occurred, and summer, when weather conditions were hot, the lignite coal layer of the Badlands became a 'hot spot' for bighorn activity. Snowmelt filters through the soil and collects in small pockets near the lignite coal layer and eventually evaporates leaving salt. The observations of sheep during these seasons suggest that the study animals utilized this area as a water source during the spring runoff and a salt lick during the hot summer months.

Overall, activity levels appeared to reach a maximum before the lambing season. Herd size did not have a consistent association with movement during feeding activities. This contradicts the results from Goodson and Bailey (1990) and may be an artifact of adjustment to a new environment or a low level of predator encounters in TRNP.

During the first 2 years following the transplant, sheep appeared to move to new sites when 50% of the forage plants in a feeding area had been utilized. If bighorn sheep in the greater TRNP area are restricted to discrete, favorable areas of habitat, this strategy

may not be feasible as the population grows. Excessive use of preferred habitat patches could result in reduced quality and quantity of forage resources (Hobbs 1996).

Wikeem and Pitt (1992) suggest that California bighorn sheep base their foraging strategies on plant availability. My analysis of foraging sites suggested that bighorns selected sites with higher plant coverage, and that they switched to new sites when biomass (as indexed by estimated volume) was reduced by their feeding activities. If feeding site selection by sheep is based on biomass, sheep site selection and movement among suitable habitat patches could be influenced by deer and bison foraging.

Most deer and bison sightings within 500 m of bighorn sheep were during the mid-day hours versus early morning and late evening hours. This may suggest that sheep avoid other ungulate species and devote more time to feeding activities in areas which are devoid of competition during the early morning and late evening hours considering bighorn sheep and other ungulate species interactions increased during the mid-day hours.

Alternatively, bighorn sheep may derive benefits from close association with bulk foragers such as bison. The ewe that colonized TRNP prior to the transplant frequently grazed within 10 m of bison bulls. McHugh (1958) noted a close association between bighorn sheep rams and bison at the National Bison Range. These associations might provide sheep with protection from medium-sized predators.

I observed sheep feeding in areas recently grazed by bison on many occasions. This pattern appeared to be most common in spring and sheep appeared to be drawn to bison foraging areas by access to short grasses and regrowth that were available on these sites. Walker (1985) indicated that grazing by large herbivores can have benefits for

smaller herbivores that follow the larger animals.

Options for improving forage on TRNP for sheep are limited because grassland communities are near climax, and forage quality will be limited by the climate (Hobbs 1996, Westoby et al. 1989, Walker 1985). One option that might improve quantity and quality of open habitats in TRNP is burning. A prescribed burn regime could reduce future range condition problems by attracting ungulate species such as bighorn sheep to other foraging sites thereby lessening the effects of competition (Hodgkinson 1984, Ludwig 1990). More forage resources, both quality and quantity, would be available to bighorn sheep along with other resident ungulate species.

Stress due to human impacts did not appear to be severe during 1996 and 1997. Sheep tended to habituate to humans activities well, and poaching was not a problem. Oil development has been identified as a potential detrimental factor to the success of bighorn sheep populations in North Dakota (Sayer 1996). Sayer (1996) believed that oil wells would most likely be a management concern during lambing and early summer when sheep are more susceptible to disturbance. Twelve sheep from the transplant occupied ranges remote from oil development. Two ewes in the transplant group established home ranges near oil wells and survived and reproduced. More data will be needed to uncover the actual impact of oil development.

Transplanted bighorn sheep that joined with resident sheep outside the North Unit appeared to adopt habituation patterns of resident sheep. Six of the transplanted sheep (ewes #1,8,14 and rams #16,17,20) followed this pattern over the course of this study. Habituation by the sheep appears to be a critical role in regard to other human activities

such as hiking, ranching, and car traffic. However, these activities occurred at low levels in the areas where I made observations. Sheep habituation may not occur if these activities were to increase to higher levels.

Reproduction in the transplanted herd decreased over the 2 years of this study. In 1996, 8 lambs were produced, 4 of which survived over the 2 years of this study. Only 3 lambs born in 1997 survived through their first year (Table 10, Appendix A Tables 11 and 12). The low reproductive rate in TRNP could be linked to predation by coyotes (Hass 1989, Festa-Bianchet and Jorgensen 1998), stress on ewes associated with harsh winter conditions experienced during the 2 years of the study, or poor nutritional quality of grasslands available to weaning lambs during late summer and autumn (Cook et al. 1990). I never observed coyotes killing lambs or close association between coyotes and sheep, and forage quality was not measured. The winter of 1995-96 was severe. Eight of 11 ewes produced lambs, but only 4 survived through the autumn of 1996. Festa-Bianchet and Jorgenson (1998) presented data that suggest ewes under severe winter stress decrease the diversion of nutrients to the fetus in order to maintain their own health. The fetus may then be reabsorbed by the ewe or the ewe may produce a small, weak lamb.

Other studies (Forrester 1971, Stelfox 1976, and Dunbar 1992) have shown that degradated range conditions may play a critical role in increasing lungworm loads in bighorn sheep and thus decreasing survival of lambs. The rapid horn and body growth of the surviving lambs indicated that the TRNP herd is healthy and has not encountered significant problems from disease (Buechner 1960, Woodard et al. 1974, Fairaizl 1978b.,

Silflow et al. 1989) or lack of quality forage (McCutchen 1985).

Stochasticity may be the most crucial short-term problem. Unfavorable combinations of any of several variables may be involved in the demise of small populations of bighorn sheep such as the North Unit transplant herd (Berger 1988, Goodson 1982). It appears that reproduction in other sheep herds in the Missouri Breaks tends to be good for 10-20 years following transplants then becomes poor without any obvious relationship to environmental conditions (Jensen per. comm. 1998). The best protection against local reproductive failure could be recolonization (Thomas 1993, Boyce 1992, Nuney and Campell 1993) within a metapopulation matrix. The TRNP transplant represents an important addition to the bighorn sheep metapopulation of the Little Missouri River Breaks where introduction efforts have established small populations of sheep connected by immigration and emigration.

CONCLUSIONS

The predictions of the modified North Unit GIS habitat model (Smith et al. 1991, Gudorf 1994) were generally validated by our field observations over the course of the 1996 and 1997 field seasons. However, the data collected during the 2 years of this study suggests that the model could be modified in the following areas:

1) Increase the model's recognition of water sources to include seeps which occur at the lignite coal layer within the Badlands.

2) Relax the topographic constraints on lambing habitat built into the model.

3) Increase the flexibility of the model by including a "burn sub-routine." Burns could be used in the western portion of the park to increase visibility and forage.

4) An intensive evaluation of bighorn sheep forage utilization appears to be a necessity in the evaluation of "basic suitable habitat." The current GIS model does not consider this variable in the habitat evaluation process.

The model could prove to be a useful tool in future transplants in other areas not included in the NPS designated study area. The transplanted herd utilized a small proportion of designated suitable habitat. Approximately 200 km^2 (Smith et al. 1991, Gudorf 1994) are still available in the study area for future transplants, and several thousand square kilometers of likely habitat are available along the Little Missouri and other badlands river systems in North Dakota.

During the first 2 years after bighorn sheep were released into the North Unit of TRNP, the population has increased in numbers, and, to a lesser degree, interacted with bighorn sheep herds adjacent to the Park. Therefore, two of the main objectives (increase

in number of bighorn sheep and increase in genetic diversity) of this transplant have been achieved. California bighorn sheep apparently acclimated moderately well in TRNP in spite of severe winter and summer weather, high numbers of other ungulate species, abundant medium-sized predators, presence of oil development, and tourism.

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APPENDICES

APPENDIX A

Tables

Table 11. Factors considered in the GIS model for determination of land area suitable for bighorn sheep (from Smith et al. 1991).

Habitat Requirement	Effect on Land Area Available
geophysical/biological parameters	
Escape Terrain (ET) and Buffer (BT)	Include land areas with slope > 27° , < 85° (i.e. escape terrain), land areas within 300m of escape terrain and land areas, ≤ 1000m wide, that are bounded on ≥ 2 sides by escape terrain
Horizontal Visibility (HV)	remove areas with visibility < 55%, as defined by the mean percent of squares visible on a m^2 target, divided into 36 equal squares, 14 m from an observer viewing N,E,W,S from a height of 90 cm along a 10 pt, 280 m transect
Water Sources (WS)	remove land areas > 3.2 km from water sources
Natural Barriers (NB)	remove land areas that can not be accessed due to natural barriers: Rivers > 2000 cfs, areas with visibility < 30%, that are 100 m wide, cliffs with > 85° slope
land management constraints	
Human-use Areas (HU)	remove land areas covered by human development
Manmade Barriers (MB)	remove land areas that can not be accessed due to manmade barriers: major highways, wildlife-proof fencing, aqueducts, major canals
Domestic Livestock (DL)	remove land areas within 10 miles (16 km) of domestic sheep

Table 12. Habitat criteria used for evaluation of suitable summer and winter ranges, lambing ranges, and migration corridors for bighorn sheep (from Smith et al. 1991).

Habitat Requirement Non categorized habitat - exclusionary criteria	**Seasonal Range**
x - y	= z
Suitable habitat - slopes > 27°	= Summer range
Suitable habitat - north, west, east facing slopes (225°-135°) - areas with snowpack >25 cm	= Winter range
Suitable habitat - slopes < 27° - north-facing slopes (315° - 45°) - areas > 1 km from water - areas < 2 contiguous ha	= Lambing range
Suitable habitat - (areas w/ HV = 30 to 55% < 4.5 km) - (areas w/ HV < 30% < 100m)	= Migration zones

Table 13. Percentage (%) of observations for transplanted bighorn sheep engaged in feeding, resting, and other activities for each predominant habitat type (Norland 1984) during the respective 1996 and 1997 field seasons

Habitat Type	feeding	resting	other
Late winter/spring (31 January 1996 to 31 May 1996, n=1042 observation minutes)			
Agropyron smithii-Stipa comata	16	23	7
Agropyron smithii-Stipa viridula	5	1	0
Stipa comata-Bouteloua gracilis	8	2	2
Artemisia tridentata-Atriplex confertifolia	0	0	0
Artemisia tridentata-Bouteloua gracilis	2	3	2
Andropogon scoparium	7	14	2
Hardwood draws	0	0	0
Steep scoria complex	2	4	1
Summer (1June 1996 to 31 August 1996, n=853 observation minutes)			
Agropyron smithii-Stipa comata	10	55	5
Agropyron smithii-Stipa viridula	1	0	0
Stipa comata-Bouteloua gracilis	9	1	4
Artemisia tridentata-Atriplex confertifolia	1	2	1
Andropogon scoparium	5	3	1
Steep scoria complex	0	1	0
Fall (1 September 1996 to 31 October 1996, n=1036 observations minutes).			
Agropyron smithii-Stipa comata	22	17	5
Agropyron smithii-Stipa viridula	1	0	0
Stipa comata-Bouteloua gracilis	16	3	5
Artemisia tridentata-Atriplex confertifolia	3	7	0
Artemisia tridentata-Boutleou gracilis	1	2	1
Andropogon scoparium	12	4	1
Winter (1 November 1996 to 31 December 1996, n=624 observation minutes).			
Agropyron smithii-Stipa comata	62	16	8
Stipa comata-Bouteloua gracilis	7	2	1
Andropogon scoparium	4	0	2
Late winter/spring (1 January 1997 to 31 May 1997, n=724 observation minutes).			

Table 13 - Continued

Agropyron smithii-Stipa comata	24	20	5
Stipa comata-Bouteloua gracilis	15	7	5
Andropogon scoparium	7	17	1
Summer (1 June 1997 to 31 August 1997, n=2117 observation minutes).			
Agropyron smithii-Stipa comata	7	26	4
Stipa comata-Bouteloua gracilis	2	1	1
Artemisia tridentata-Atriplex confertifolia	3	27	6
Artemisia tridentata-Bouteloua gracilis	2	1	1
Andropogon scoparium	5	5	3
Hardwood draws	4	0	0
Steep scoria complex	1	0	1

Table 14. Bighorn sheep reproduction for 13 ewes introduced into North Unit of Theodore Roosevelt National Park during lambing season (15 April 1996 to 30 June 1997).

EWE NUMBER	EWE AGE (YRS.)	EWE OFFSPRING	LAMB DATE OF BIRTH^	STATUS OF LAMB
#1	3	1 lamb	5/18/96	alive
#2	5+	1 lamb	6/6/96	alive
#3	3.5	1 lamb	5/10/96	died: 6/19/96
#5	4	**	N/A	N/A
#6	8	1 lamb	5/21/96	alive
#7	6	1 lamb	6/6/96	alive
#8	4	1 lamb	7/3/96	died:10/31/96
#9	4	1 lamb	5/4/96	died: 7/3/96
#10	6	**	N/A	N/A
#11	5	**	N/A	N/A
#12	5	1 lamb	6/6/96	alive
#14	5	**	N/A	N/A
#15	6	**	N/A	N/A

**denotes ewe that did not produce lamb or lamb was not observed before its death
^birth dates are estimated; lamb was first observed within the first week after its birth.
N/A = not applicable

Table 15. Bighorn sheep reproduction (15 April 1997 to 30 June 1997) for 11 ewes from the Theodore Roosevelt National Park (North Unit) transplant herd as of September 1, 1997.

EWE NUMBER	EWE AGE (YRS)	EWE OFFSPRING	LAMB DATE OF BIRTH	STATUS OF LAMB
#2	5+	**	N/A	N/A
#5	4	**	N/A	N/A
#6	8	**	N/A	N/A
#7	6	1 lamb	5/27/97	alive
#8	4	**	N/A	N/A
#9	4	**	N/A	N/A
#10	6	**	N/A	N/A
#11	5	1 lamb	6/3/97	alive
#12	5	**	N/A	N/A
#14	5	**	N/A	N/A
#15	6	**	N/A	N/A
#51	10+	1 lamb	6/10/97	alive

**denotes ewe that did not produce lamb or lamb was not observed before its death
^birth dates are estimated; lamb was first observed within the first week after its birth.
N/A = not applicable

APPENDIX B

Figures

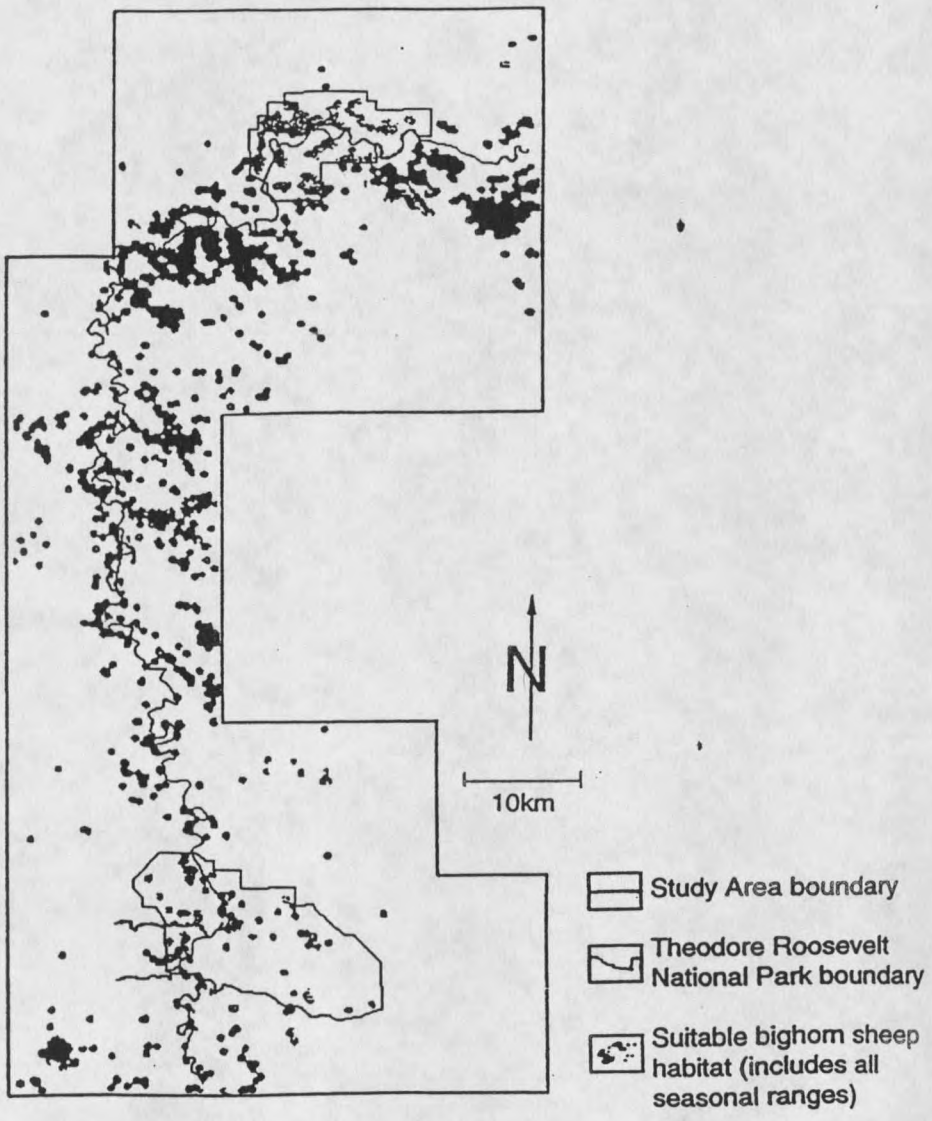


Figure 7. Suitable bighorn sheep habitat in the greater Theodore Roosevelt National Park area (from Smith et al. 1991).

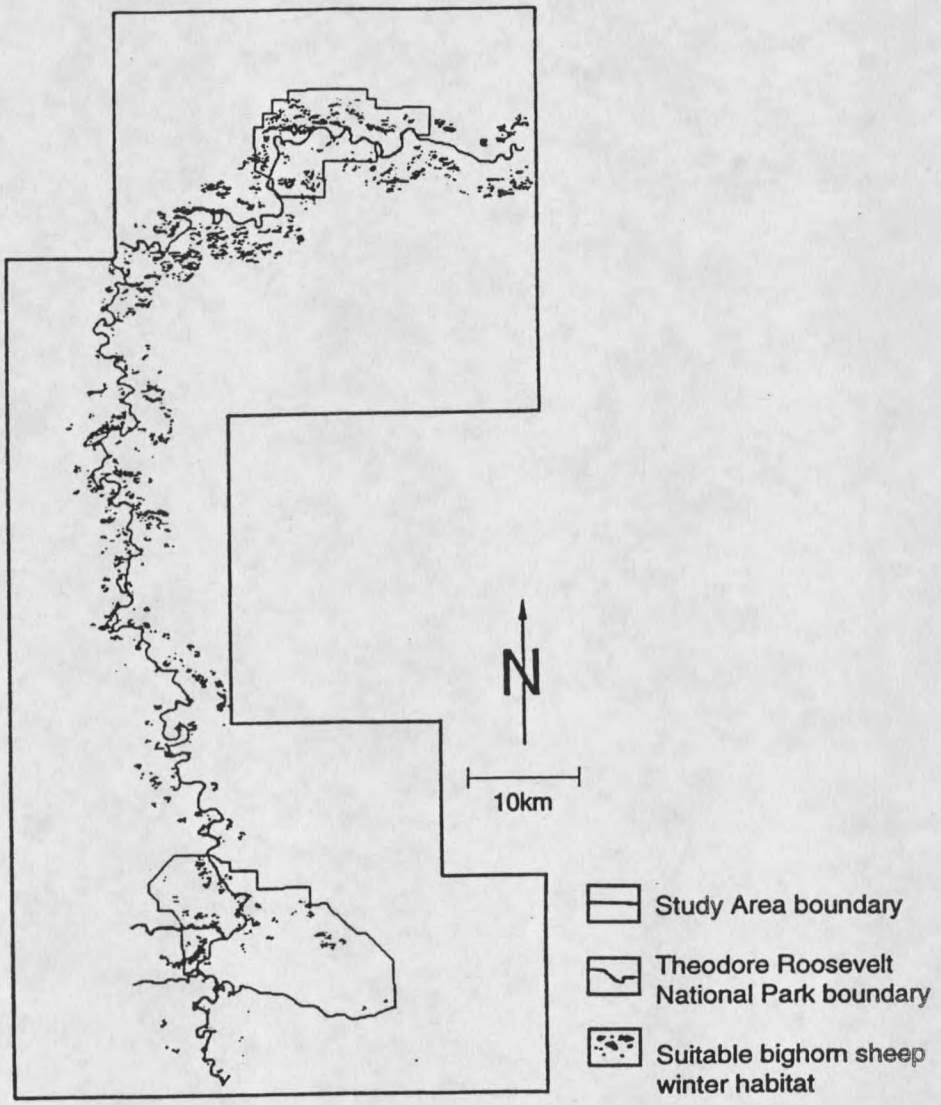


Figure 8. Suitable bighorn sheep summer habitat in the greater Theodore Roosevelt National Park (from Smith et al. 1991).

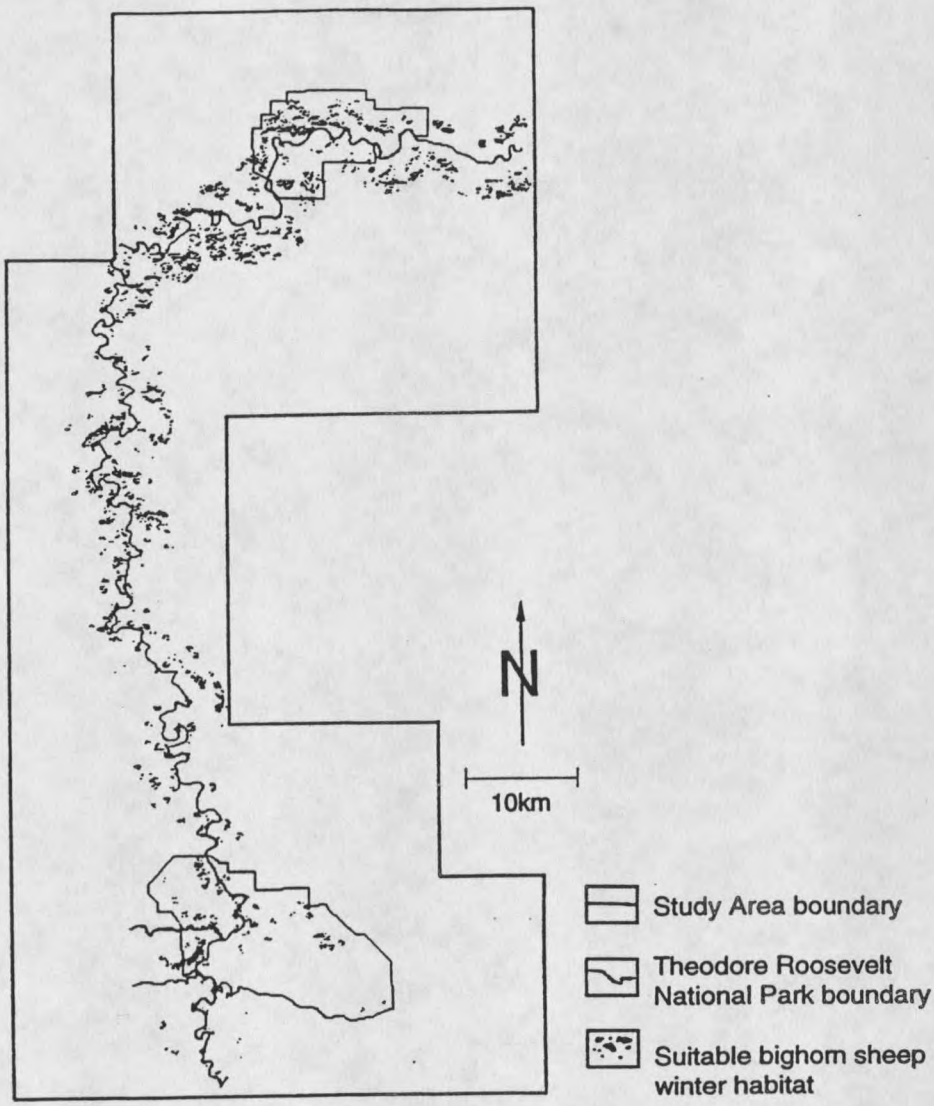


Figure 9. Suitable bighorn sheep winter habitat in the greater Theodore Roosevelt National Park area (from Smith et al. 1991).

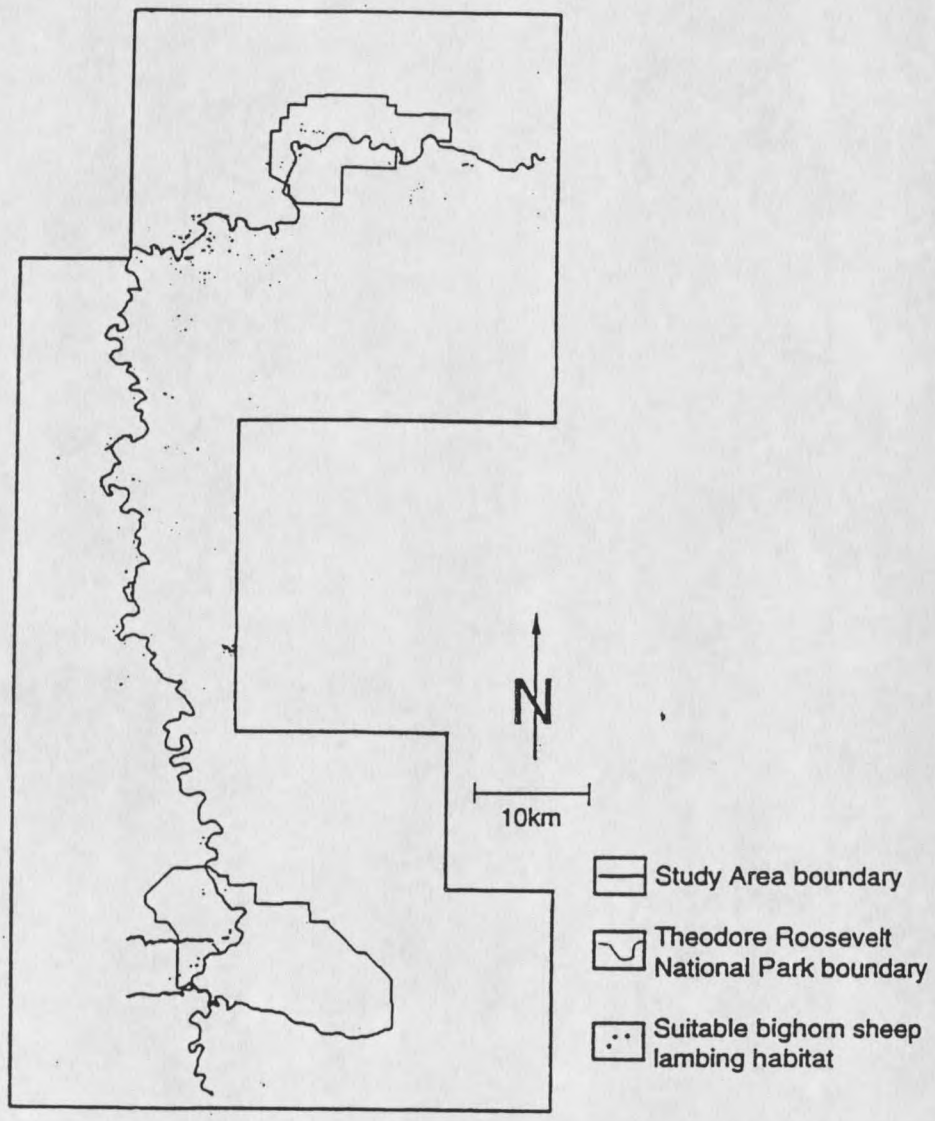


Figure 10. Suitable bighorn sheep lambing habitat in the greater Theodore Roosevelt National Park area (from Smith et al. 1991).

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