

## MOOSE HOME RANGE FIDELITY AND CORE AREA CHARACTERISTICS IN SOUTH-CENTRAL MONTANA

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**ABSTRACT:** Long-term studies of animal home range are important to determine the stability of such ranges, their activity centers, and characteristics of core area use. We estimated home range sizes, range fidelity, and core area use of 11 radio-collared Shiras moose (*Alces alces shirasi*) in south-central Montana from 9 January 1989 to 16 August 1993. Respective mean winter-spring and summer-autumn home range size was 12.3 km<sup>2</sup> and 15.2 km<sup>2</sup> for males and 21.2 km<sup>2</sup> and 16.3 km<sup>2</sup> for females. Mean annual home range size for males and females was 22.2 km<sup>2</sup> and 26.6 km<sup>2</sup>, respectively. Home range size was independent of sex, season, and sex-season interaction. Moose used home ranges in non-uniform patterns with well-defined core areas. Moose generally remained faithful to seasonal and annual ranges in successive years, though 2 individuals showed evidence of changes in utilization within established home range boundaries. Moose in this population would likely benefit more from long-term, intensive management of heavily used areas than from extensive management of larger areas.

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Seasonal variation in moose home range size and use has been studied in boreal forest moose in Minnesota (Peek *et al.* 1976), Canada (Hauge and Keith 1981, Mytton and Keith 1981), and Sweden (Cederlund and Okarma 1988), and in Shiras moose of the western United States (Pierce and Peek 1984), but few studies have assessed home range use on an annual basis for  $\geq 3$  years, or determined the fidelity of moose to seasonal and annual ranges. The question of home range fidelity is particularly important, because the long-term value of all home range studies, including moose home range studies, depends on the assumption that the animals studied show faithfulness to their home ranges from year to year. If this assumption is false, many of the management implications derived from such studies, especially short-term studies, are unreliable. Despite the obvious importance of this assumption and the proliferation of moose home range studies, the assumption that resident adult moose are faithful to their home ranges has never been tested. In this study, we examined the faith-

fulness of moose to their seasonal and annual home ranges through the testing of two null hypotheses: (1) there would be no difference in seasonal and annual home range activity centers in resident adult moose in successive years and (2) there would be no difference in the distribution of moose locations within individual home ranges in successive years.

Because moose typically use their home ranges slowly (Garton *et al.* 1985) and in a non-uniform manner (Van Ballenberghe and Peek 1971), long-term home range studies with relatively large time intervals between locations of individual animals are important in avoiding problems associated with the serial correlation and non-independence of such locations (Swihart and Slade 1985, 1987). Additionally, longer-term studies are required to address the issue of range fidelity. Only when it can be demonstrated that home range boundaries and home range utilization do not change significantly between years can long-term data be assumed to provide reliable and consistent home area estimates.

Such longer-term studies also must pro-

vide more detailed analysis of home range utilization if managers intend to identify which subunits of home range provide the majority of needed resources. This is of particular concern in moose, where the importance of core use areas (Kaufman 1962:170) in home ranges has become increasingly clear in numerous studies. Van Ballenberghe and Peek (1971) described moose home ranges as a series of high use areas connected by wanderings. Cederlund and Okarma (1988) hypothesized that moose home areas actually may be comprised of closely located feeding sites on less than a few ha that could be used for a few days up to several weeks. In our study, preliminary analysis of home range use and movement patterns in a south-central Montana moose population suggested that greater insight into moose home range characteristics could be gained from a more intensive examination of utilization patterns of core use areas.

We studied seasonal variation in home range size, range fidelity, and core area use in a moose population inhabiting the Beartooth Mountains of south-central Montana. We sought to provide a precise description of

moose home range fidelity and core area use to aid in the development of a comprehensive moose management plan for the Beartooth District of the Custer National Forest.

Our objectives were to: (1) estimate seasonal home range sizes of moose; (2) determine year-to-year changes in seasonal and annual home range activity centers and range utilization; and (3) determine absolute and relative contributions of core foraging areas to total home areas. The null hypotheses were that: (1) home range size would not differ between seasons or sexes; (2) activity centers and range utilization would not change significantly from year to year; (3) core area use would not differ between seasons or sexes.

### STUDY AREA

The Fiddler and Fishtail Creek drainages are tributaries of the Stillwater River in south-central Montana along the northeastern edge of the Absaroka-Beartooth Mountains (Fig. 1). Moose in this area use elevations between 1500 m and 2800 m in terrain characterized by gently rising east-facing slopes of the Fishtail and Stillwater Plateaus in Carbon

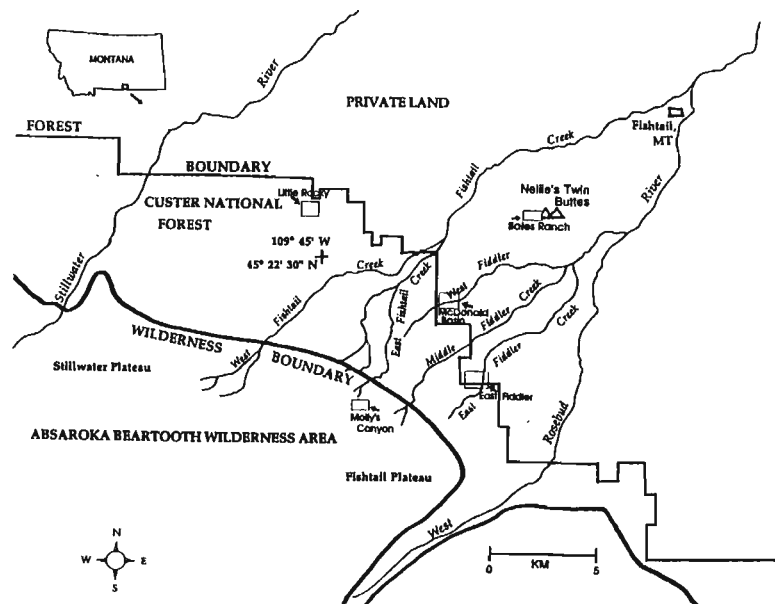


Fig. 1. Study area of the Fiddler-Fishtail moose population in south-central Montana, 1989-93.

and Stillwater Counties, and are near the eastern edge of historic moose range in Montana (Stevens 1971, Peek 1974). Ratios of collared to uncollared observed moose on repeated winter survey flights indicated that the area contained approximately 60-70 individuals within approximately 125 km<sup>2</sup>, or approximately 1 moose/2 km<sup>2</sup> (S. T. Stewart, MDFWP, pers. commun.). Observations from the same flights suggested that the population was female-dominated at a ratio of approximately 1 male: 3 females. Both sexes are hunted in the area by permit only. Numbers of permits have varied from year-to-year, but annual harvest has averaged 10-20 individuals since 1980 (C. E. Eustace, MDFWP, pers. commun.). No reliable long-term population estimates or indices existed, but hunter harvest and success rates (>75% annually and steadily increasing, C. E. Eustace, pers. commun.) circumstantially suggested an increasing population. Other ungulates present on the study area included mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), elk (*Cervus elaphus*), and domestic cattle and sheep.

Long, cold winters and short, cool summers typify climate. Snow began to accumulate by November and usually remained until May. During the main period of the study (1989-91), mean January and July temperatures at the Mystic Lake, Montana, reporting station near the center of the study area (elevation 1997 m) were -3°C and 18°C, respectively. Annual temperatures ranged from -46°C to 38°C. Annual rainfall averaged 56.8 cm and annual snowfall averaged 386 cm (U. S. Department of Commerce 1992).

Upland areas usually were dominated by immature stands of lodgepole pine (*Pinus contorta*) to the base of the plateaus, with less frequent occurrence of Douglas fir (*Pseudotsuga menziesii*) on steeper north slopes of lower elevation ridges. Subalpine forests of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies*

*lasiocarpa*) occurred on mesic sites at higher elevations. On mesic sites at low and intermediate elevations, widely dispersed stands of quaking aspen were common, and often adjacent to shrub-dominated wetland communities characterized by mountain alder (*Alnus incana*), willow (mainly *Salix planifolia* and *S. discolor*), and red osier dogwood (*Cornus stolonifera*). On drier sites at lower elevations stands of Ponderosa pine (*Pinus ponderosa*) often occurred adjacent to upland shrub communities dominated by chokecherry (*Prunus virginiana*), ninebark (*Physocarpus malvaceus*), and wild plum (*Prunus americana*).

## METHODS

### Home Range Measurement

Thirteen moose (3 males, 10 females) were captured by helicopter darting (Nielson and Shaw 1967) during December 1988 and 1990 and January 1991 and fitted with radio neck-collars (SB2 transmitter and Lonner module collar, AVM Instrument Co., Livermore, CA and Mod 500 transmitters, Telonics, Mesa, AZ). Eleven moose were located 637 times from 9 January 1989 to 6 March 1992. Each moose was located an average of once per week. Field work was temporarily suspended at this time due to changes in study personnel and research priorities. It was subsequently resumed from 18 June 1993 to 16 August 1993, with particular emphasis on additional investigation of summer home range characteristics of 6 of the moose (3 males, 3 females) collared in January 1991. These individuals were located 78 times during this period.

Moose were located by fixed-wing aircraft or by close ground triangulation between 0500 and 2200 hours. Non-visual aerial locations were tested for accuracy by placement of a transmitter at an unknown location. Average error was 143 m. Aerial locations were recorded after visual observation or after repeated circlings permitted the

signal to be confined within a 300 m diameter using a directional antenna mounted beneath the aircraft. Ground locations were recorded after visual observation, close triangulation (triangulation from  $\geq 2$  points  $\leq 100$  m from the moose), or ability to hear the signal on the receiver without the antenna or cable. Field tests prior to the start of the study demonstrated that the latter occurred only at distances  $< 50$  m. Every effort was made to avoid disturbing moose during ground locations, and these efforts were usually successful. Two females died  $\leq 13$  weeks after captures. Their locations (15) were insufficient for home range calculation and were excluded from further analysis.

Locations were recorded in Universal Transverse Mercator coordinates to the nearest 100 m. Locations were organized by seasons defined as winter (December-February), spring (March-May), summer (June-August), and autumn (September-November). Minimum convex polygon (MCP) (Hayne 1949) estimates of home range using 95% innermost locations were calculated using the HOME RANGE animal location analysis program (Ackerman *et al.* 1990). We chose the MCP model to represent and evaluate home range size because this model possesses statistical stability, does not require prior assumption of home range shape, and permits comparison to results of studies published prior to the development of other home range estimation models.

Preliminary analysis indicated substantial overlap between winter and spring ranges and between summer and autumn ranges. These seasons were combined in subsequent analyses as winter-spring and summer-autumn ranges. We evaluated only moose with  $\geq 20$  seasonal locations ( $X = 35.0$ , range 20-61) and  $\geq 40$  total locations ( $X = 65.0$ , range 40-115) for seasonal and annual home range estimates, respectively.

To test for adequacy of sample size, we made multiple estimates of home range size

with successively smaller numbers of locations for each moose (4-18 locations for seasonal ranges, 4-38 locations for annual ranges) and computed the average percentage of the maximum estimate generated by each sample size. Plotted results of these averages generated convex curvilinear relationships, fitted to a quadratic equation, which indicated that estimated home range size asymptotically approached the maximum estimate with increasing sample size (Fig. 2). For seasonal ranges, 16 location estimates averaged 87% ( $\pm 7\%$ , 95% CI) of final estimates, and 18 location estimates averaged 94% ( $\pm 4\%$ , 95% CI) of final estimates. For annual ranges, 36 and 38 location estimates averaged 96% ( $\pm 6\%$ , 95% CI) and 97% ( $\pm 6\%$ , 95% CI), respectively, of final estimates.

Fidelity to total home area was evaluated in 4 adult female moose that were followed

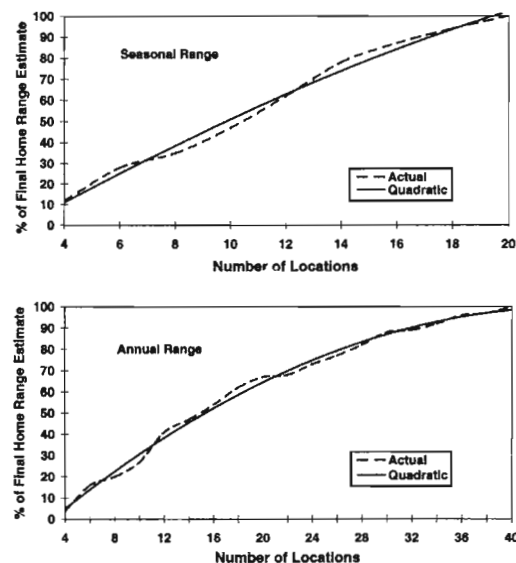


Fig. 2. Average relationship between number of moose locations and size of home area estimate (as percent of final Minimum Convex Polygon estimate) for seasonal (top) and annual (bottom) ranges of 11 radio collared moose in the Fiddler-Fishtail moose population in south-central Montana, 1989-93. Dashed line indicates actual data. Solid line indicates actual data smoothed to best fitted quadratic equation.

for  $\geq 2$  years. In these individuals, we used the TELDAY computer program (Lonner and Burkhalter 1986) to determine distances moved between seasonal and annual arithmetic mean activity centers (Van Winkle 1975, Lair 1987, Ackerman *et al.* 1990) between years as one index of range fidelity (all pairwise combinations). Differences in distances associated with activity center change in different seasons were compared by t-tests. An alpha of  $P \leq 0.05$  was considered significant in these and all other comparisons. As an additional assessment of range faithfulness, we compared distances associated with changes in seasonal activity centers to the standard radius of the corresponding home range (1/2 the standard home range diameter, MCP estimate) in that season, determined from the same analysis program. Ratios  $> 1.0$  were considered evidence that the range activity center may have moved beyond the previous year's home range boundaries and that a range shift of potential biological significance had occurred. To further evaluate fidelity of overall range utilization, we followed the procedure proposed by White and Garrott (1990:136-137) of dividing each home area of these moose into equal-sized (3X3 km<sup>2</sup>) cells (3 or 4 per moose, depending on total home range size). This procedure allowed inclusion of all moose locations and permitted cell sizes to be the same for all individuals. Numbers of cell locations and years then were tested for independence (White and Garrott 1990:136-137). Statistically significant results were considered evidence of change in range utilization over time. Finally, we evaluated distributions of Euclidean distances between locations in individual moose in different years through a Multiple Range Permutation Procedures (MRPP) test. Such procedures, initially described by Mielke *et al.* (1976), evaluate distance functions between r-dimensional points associated with  $\geq 2$  groups (Berry and Mielke 1983).

### Analysis of Home Range Size and Core Area Utilization

Seasonal and sexual differences in home range size, with interactions, were compared through a General Linear Model (GLM) (SAS Institute Inc. 1989:949-951) in which home range size was treated as the dependent variable and sex and season as independent (classification) variables. Annual range size estimates were not included in the model because they were not independent of seasonal estimates. Instead, comparisons of annual range sizes between sexes were evaluated through a t-test.

An analysis of the size and utilization of core areas was performed using the computer program HOME RANGE (Ackerman *et al.* 1990) by comparing utilization distributions generated from harmonic mean estimation of home range (Dixon and Chapman 1980) to a hypothetical uniform utilization distribution (Samuel *et al.* 1985). Conceptually, core areas denote areas of consistent or intense use (Kaufmann 1962:170). Mathematically, core areas may be defined as the maximum area where the observed utilization distribution exceeds a uniform utilization (Ackerman *et al.* 1990). We described core areas quantitatively by determining: (1) the proportional contribution of the core area to the home area (percent of home area within the core area); (2) the proportional utilization of the core area (percent of total locations of the individual within its core area) and (3) the ratio of percent utilization to percent area contributed, a value we used as an index to the intensity of use within the core area. The effects of season, sex, and season-sex interaction on the ratio of core area utilization to core area contribution to home area were evaluated using a GLM procedure similar to that described above for evaluating seasonal and sexual effects on home range size. As in home range size, annual core area utilization/contribution ratios in different sexes were

compared through a t-test.

**RESULTS**

Mean seasonal range sizes varied from 12.3 km<sup>2</sup> (winter-spring, males) to 21.2 km<sup>2</sup> (winter-spring, females), but neither season nor sex, nor their interactions, had a significant effect on estimate of home range size (Table 1;  $F = 0.26, 0.43, \text{ and } 0.34; df = 1; P = 0.62, 0.52, \text{ and } 0.57$  for season, sex, and season-sex interaction, respectively). Estimates of annual range size were not different between sexes ( $t = 0.41, df = 9, P > 0.25$ ).

Only 1 moose, M10, used 1 of its seasonal home areas (summer-autumn) in a uniform manner. All other moose had distributions of locations significantly different from uniform with significant core areas present ( $P < 0.05$ , Kolmogorov-Smirnov goodness of fit

test). Such core areas contributed 59-73% of all moose locations (utilization) but only 30-52% of the total home area (Table 2). The seasonal ratios of core area utilization to core area contribution to home area were approximately 2:1 throughout the year, and were not affected by season, sex, or their interactions ( $F = 0.03, 0.99, \text{ and } 0.13; df = 1; P = 0.87, 0.34, \text{ and } 0.72$ , respectively). Estimates of the annual utilization/contribution ratios also did not differ between sexes ( $t = 0.89; df = 9; P > 0.20$ ).

Four female moose had sufficient relocation data over a period of  $\geq 2$  years to permit evaluation of activity center movement through successive years (Table 3). These moose showed strong faithfulness to both seasonal and annual home ranges each year, with little change in activity centers. Most

Table 1. Average size (km<sup>2</sup>) of seasonal and annual home ranges of moose in Fiddler and Fishtail Creek drainages in south-central Montana, 1989-93. SE in parentheses. N = 3 male and 8 female moose for summer-autumn and annual estimates; 2 and 6, respectively, for winter-spring estimates.

Sex	Season					
	Winter-Spring		Summer-Fall		Annual	
Males	12.3	(1.1)	15.2	(2.1)	22.2	(6.5)
Females	21.2	(19.7)	16.3	(7.9)	26.6	(17.8)
Combined	18.8	(17.2)	16.0	(6.7)	25.4	(15.3)

Table 2. Utilization characteristics of core use areas of male and female moose in south-central Montana, 1989-93. M = male. F=female. SE in parentheses. N=2 and 6 male and female moose in winter-spring, 3 and 8 in other seasons, respectively.

Characteristic	Season											
	Winter-Spring		Summer-Fall		Annual							
	M	F	M	F	M	F						
Percent utilization	62.9	(2.3)	59.4	(2.2)	73.4	(13.6)	60.0	(1.3)	62.4	(1.7)	61.7	(1.6)
Percent contribution to home area	38.3	(3.0)	30.6	(3.0)	52.0	(24.0)	31.9	(1.8)	31.5	(1.8)	30.5	(1.5)
Utilization/contribution ratio	1.7	(0.1)	2.1	(0.3)	1.8	(0.4)	2.0	(0.2)	2.0	(0.3)	2.1	(0.1)

Table 3. Average distances (km) between seasonal and annual activity centers (range fidelity) of 4 female moose in Fiddler and Fishtail Creek drainages, south-central Montana, 1989-92. SE/N (Number of distance changes measured) in parentheses. Fourth column indicates ratio of average Activity Center Change (ACC) in km to average Standard Radii (SR) in km of minimum convex polygon home range estimates.

Moose	Distances between activity centers			
	Winter-Spring	Summer-Autumn	Annual	ACC/SR
71	2.4 (1.2/3)	0.5 (---/1)	0.7 (---/1)	0.33 (0.25/3)
73	1.6 (0.7/6)	0.8 (0.3/3)	0.7 (0.3/3)	0.37 (0.14/3)
74	0.9 (---/1)	1.4 (---/1)	1.1 (---/1)	0.71 (9.05/3)
75	1.7 (0.5/6)	2.5 (0.2/3)	0.8 (0.5/3)	0.57 (0.25/3)
Total	1.8 <sup>a</sup> (0.8/16)	1.5 (0.9/8)	0.8 (0.3/8)	0.49 (0.23/12)

<sup>a</sup>Different from annual mean.  $P < 0.01$ .

seasonal activity centers changed less than 2.0 km over the entire study period, and changes in annual activity centers averaged less than 1.0 km. Although shifts were larger for winter-spring ranges than for annual ranges ( $P < 0.01$ ), all shifts averaged less than one standard radii of the home areas themselves (2.6, 2.4, and 2.7 km for standard radii of winter-spring, summer-autumn, and annual home ranges, respectively), indicating that changes in activity centers occurred within, not beyond, home range boundaries. Distributions of locations within home range grid cells did not differ among years, suggesting that range utilization was relatively constant ( $P > 0.20$ , all cases). MRPP analysis did indicate significant change in range utilization in 2 of these 4 moose (Table 4; F74 and

F75,  $P < 0.01$  and  $P = 0.02$ , respectively). However, when interpreted in light of the other analyses of range utilization (grid cell analysis and activity center movement), these differences appeared to represent relatively fine scale changes of utilization within normal home range boundaries, not a major shift of the home range itself.

## DISCUSSION

### Home Range Sizes

Winter-spring home areas of moose were greater than those documented in a number of other studies (Houston 1968, Goddard 1970, Van Ballenberghe and Peek 1971, Phillips *et al.* 1973, Mytton and Keith 1981, Cederlund and Okarma 1988), similar to those documented by Mytton and Keith (1981),

Table 4. Results of Multiple Range Permutation Procedures (MRPP) analysis comparing range utilization in 4 cow moose in successive years in south-central Montana, 1989-91.  $P \leq 0.05$  interpreted as evidence of significantly different range utilization in different years.

Moose	Years Compared	Standardized test statistic	P
F71	1989 and 1990	0.08	0.38
F73	1989, 1990 and 1991	-1.07	0.13
F74	1989 and 1990	-4.86	<0.01
F75	1990 and 1991	-2.80	0.02

and less than those documented by Hauge and Keith (1981). Summer-autumn ranges were similar to or less than those documented by some investigators (Hauge and Keith 1981, Mytton and Keith 1981, Leptich and Gilbert 1989), but greater than those documented by others (McMillan 1954, de Vos 1956, Knowlton 1960, Van Ballenberghe and Peek 1971, Cederlund and Okarma 1988).

Sample size differences in different studies may affect results of home range estimation and accuracy of estimate. Generally, our results were more similar to more recent studies with larger numbers of relocations than to earlier (pre-1980) studies with smaller numbers of relocations. The sample sizes on which our home area estimates are based ( $\geq 20$  seasonal locations,  $\geq 40$  annual locations) generally are considered sufficient for accurate determination of home range estimates (Ackerman *et al.* 1990). Our minimum sample sizes were larger and our consecutive locations more widely separated in time (less subject to serial correlation) than those in several recently published studies (Cederlund and Okarma 1988, Leptich and Gilbert 1989, Cederlund and Sand 1994). Direct experimental investigations of the relationship between home range and numbers of locations (Bekoff and Mech 1984, Boulanger and White 1990) have determined that larger samples can result in improved accuracy of estimation. However, in this study, our own tests of sample size adequacy, previously described, indicated that additional locations beyond our minimums added little additional area to the home range estimate.

All resources needed by an animal are found within its home range. Therefore the size of an animal's home range provides an index to the density and distribution of needed resources, and, for managers, a first approximation of habitat quality. The home areas of moose in this population were within previously documented limits for moose in other areas, but tended to be larger than those

reported in most previous studies. The relatively large home ranges of moose in this study area were probably reflective of the relative scarcity and patchy distribution of favored habitats, especially aspen and shrub-dominated wetlands (Van Dyke *et al.* 1996). In our study area, such preferred habitats were separated by large contiguous blocks of coniferous, especially lodgepole pine, forests, which were used at lower than expected rates by moose in all seasons (Van Dyke *et al.* 1996). Moose movement patterns were characterized by intensive use of individual core areas, interspersed with deliberate, long-distance movements from one core area to another. This pattern produced our observed combination of large home areas and highly non-uniform home range use, and is similar to patterns of moose home range use described by Van Ballenberghe and Peek (1971) and by Cederlund and Okarma (1988).

Competition from other ungulates can affect home range size and use in moose. However, in this study area, differences in habitat use normally created spatial separation of ungulates in all seasons. Elk normally used higher elevations and spent more time in coniferous forest habitats in summer, and moved out of the study area entirely during winter. In summer, moose in this area avoided coniferous forest and were usually located in aspen (Van Dyke *et al.* 1996), thus minimizing contact with elk. Livestock and mule deer in this area normally used lower elevations than moose in all seasons and concentrated use in bunchgrass-forb and bunchgrass-sagebrush communities, habitats which moose rarely used (Van Dyke *et al.* 1996). The greatest amount of seasonal habitat overlap appeared to be between moose and white-tailed deer in riparian areas in winter. Densities and use of both species were high in these habitats in this season, but neither appeared to change patterns of habitat use in response to presence or absence of the other. Hayden-Wing (1979), investigating a similar mix of



ungulate species in southeastern Idaho, found little interaction between species. In that study, distributions of each ungulate, including moose, were explained more by snow depth, vegetation, and human activity than by interspecific interaction. In Manitoba, Rounds (1981) found little overlap in habitat use by moose and elk. In northwestern Montana, Singer (1979) found distinct habitat use by moose, elk, and white-tailed deer. In this study area, we saw no evidence that seasonal or annual home range use in moose was influenced by other ungulates.

### **Patterns of Home Range Fidelity**

The small changes in home range activity centers, combined with similar distributions of moose locations in home range cells in different years, lead us to accept the null hypothesis than activity centers and overall distribution of animal use in the home range does not differ from year to year. This supports the assumption that adult cow moose remain faithful to their home range over time and that their use of such home range, while non-uniform, does not vary between years. However, results of our MRPP analysis did indicate some annual variation in distributions of locations within some home ranges. The MRPP test is valuable as a quantitative assessment of home range fidelity because it tests whether groups of locations come from a common probability density distribution (White and Garrott 1990:135). Such a test has considerable advantages over traditional range overlap estimations in both quantitative precision and statistical power (Holzenbein and Marchinton 1992), and was able to detect fine-scale differences in home range use that were not detected by comparisons of annual activity centers or by distribution of locations in home range cells.

The tendency of moose to use their home ranges slowly and in a non-uniform manner suggests that short-term studies of moose home range, regardless of sample sizes gen-

erated, may underestimate sizes of both seasonal and annual ranges. A potential criticism of long-term home range studies is that animals may change home range boundaries over time, effectively subdividing locations into temporal subsets and reducing effective sample size (Lair 1987). Increased attention to the problem of range fidelity would help to evaluate this criticism. Such attention also would help to determine whether biological inferences and management decisions based on home range data should assume single or multiple home ranges over an animal's life span. The lack of change in home range activity centers and in distributions of locations in major home range subunits (grid cells) supported the hypothesis that resident adult female moose in this population had relatively constant home ranges for  $\geq 2$  years, that such time frames are appropriate for home range study, and that sufficient animal locations systematically spread over such time periods would provide accurate estimates of range sizes and boundaries.

### **MANAGEMENT IMPLICATIONS**

The faithfulness of resident female moose to seasonal and annual home ranges for up to 3 years, coupled with the relatively slow rates at which moose use their home ranges suggest that managers may gain more reliable information on this species through greater investment in long-term studies of annual home range characteristics. Such long-term data may provide more reliable estimates of home range sizes and boundaries and more complete identification of high use areas. In addition, our results support the hypothesis that, once reliably identified, home range boundaries, sizes, and use patterns may remain relatively stable throughout the life of resident adult moose. The more permanent seasonal ranges of moose in this population, like those of other Shiras moose populations, favor a management system in which long-term data contribute to an accurate assess-

ment of condition and trend in forage supplies in core use areas (Peek 1974).

Because of the disproportionate utilization of moose in this population made of their core areas, managers should consider shifting emphasis from traditional strategies of broad scale habitat management to more intensive, site specific management of intensively used areas. In fact, our results suggest that it is far more valuable in moose management to identify core use areas than to simply plot seasonal and annual home range boundaries. Once identified, the most effective use of management resources is to enhance beneficial characteristics of core areas for moose and, where possible, replicate such characteristics on other sites within moose range. Such intensive management could prove more cost-effective than management aimed at larger land units, much of which is never used by moose. This strategy may be especially applicable for other western moose populations where preferred habitats are patchily distributed.

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