A GIS-based approach to landscape habitat selection by bighorn sheep in the Missouri River Breaks, Montana

by Wayne Clayborne Hickey, III

A thesis submitted in partial fulfillment of the requirements for the degree of Masters of Science In Fish and Wildlife Management

Montana State University

Abstract:

Although reintroduction efforts for prairie/breaks bighorn sheep have met with limited success, the 1980 reintroduction of 28 RockyMountain bighorn sheep (Ovis canadensis canadensis) from the Sun River, Montana to the Stafford Ferry area of Fergus County appears to be successful while other nearby populations are stagnant or declining.

In an effort to find out why this population has been successful, 30 sheep where radio-collared in March 1998 and studied for 2 years. The objectives of this study were 2 fold: 1) to identify the distribution, movement patterns and estimate total numbers for the population on the north side of the river; and 2) to use a geographic information system (GIS) to develop a landscape level habitat selection model for the Missouri River Breaks. Ewes in the study population had mean home ranges of 4,265 ha, 5,416 ha, and 6,816 ha for winter, summer/spring, and fall, respectively, based on the 95% adaptive kernel method. Rams had mean home ranges of 11,751 ha, 13,610 ha, and 18,779 ha for winter, summer/spring, and fall, respectively. Overall, the radio-collared sheep showed no distinct seasonal home ranges and had an average of 75% overlap in individual seasonal home ranges. Estimates of total numbers of sheep within the study area varied from 326 to 403 individuals. I was unable to detect any population trends during the 2 years of my study. These estimates were too variable to tell if the population was growing, but total numbers counted indicated the population was stable during 1998 and 1999. My analysis of habitat selection was based on information from GIS data layers that provided slope, elevation, aspect, and type of vegetation at a 30 meter2 pixel resolution. I tested habitat selection at 4 separate scales: 0 (the individual pixel that contained the sheep location); 105m, 195m and 285m (dominant attributes encompassed in radius around the pixel that contained the sheep location). The habitat selection models at each of the 4 scales were investigated and compared using Akaike's information criteria (AIC). This allowed the models at different scales to be directly compared. All Models identified slope and cover type as being the most important variables for identifying use by bighorn sheep regardless of the scale. Estimates of coefficients for the individual cover types were too variable to put much faith in point estimates but did allow ranking of the relative importance of each cover type. Agricultural land was the least important cover type for bighorn sheep. Grassland, shrub, shrub-grass mosaic, and forest were all of the same importance, and all were used by sheep more than agricultural land. The cover type of water was more important in bighorn sheep selection than the previous variables. The most important cover type for bighorn sheep was the barren/badland cover type. The 285 m scale model had the lowest AIC scores, but the 195 m scale was selected as optimal because estimates of cover type coefficients were less variable. I concluded that the best habitat available for bighorn sheep in the study area were the steep badlands adjacent to the Missouri River with direct contact with native shrub and grasslands on the bench tops above slopes. However, this 2 variable model might be improved by the addition of other digital layers such as biomass estimates to improve predictions of sheep use within cover types. The effect of scale should be validated in other locations and habitat types. Delineation of this habitat complex at the 195-m scale was useful for eliminating patches of appropriate habitat that were too small for sheep to effectively

exploit.

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APPROVAL

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Wayne Clayborne Hickey III

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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Date 12/4/2006

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ABSTRACT

Although reintroduction efforts for prairie/breaks bighorn sheep have met with limited success, the 1980 reintroduction of 28 Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) from the Sun River, Montana to the Stafford Ferry area of Fergus County appears to be successful while other nearby populations are stagnant or declining. In an effort to find out why this population has been successful, 30 sheep where radio-collared in March 1998 and studied for 2 years. The objectives of this study were 2 fold: 1) to identify the distribution, movement patterns and estimate total numbers for the population on the north side of the river; and 2) to use a geographic information system (GIS) to develop a landscape level habitat selection model for the Missouri River Breaks. Ewes in the study population had mean home ranges of 4,265 ha, 5,416 ha, and 6,816 ha for winter, summer/spring, and fall, respectively, based on the 95% adaptive kernel method. Rams had mean home ranges of 11,751 ha, 13,610 ha, and 18,779 ha for winter, summer/spring, and fall, respectively. Overall, the radio-collared sheep showed no distinct seasonal home ranges and had an average of 75% overlap in individual seasonal home ranges. Estimates of total numbers of sheep within the study area varied from 326 to 403 individuals. I was unable to detect any population trends during the 2 years of my study. These estimates were too variable to tell if the population was growing, but total numbers counted indicated the population was stable during 1998 and 1999. My analysis of habitat selection was based on information from GIS data layers that provided slope, elevation, aspect, and type of vegetation at a 30 meter^2 pixel resolution. I tested habitat selection at 4 separate scales: 0 (the individual pixel that contained the sheep location); 105m, 195m and 285m (dominant attributes encompassed in radius around the pixel that contained the sheep location). The habitat selection models at each of the 4 scales were investigated and compared using Akaike's information criteria (AIC). This allowed the models at different scales to be directly compared. All Models identified slope and cover type as being the most important variables for identifying use by bighorn sheep regardless of the scale. Estimates of coefficients for the individual cover types were too variable to put much faith in point estimates but did allow ranking of the relative importance of each cover type. Agricultural land was the least important cover type for bighorn sheep. Grassland, shrub, shrub-grass mosaic, and forest were all of the same importance, and all were used by sheep more than agricultural land. The cover type of water was more important in bighorn sheep selection than the previous variables. The most important cover type for bighorn sheep was the barren/badland cover type. The 285 m scale model had the lowest AIC scores, but the 195 m scale was selected as optimal because estimates of cover type coefficients were less variable. I concluded that the best habitat available for bighorn sheep in the study area were the steep badlands adjacent to the Missouri River with direct contact with native shrub and grasslands on the bench tops above slopes. However, this 2 variable model might be improved by the addition of other digital layers such as biomass estimates to improve predictions of sheep use within cover types. The effect of scale should be validated in other locations and habitat types. Delineation of this habitat complex at the 195-m scale was useful for eliminating patches of appropriate habitat that were too small for sheep to effectively exploit.

INTRODUCTION

Bighorn sheep have a historic range that extends from southern British Columbia and Alberta to Mexico. In the 1700's, the total bighorn sheep population in North America may have been as high as 2 million sheep (Buechner 1960). By the early 1900's, sheep numbers had declined to approximately 20,000 over the same range. When Lewis and Clark first explored the Missouri River, they observed populations of sheep in prairies and breaks in what is now Montana (Buechner 1960). These sheep were later classified as *Ovis canadensis auduboni* or Audubon's bighorn sheep. This sub-species was driven to extinction in the early 1900's by over-hunting, disease, and competition from domestic livestock (Geist 1971). The decline in populations in the Missouri Breaks may have largely been due to anthrax introduced by domestic sheep in 1885 (Grinnell 1904:287 cited in Buechner 1960): "By 1897, no sheep remained in the Little Rocky, Bearpaw, Little Belt, Judith, Highwood, or Castle Mountains, according to L. V. Pirsson of Yale University" (Buechner 1960).

Currently, Montana has a total of 42 populations of Rocky Mountain bighorn sheep (Erickson 1999). Of these 42 populations, 39 are located in mountainous areas that vary from alpine to low montane environments. Sixteen of the 42 populations are native and the remaining are transplanted populations (Erickson 1999). Of the 16 native populations, 6 have required supplementation by transplants to remain viable.

Management agencies began using translocations to return bighorn sheep to parts of their historic range as early as the 1930's (Bleich et al. 1990, Dunn 1996). In 1947, the Montana Department of Fish, Wildlife and Parks (MDFWP) began efforts to reestablish sheep in the Missouri River Breaks region of Montana. Sixteen Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) from Colorado were relocated near Billy Creek in Garfield County, Montana. This population grew rapidly at first but by 1956 had begun to decline, and by 1963 had completely disappeared. Failure of this population has been attributed to competition for forage, disease, inter-breeding with domestic sheep, and social intolerance of domestic sheep in the area (Sullivan 1996). From 1958 through 1961, a series of reintroductions placed 43 Rocky Mountain bighorn sheep in the Two Calf area of Fergus County, south of the Missouri River and slightly east of the location of this study. Eventually this attempt failed as well. A series of weather events, disease, and competition with domestic livestock and deer were reported as responsible for the failure (Eihhorn and Watts 1972). However, some remnants of this introduction were probably present when additional sheep were released at Chimney Bend (Stafford Ferry population) in 1980. Another introduction into the Missouri River Breaks area occurred in 1974 in the Little Rockies when 21 sheep from the Sun River were released (McCarthy 1996). The population increased to approximately 100 individuals before declining in the mid 1990's. No sheep were sighted in helicopter or ground surveys in 1998. The cause for this die off has been attributed to disease (Sullivan, unpublished data).

In 1980, Rocky Mountain bighorn sheep from the Sun River area in Montana were again relocated to the Stafford Ferry area of Fergus County and to Mickey Brandon Buttes of Phillips County (McCarthy 1996). Twenty-eight animals were released in each location. The population introduced at the Stafford Ferry area has since grown and pioneered areas that include both sides of the Missouri River. In August 1998, this population had a minimum of 540 animals: 230 north of the Missouri River and 310 on the south side. The population at Mickey Brandon Buttes peaked at 88 individuals in 1994 but declined to 39 sheep by 1999. The Stafford Ferry population complex appears to be successful where other nearby prairie/breaks populations are stable or declining.

The mixed success of transplanted populations in the Missouri River Breaks may be due to inadequate habitat assessment at release sites (Smith et al. 1988, Dunn 1996). Suitable habitat for bighorns is superficially easy to define; open grassland in proximity to high relief escape terrain (Lawson and Johnson 1982), but the failure of many Missouri River Breaks transplants in areas of grassland adjacent to topographic relief suggested that a more sophisticated approach to habitat suitability was warranted.

My study included two primary objectives. The first objective was to generate information to describe population characteristics of bighorn sheep occupying MDFWP Hunting District 680 (HD 680) on the north side of the Missouri River. This objective involved; assessing population status by total enumeration, lamb-ewe ratios and demographic characteristics; use of home range calculations to identify winter and summer habitat; tracking movement and distribution to identify ewe and ram use areas as well as document interactions with sheep in other hunting districts; and assess the health of sheep in HD 680.

The second objective was to develop a model identifying suitable habitat for sheep in the Missouri Breaks. This was accomplished using a Geographic Information System (GIS) database, locations of radio-collared sheep, and logistic regression. My analysis was conducted at 4 spatial scales to identify the scale at which sheep are selecting habitat. This approach should allow managers to identify potential sheep habitat over large spatial expanses without expensive site reconnaissance or digitizing costs because it eliminates direct ground measurement and/or the need to digitize local databases. Results may improve planning for future sheep introductions and may be useful in determining if habitat is limiting for existing populations.

STUDY AREA

My study area was located in southern Blaine County in north central Montana. The southern boundary of the study area was the Missouri River. The western boundary was a line running north from the junction of Birch Creek and the Missouri River, east of Montana State road 236. The eastern boundary was a line running north of the junction of Bullwacker Coulee and the Missouri River and followed the coulee. The northern boundary was an arbitrary line that roughly followed the edge of the breaks habitat. These boundaries encompassed an area of approximately 275 km^2 (Figure 1).

The study area was dominated by topography typical of the Missouri River Breaks and was characterized by rolling benches with many deeply dissected drainages (coulees) that have steep, sparsely vegetated slopes. These dendritic coulees become deeper and wider as they approach the Missouri River. Bench tops merge into a rolling plain north of the study area. Elevation within the study area varied from 690m to 1063m. See Hamlin and Mackie (1989) for a more detailed description of the breaks habitat.

Climate of the Missouri Breaks is semiarid, dominated by variable precipitation and prone to moderate to high winds and extremes in temperature. The 50-year average for precipitation is 37.9 cm per year. In 1998 a total of 44.9 cm of precipitation was recorded, with most of the above average precipitation falling in June and July. All reported weather information is from the weather station at Winifred, Montana. Annual

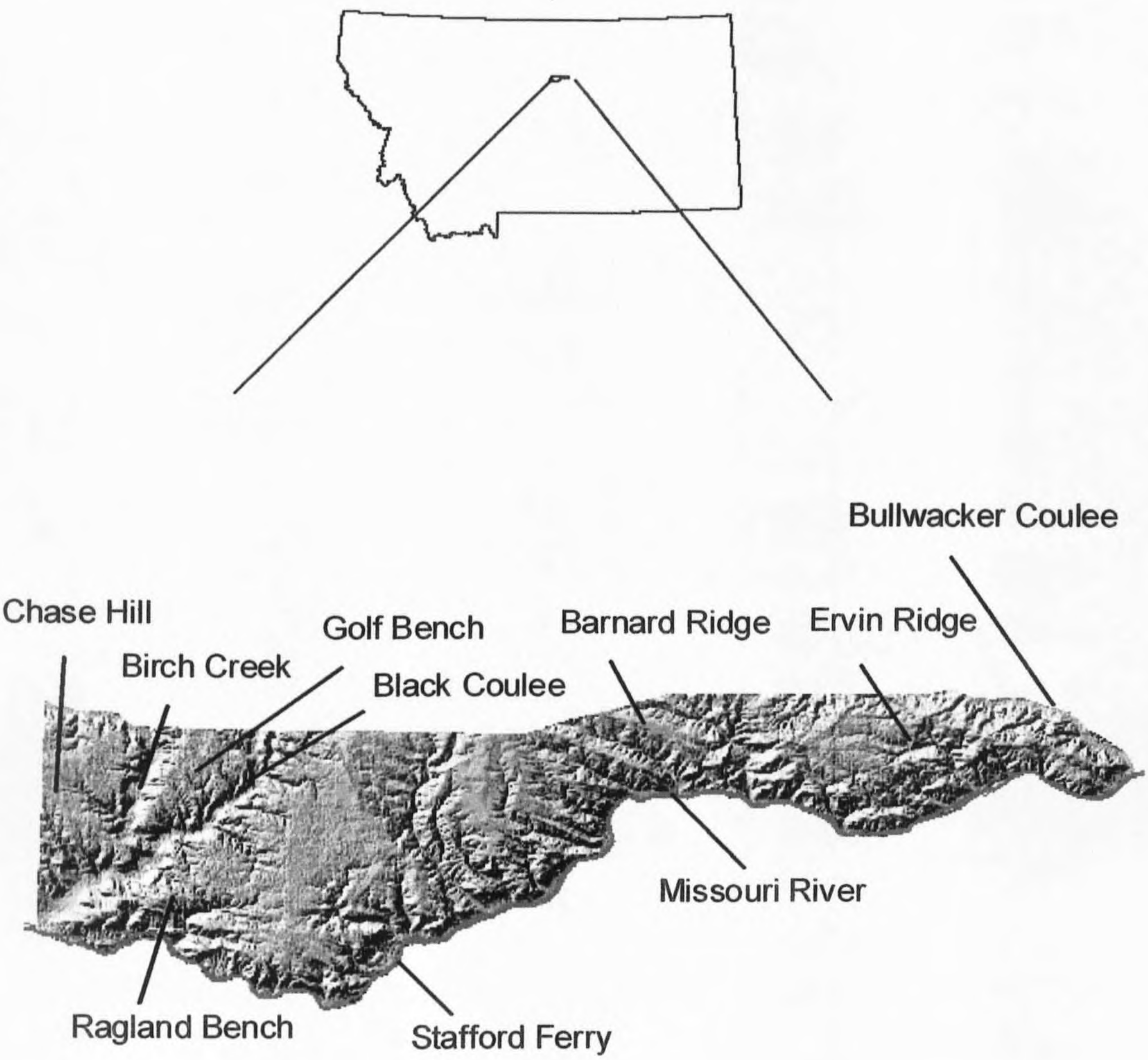
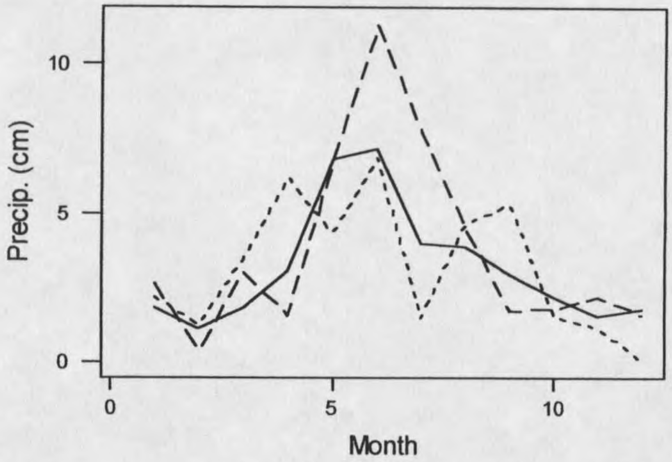


Figure 1. Map of study area with place names.

precipitation in 1999 was average (38.3 cm), but the spring and fall seasons had above average precipitation while the summer was below average (Fig. 2). Winter temperatures in 1998 and 1999 were milder than average (Fig. 3). Spring and summer temperatures were close to average in 1999 but warmer than average in 1998.

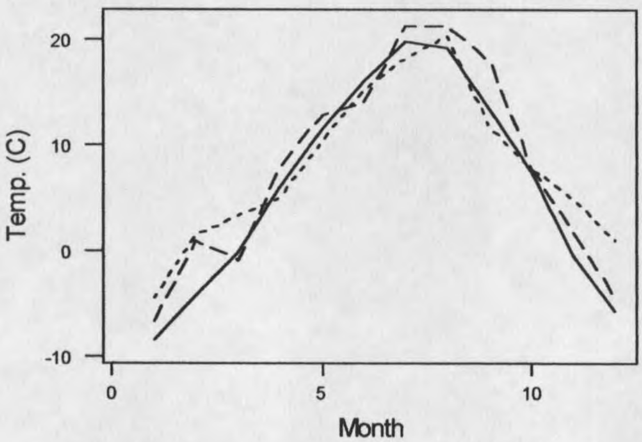
Soils in the Missouri Breaks are clay loam derived from the Bearpaw Shale Formation. The high clay content of these soils makes it relatively impermeable to water and helps contribute to the high rate of natural erosion. Many coulees in the study area had ephemeral water following rains. The only permanent water sources in the study area were the Missouri River and Birch Creek. An extensive system of stock tanks was present in the area. Most held water during 1998 and 1999 but would be dry in a drought year.

Land ownership was a mixture of private and Bureau of Land Management (BLM). Cattle ranching and dry land wheat farming were the dominant land uses at the time of this study. Cattle grazed throughout the study area, but wheat fields were located predominately at the west end of the study area. Agricultural fields in the study area were a mixture of untilled fields in the Conservation Reserve Program (CRP) and active fields. Many CRP contracts were scheduled to expire in 1999 – 2005, and many of the landowners were not planning to renew them. This suggested that agricultural acreage will increase in the future in the west end of the study area. Domestic sheep husbandry in the study area began in the late 1800's, but the last of these operations on the north side of the river was discontinued in the late 1970's.



Solid line = 50 year average precipitation
Dashed line = 1998 precipitation
Dotted line = 1999 precipitation

Figure 2. Monthly precipitation in the study area by year.



Solid line = 50 year average temperature
Dashed line = 1998 average temperature
Dotted line = 1999 average temperature

Figure 3. Monthly average temperature in the study area by year.

Potential predators of bighorn sheep within the study area included mountain lions (*Felis concolor*), bobcats (*Felis rufus*), coyotes (*Canis latrans*), and golden eagles (*Aquila chysaetos*). Possible competitors were domestic cattle (*Bos mcdonaldii*) and mule deer (*Odocoileus hemioneus*). Elk (*Cervus elephus*) and white-tailed deer (*Odocoileus virginianus*) were present but uncommon.

Hunting of bighorn sheep in Montana was not legal from the 1920's until the early 1950's. At that time specific populations were opened to regulated hunting when biologists concluded that populations could tolerate harvest. The population in my study area was first hunted in 1987. All the sheep on the north and south side of the Missouri River, in what are now hunting districts 482 and 680, were originally managed by Region 6 of MDFWP as hunting district 680. The area was split into 2 different administrative areas in 1996. The original hunting district had 15 either-sex permits and 10 ewe permits in 1996. By 1999, the quota had decreased to 10 either-sex permits and 10 ewe permits for HD 680 and 8 either-sex permits and 8 ewe permits in HD 482.

METHODS

Capture and Collaring

Sheep fitted with radios used in this study were captured in March 1998 by a professional wildlife capture service using net-guns mounted on a helicopter. Captures were spread over a large area in an effort to include 1 or 2 collars within several different bands of sheep. Radio-transmitters with mortality sensors and individually recognizable neckbands were fitted to each animal. At capture, blood was drawn to assess initial health and each animal was sexed and aged using tooth wear and irruption patterns (Lawson and Johnson 1982).

Sampling

Ground radio-locations of sheep were collected using a systematic sampling scheme amongst the 8 zones in my study area (Figure 4). The 8 zones were established based on access into the area and were sized so that each could be sampled in a single day. Seven zones were accessible by vehicle. The eighth zone was the river corridor on the east half of the study area and was only accessible by boat. A random number generator was used to select a random zone among the 8 zones and the order zones were searched (increasing or decreasing order). For example if zone 2 was selected and the zone search order was decreasing the zones would be sampled 2, 1, 8, 7, 6, 5, 4, and 3. If the search direction was increasing the zones would be sampled 2, 3, 4, 5, 6, 7, 8 and 1. Each zone was alternately sampled starting at the opposite end (*i.e.* if a zone was sampled east to west one time it was sampled west to east the next time). The exception to this was zone 8, which was sampled from the river by boat; it was always sampled from upstream to downstream.

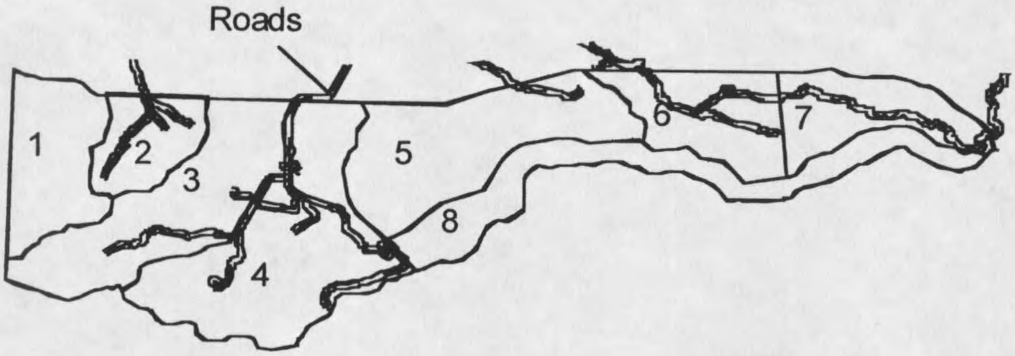


Figure 4. Map of sampling zones within the study area.

For each zone, I used radio telemetry to determine all collared sheep in the zone. Only animals actually observed were included in analysis using locations from the ground. Once an animal was located location co-ordinates, a brief site description, and group characteristics (number, gender, activity, etc.) were recorded. I used a non-correctable Global Positioning System (GPS) to identify my position in Universal Transverse Mercator (UTM) coordinates (WGS 84 Datum). Each animal's location was estimated using a compass bearing, estimated distance from the observer, and site descriptions. GPS data were converted to North American Datum (NAD) 27 datum using the program CORPSCON (U.S. Army Corps of Engineers 1997) and plotted on

7.5-minute USGS maps. The bearing, distance, and site description was then used to generate a sheep location on the map. These locations were then converted to North American Datum 1983 (NAD 83) using the CORPSCON program.

When locations were collected from a fixed-wing aircraft, the pilot circled the marked animal, if visible, or the area of strongest signal strength if the animal was not visible. This location was recorded with the same style GPS unit as used for locations from the ground. We attempted to locate all radio-collared animals on every flight even if animals were outside the defined study area. Flights occurred year round and employed the same pilot throughout the study. All flights were conducted using a Belanca Scout, model 8GCBC aircraft. Flights occurred at intervals of 10 days to 2 weeks.

Population Status

I attempted complete (100% of the study area) counts of the population on 4 occasions over 2 years from a helicopter. On the day before or the morning of the flight, all collars were located using a fixed-wing aircraft to determine if marked animals were present in the census area. The study area was then flown at low speed in the helicopter using a systematic search pattern. All sheep were counted and classified and collars described. Only data from the last 3 surveys were used to estimate population size. The first helicopter survey was not included because a helicopter malfunction forced a week delay between counts of the east and west halves of the study area. The interval between partial surveys gave animals time to move and made total estimation unreliable.

The population size in the survey area was estimated using a modified Lincoln-Peterson estimate (Lancia et al. 1996). The assumptions of this model are:

1) population is closed
2) no marks are lost, gained or overlooked
3) all animals have equal capture probability.

The first assumption was met by attempting the surveys in 2 days. The second assumption was met and confirmed using radio telemetry. The last assumption is difficult to test. I used the program CAPTURE (White, no date) as an indirect test of the third assumption. If the capture probabilities I observed did not vary among collared individuals or between capture events, this would suggest the probability of being seen was relatively constant across individuals. The program CAPTURE compares fit of several models to a set of observed capture probabilities. The null model (constant capture probability) fit my data better than the heterogeneous model (where capture probabilities vary between individuals), the time model (where capture probabilities vary between capture events), or the behavior model (where the capture probabilities varied for individuals which were trap happy or trap shy).

In addition to total enumeration, individual estimates by gender were calculated using the same method. No lambs were marked; consequently, a robust method was not available to estimate numbers; therefore, I used the point estimate for ewes multiplied by the lamb-ewe ratio (lambs per 100 ewes). Confidence limits on lamb numbers were calculated by multiplying the confidence intervals for ewes by lamb-ewe ratio. The monthly ratios of lambs, rams, and yearlings to the number of ewes for ground locations were calculated directly from the monthly totals.

Home Ranges

Home ranges were calculated in order to identify seasonal habitat such as winter and summer ranges. Home range calculations were done using CALHOME (Kie et al. 1994). This program was used to calculate both the minimum convex polygon (MCP) and adaptive kernel (ADK) home ranges for each individual. I have reported 95% home ranges using both techniques, but the percentages associated with these two methods have different meanings. Both methods employ an algorithm that calculates a center based on location data. This center is the point about which the home range is calculated. For the ADK method, the 95% percentile represents probabilities of containing the radioed animal and is plotted as a contour. The 95% percentile in the MCP method represents the percentage of the total locations used to create the polygon. For example, the 95% percentile of the MCP polygon would represent 95% of the points closest to the center point and eliminate the 5%.

Sheep locations used for home range calculations were the combination of ground and flight data from December 1998 through November 1999. Summer and fall data from 1998 were not included because, after stratification, sample sizes were too small. These data were divided into 3 seasonal strata. The first season was a spring/summer stratum from April 1999 through July 1999. This period covered the initiation of herbaceous plant growth to summer dormancy in the study area. The second stratum was fall, which extended from August 1999 through November 1999. Vegetation was generally dormant during this period, but weather was still reasonably mild and little or no snow had accumulated. The third seasonal stratum was winter and covered December 1998 through March 1999. This included the coldest weather events.

The Wilcoxon rank sum test was used (Mathsoft 1999) to test for differences in the sizes of average seasonal home ranges and differences between sexes by season. I used this test was used because samples were skewed toward values lower than the mean. Sample sizes were too small to apply the central limit theorem. The Wilcoxon rank sum test is also robust for samples that are not from a normal distribution (Mathsoft 1999).

Movement and Distribution

The distribution of sheep within the study area and movements in and out of the study area were based on combined ground and flight locations. I used plots of locations to define population sub-units within the study area as well as areas used by ewes and rams.

Health Indicators

Health of the sheep population was monitored by observing physical condition and examining fecal samples for lungworm (*Protostrongylus* spp.). Lungworm counts