The Status, Habitat, and Response to Grazing of Water Vole Populations in the Big Horn Mountains of Wyoming, U.S.A.

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The Status, Habitat, and Response to Grazing of Water Vole Populations in the Big Horn Mountains of Wyoming, U.S.A.

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Abstract

Microtus richardsoni, the water vole, was listed as a sensitive species in Region 2 of the USDA Forest Service in 1994. Historical records indicate water voles were found in the Big Horn Mountains, but little was known about their current status. The purpose of this study was to locate water voles in the Big Horn Mountains of Wyoming, develop a habitat profile, and evaluate the extent to which livestock grazing affects them. Accessible creeks with habitat requirements for water voles were surveyed. Water voles were not captured below 2440 m. Grazed and ungrazed sites occupied by water voles were matched and analyzed for percent plant cover, dry weight biomass, riparian classification, mean stream depth, channel type, elevation, precipitation, and temperature. Capture success was significantly greater in ungrazed areas. Percent cover by ferns and thallophytes was significantly greater in areas where water voles were more abundant, and bare ground was significantly greater at grazed locations. Water voles were most abundant on Rosgen B or E streams with a willow/wet *Carex* riparian class that is found on relatively undisturbed sites with stable, well-developed soils and bank structure. In the Big Horn Mountains, water vole captures were low in comparison to the Beartooth Mountains and synergistic effects of grazing and drying might negatively impact this species.

Introduction

The Rocky Mountain Region, Region 2 of the USDA Forest Service, listed *Microtus richardsoni* (formerly *Arvicola richardsoni*), the water vole, as a sensitive species in 1994 because it was thought to be uncommon to rare in this region and because its habitat may be declining due to damage caused by poor livestock grazing practices (USDA Forest Service, 1994; Friedlander, 1995). Within Region 2, water voles are found only in Wyoming. The Wyoming Natural Diversity Database (WYNDD) at the University of Wyoming, Laramie, is updating the water vole state heritage rank to G5/S1. The data indicate that the water vole is critically imperiled and has a relatively high probability of extinction in the state (Keinath and Beauvais, 2002). Water voles in the Big Horn Mountains are at the eastern edge of their distributional range, and WYNDD has maintained a separate status ranking for them, which is being revised to G5T1Q/S1 (Keinath and Beauvais, 2002). This rank indicates a unique intraspecies taxon with a high probability of extinction. Unfortunately, little is known about water voles in the Big Horn Mountains. The purpose of this study was to locate water voles in the Big Horn Mountains, develop a quantitative profile of occupied habitat, and evaluate the extent to which livestock grazing affects them.

Water voles have a limited and discontinuous geographic range, small local populations, and are habitat specialists (Ludwig, 1981). Water voles are distributed along alpine and subalpine streams in linear patches with small populations of 8 to 40 animals (Hollister, 1912; Racey and Cowan, 1935; Pattie, 1967; Hooven, 1973; Anderson et al., 1976; Clark and Stromberg, 1987; Ludwig, 1988). They occur between 914 and 3201 m in the U.S.A. and between 1524 and 2378 m in Canada. Water voles are semiaquatic and use clear, spring-fed mountain streams with gravel bottoms for escape and as transportation routes for daily movement and postjuvenile dispersal (Anderson et al., 1976; Ludwig, 1984). Preferred habitat includes sites with about 5° slope, narrow stream channels, and a well-developed substratum of soil for burrowing next to the stream (Pattie, 1967; Anderson et al., 1976; Ludwig, 1981; Getz, 1985; Reichel, 1986; Anthony et al., 1987). Water voles use mid-to-late seral stage streamside vegetation of willow, sedges, grasses, and mesic forbs that provide 75% cover (Pattie, 1967; Anderson et al., 1976; Ludwig, 1981; Getz, 1985; Reichel, 1986; Anthony et al., 1987; Blankenship, 1995). They live at higher elevations with a short 3- to 4-mo period of vegetative growth (Ludwig, 1981).

Livestock can alter the abiotic characteristics of riparian ecosystems, causing wider stream channels, compacted soil, fractured stream banks followed by erosion and sedimentation, altered nutrient cycles, and changes in soil moisture patterns (Gifford and Hawkins, 1978; Kauffman and Krueger, 1984; Marcus et al., 1990; Platts, 1991; Fleishner, 1994; Belsky et al., 1999; Clary, 1999). When cattle compact the soil, water runoff increases and the availability of water to riparian vegetation is reduced. Gifford and Hawkins (1978) found significantly different water infiltration rates between grazed and ungrazed sites. Erosion caused by deteriorating stream banks can lower water tables and reduce stream flow (Armour et al., 1991; Platts, 1991). Temperature and evaporation increase as vegetative cover decreases and accelerates water loss (Platts, 1991).

Plant cover influences abiotic characteristics such as penetration of light to underlying plants and soil, air and soil temperature, plant growth, and soil moisture or texture (Platts, 1991) and provides protection from predation, security habitat, and food for voles (Birney et al., 1976). In winter, heavy cover makes the subnivean space more hospitable to voles by pre-

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venting dense packing of snow (Birney et al., 1976). The composition of small mammal communities is affected by these structural attributes (Grant et al., 1982) and these features probably combine to make an area either suitable or unsuitable for water voles (Clark and Stromberg, 1987; Blankenship, 1995).

Fleischner (1994) found a reduction in small mammal density and diversity on grazed sites. Getz (1970) concluded that heavy predation on voles occurred where cover was removed and *Microtus pennsylvaticus* was more abundant in areas of heavy cover (Eadie, 1953). At their grazed montane sites, Grant et al. (1982) found a sharp reduction of small mammal biomass accompanied by the loss of rare species with one or more of the remaining species becoming dominant. Reduced cover increases the vulnerability of *Microtus montanus* to predation and population densities remained low (Douglass and Frisinna, 1993). Klaus et al. (1999) had significantly greater capture success of *Microtus richardsoni* at ungrazed sites. Loss of cover may inhibit extreme population fluctuations (Douglass and Frisina, 1993). The regular irruptions characteristic of other *Microtus* species have not been reported in water voles and were not observed during this study.

Materials and Methods

STUDY SITE DESCRIPTION

The Big Horn Mountains are an island mountain range that lies east of the Rocky Mountain chain and sweeps in a north-to-south arc from Montana at about 45°N latitude toward the center of Wyoming at about 43°30′N latitude. The first phase of this study was to survey alpine and subalpine streams in the Big Horn Mountains that met the criteria for water vole habitat. In 1997, creeks on the south end of the range were surveyed and in 1998, the creeks on the north end were surveyed (Fig. 1).

When the survey was complete, the study's second phase began in 1999. Trapping efforts focused on matched grazed and exclosed sites where water vole populations and key habitat features could be compared (Table 1). Sites at the north end were selected for further study because at these sites there were more creeks occupied by water voles and because two south-end sites became inaccessible after access through private land was curtailed. Duncum Creek was selected and studied in 1999, but in 2000 the access road was permanently blocked. Wyoming Gulch and the Rooster Hill Exclosure were substituted for the Duncum Creek site. Habitat features for the selected locations are summarized in Table 2. Historically, sheep grazed these sites as well as cattle and Wyoming Gulch was mined (Murray, 1980; Bischoff, pers. comm., 2001). Cattle now graze these sites on rotation and use them at about the same time each season.

CAPTURE TECHNIQUES AND HANDLING

Live trapping was conducted according to the American Society of Mammalogists guidelines (Animal Care and Use Committee, 1998). Large Sherman live-traps were baited with a mixture of oats, peanut butter, and vanilla flavoring and placed approximately 3 m apart along alpine and subalpine streams according to the procedure used by Anderson et al. (1976), Ludwig (1981), and Klaus et al. (1999). Each location was trapped for four consecutive nights and the number of traps used varied with the length of water vole habitat at the site (Table 3). Traps were checked a minimum of twice daily, once early in the morning and once in the late afternoon or early evening. In 1997, 1998, and 1999, two trapping sessions were conducted, one in late May and early June and the other in late July and early August. The purpose was to mark water voles for later recapture to estimate population size. Bald Mountain Creek was the only site where water voles were captured during the early trapping session and none of these was recaptured. Therefore, in 2000 and 2001, all trapping was done in late July and early August. Simple ecological density was estimated for each selected site by taking the mean number of water voles captured per meter along the length of the stream trapped times 1000 (Table 2).

All captured animals were identified by species, weighed, and sexed. Each water vole was given a unique and permanent tattoo number code, classified into one of three age categories based upon body weight (Table 4), and released at the site of capture. The age categories were Adult (70–125 g), Class II (50–69 g), and Class I (13–49 g) (Ludwig, 1981). Males were considered reproductively active if testes were scrotal or could be palpated. Females were considered reproductively active if they were in estrus or lactating, the vaginal opening was perforate, or the pubic symphysis was open.

ANALYSIS PROTOCOLS

Trap intervals, relative abundance of all small mammals, relative abundance of water voles, and the Shannon-Wiener Diversity Index were calculated for each creek trapped in the second phase of the study (Table 3). To clarify whether creeks with similar Shannon-Wiener indices are similar in evenness and richness patterns or whether one is the product of similar evenness and the other of species richness, relative abundance and diversity of species within each community were evaluated by plotting the relative abundance of species against their rank in abundance (Cox, 1996; Fig. 2).

At each site, six streamside canopy cover estimates were made at randomly determined locations with a 20-cm-by-30-cm Daubenmire frame (Daubenmire, 1959). Cover was defined as all horizontal extensions of the plant and the summed values may exceed 100%. Cover was recorded as estimates of the percent of the quadrat covered by each species within the frame following Goldsmith et al. (1986). Daubenmire frames were placed at randomly determined locations along each creek every time the creek was trapped. Plants in the quadrant were identified to species before type-grouping them according to Whittaker (1975) (Table 5). The vegetation within each frame was clipped, dried in an oven at 80°C for 48 h, and weighed to obtain dried biomass (Table 5). Girard et al. (1997) developed a classification system for riparian habitat in the Big Horn Mountains using characteristics of vegetation and soil types, seral stage, and potential natural community and these classifications were used to evaluate the sites (Table 2).

Mandrella (pers. comm., 2001) classified the streams as B, E, or G (Table 2) using the Rosgen system (Rosgen, 1994, 1996). Type B channels are riffle dominated and moderately entrenched with moderate width-depth ratio and sinuosity. Type E streams have gentle gradient, riffle/pool type channels that are slightly entrenched with very low width-depth ratio and very high sinuosity. Type G streams are entrenched gully step/pool channels with low width-depth ratio and moderate sinuosity. All of these channel types have water surface slopes between 2 and 4%. Water depth was measured at three randomly determined locations along each creek (Table 2).

In each pairwise comparison of data sets, mean percentages were arcsine transformed prior to statistical analysis. Each data set was then tested using one-way analysis of variance (ANOVA). If variances were homogeneous, a two-tailed *t*-test was

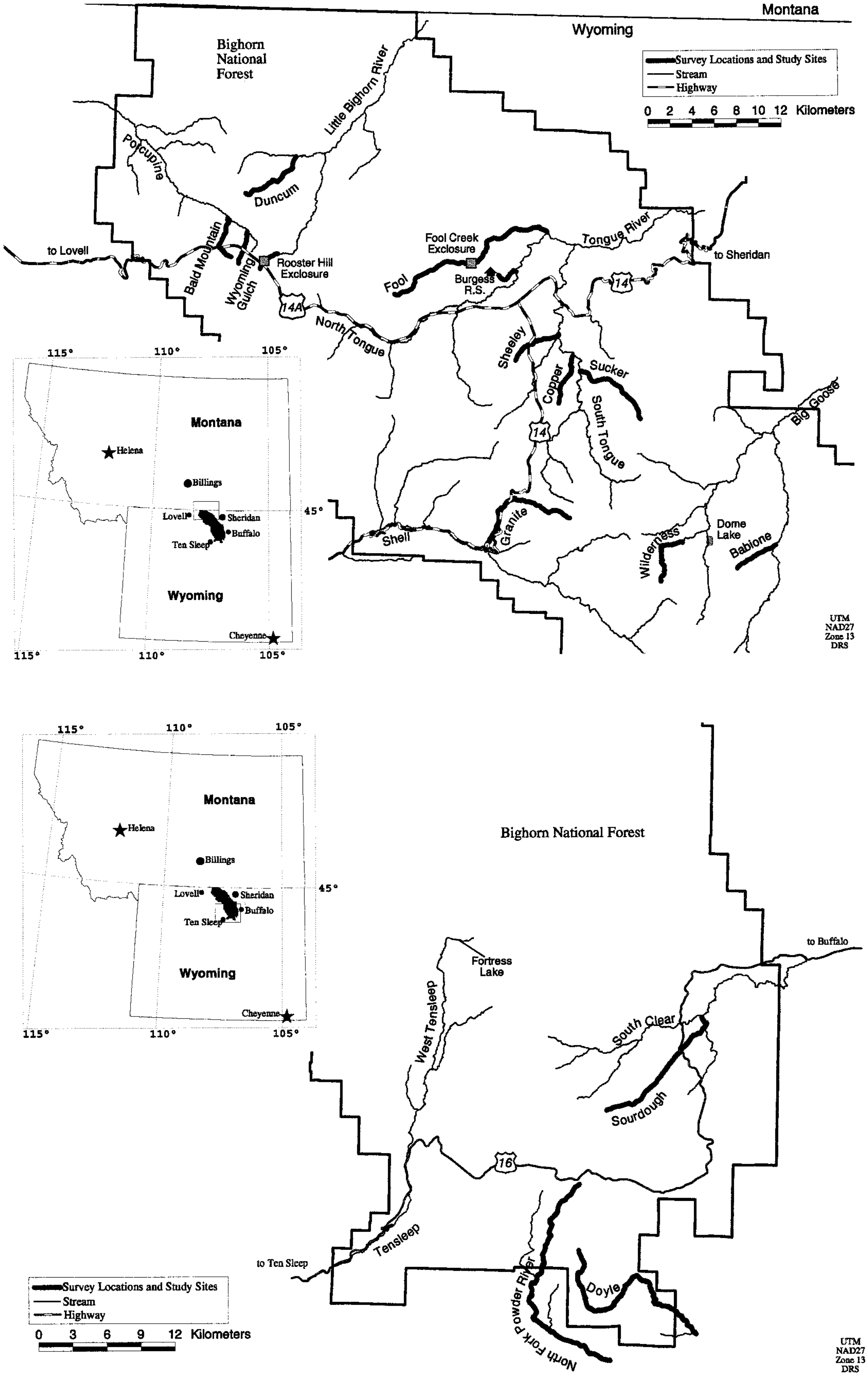

FIGURE 1. Regional map of the Big Horn Mountains and trapping locations within the Big Horn Mountains (map by D. Scaife).

TABLE 1

Matched sites studied for water voles in grazed and ungrazed habitats of the Big Horn Mountains. The permitted grazing dates and the number of mature cattle and yearlings at each site are the times and numbers allowed in the grazing permit. The Fool Creek exclosure effectively excluded cattle for only one year of this study.

Grazed Locations	Permitted Grazing Dates; Mature Cattle; Yearlings	Matched Ungrazed Locations	Date of Effective Exclosure
Bald Mountain Creek	7/6–9/30; 225; varies	Rooster Hill Exclosure	1950
Duncum Creek	6/26–10/10; 1087; —	Duncum Creek	Lay down exclosure; up in June, down in Aug.
Fool Creek	6/16–10/10; 1008; —	Fool Creek Exclosure	1979, down in 1999 and rebuilt in new location, 2000
Wyoming Gulch	7/6–9/30; 225; 125–140	Rooster Hill Exclosure	1950

used to determine significance. If variances were heterogeneous, the Wilcoxon Mann-Whitney *U*-test was used. To determine if the relative abundance of water voles was dependent upon certain habitat variables, r^2 values were computed in a linear regression analysis (Table 5). The mean percent cover by all plant life forms, dry weight biomass, water depth, and elevation as well as precipitation and temperature (Burgess Junction Climate Station, Western Regional Climate Center, 2001) were compared with the relative abundance of water voles in a multivariate principal components analysis to account for the correlations among variables and to reduce the number of variables to those that best explain the variation in the data (Kleinbaum et al., 1988). Then, the four variables most closely aligned with water vole relative abundance were compared using a second multivariate principal components analysis followed by orthogonal rotation of the axes (Fig. 3). Minitab version 13.31 was used for these calculations.

Results

The initial surveys provided information regarding the presence or absence of water voles at potential habitat sites in the Big Horn Mountains. Babione Creek, Baby Wagon Creek, Copper Creek, Doyle Creek, Duck Creek, Fortress Lake, Granite Creek, North Fork of the Powder River, Sheeley Creek, Sourdough Creek, Sucker Creek, and an unnamed tributary of the Tongue River near the Burgess Ranger Station were surveyed, but water voles were not captured. Doyle Creek, Owen Creek, and Circle Park were also sampled by Beauvais (pers. comm., 1999) without water vole captures. Elevations of these sites ranged from 2317 m to 3207 m with a mean of 2613 m. Water voles were not captured at elevations below 2440 m. The unnamed tributary to the Tongue River at the Burgess Ranger Station, Sheeley Creek, Sourdough Creek, and Sucker Creek were all below 2440 m.

Capture success was significantly greater overall in ungrazed drainages ($U = 103.5$, $P = 0.034$). Only juvenile water voles (Class I and Class II) were trapped at the Fool Creek exclosure. The Fool Creek Exclosure was taken down in 1999 and a new one was built that was an effective exclosure for only one year of this study. At Duncum Creek, Fool Creek, and Wyoming Gulch, only one adult water vole was captured during the study period. Bald Mountain Creek and the Rooster Hill Exclosure were the only sites where more than one adult water vole was trapped. Both sites are classified as willow/wet *Carex* (Table 2) and have much more willow (shrub) cover than any of the other locations (Table 5, Fig. 4).

At the matched sites, there were no significant differences in elevation, precipitation, temperature, water depth, or dry weight biomass between grazed and ungrazed locations. These

TABLE 2

Comparison of water vole habitat variables on each of the streams studied. The Rooster Hill Exclosure seep and Bald Mountain Creek were the two best sites for water vole capture. Note that both have a willow/wet Carex *riparian classification while the other creeks are classified differently.*

Location	Elevation (m)	Aspect	Rosgen Stream Class[a]	Riparian Class[b]	Mean Water Depth (cm)[c]	Ecological Density of water voles[d]	Site Rank (1 = best)
Bald Mountain Creek	2743	40° NE	B	Willow/wet *Carex*	35	24	2
Duncum Creek	2572	48° NE	G	Dece/Forb and Cami/Dece	27.9	3	6
Fool Creek	2484	78° NE	B	Cami/Dece	21.5	9	5
Fool Creek Exclosure	2490	90° E	B	Cami/Dece	17.0	15	3
Rooster Hill Exclosure	2798	72° NE	E	Willow/wet *Carex*	1.85	57	1
Wyoming Gulch	2804	22° NE	E	Popr/Taof and Dece/forb	21.1	12	4

[a] Mandrella (2001).
[b] Beard (2001) and Bischoff (2001); Dece = *Deschampsia cespitosa,* Cami = *Carex microptera,* Popr = *Poa pratense,* Taof = *Taraxacum officinale.*
[c] Mean of means; N = 6.
[d] Number of water voles/mean distance trapped × 1000.

TABLE 3

Summary of sampling effort, relative abundance, Shannon-Wiener Diversity index, and mean population density at each location for all years of the study

Location	Mean Distance Trapped (meters)	Trap Interval[a]	Total Captures	Relative Abundance of Small Mammals[b]	*M. richardsoni* Captures	Relative Abundance of *M. richardsoni*[b]	Shannon-Wiener Diversity Index[c]
Bald Mountain	920	1522.5	132	0.087	22	0.014	0.51
Duncum Creek	854	418.0	10	0.024	3	0.007	0.48
Fool Creek	662	752	78	0.104	6	0.008	0.58
Fool Creek Exclosure	465	440	99	0.225	7	0.016	0.66
Rooster Hill Exclosure	88	130.5	10	0.077	5	0.038	0.04
Wyoming Gulch	243	726	41	0.056	3	0.004	0.62

[a] Trap Interval = (number of traps placed × number of intervals) − (number of sprung traps × 0.5), where 1 interval = 24 hours and sprung traps = all traps closed, with or without captures at all intervals (Nelson and Clark, 1973).

[b] Relative Abundance = number captured/trap interval.

[c] $H' = -\Sigma_{i=1}^{k} p_i \log p_i$; where $p_i = n_i/N$ (Cox, 1996).

sites were northeast or east in aspect (Table 2). The amount of bare ground at grazed locations was significantly higher (t = 2.93, $P < 0.061$). Variables that correlate most strongly with the relative abundance of water voles are the percent cover by ferns, thallophytes (mosses and liverworts), and shrubs. However, only cover by ferns and thallophytes was significant. Ferns were significant at $\alpha_{0.01}$ (F 26.30, df = 1 and 4, P = 0.007) and thallophytes were significant at $\alpha_{0.025}$ (F 15.68, df = 1 and 4, P = 0.017). Ferns were only found at the Rooster Hill Exclosure site where cattle have been effectively excluded since 1950. This exclosure had the highest percent cover by thallophytes and shrubs and the most dry weight biomass (Table 5). After the initial screening of all available components, the second multivariate principal components analysis generated two main clusters (Fig. 3). The first cluster, which included relative abundance, percent cover by ferns, and percent cover by thallophytes, had an eigenvalue of 4.1 and accounted for 82% of the variance. The second cluster, which included percent shrubs and dry weight biomass, had an eigenvalue of 0.68 and accounted for 14% of the variation.

The Rooster Hill Exclosure had the lowest Shannon-Wiener Diversity Index. Half of the small mammals captured at this exclosure were water voles. Both adult and juvenile water voles were captured there, despite the shallow seep of water available to them (Tables 2, 3). With a mean depth of only 1.85 cm, the Rooster Hill Exclosure seep is too shallow for an adult water vole to swim for escape or transportation. At this site, released water voles invariably ran into the willows for escape and away from the shallow seep. At other sites, released water voles ran to the water for escape. Water voles were captured along streams classified as Rosgen types B, E, and G (Table 2) with a mean water depth of 19.4 cm.

Water vole mean ecological density, reproductive maturity, and body weight variables are grouped for grazed and ungrazed sites in Table 4. There were no significant differences in age at time of capture between grazed and ungrazed creeks in pairwise comparisons by class and by clustering all the young captured in grazed and ungrazed locations. No significant differences in comparisons of body weight or age of sexual maturity at grazed and ungrazed locations were found even though more juvenile water voles were found and they generally reached sexual maturity earlier at grazed sites (Table 4).

TABLE 4

Water vole capture summary from the matched grazed and ungrazed sites as well as body weight and reproductive maturity for each age class

Water Vole Characteristic	Grazed	Ungrazed
Estimated ecological density of water vole populations (voles/m × 1000)	12.0	36.0
Young in the population (% Class I and II)	38%	28%
Male weight (mean ± SEM g)		
Class I	26.0 ± 0.58, N = 3	27.8 ± 6.0, N = 5
Class II	57.5 ± 2.64, N = 11	57.8 ± 2.0, N = 6
Adult	106.5 ± 5.81, N = 8	114.5 ± 1.5, N = 2
Female weight (mean ± SEM g)		
Class I	27.0 ± 13.0, N = 2	24.5 ± 4.5, N = 2
Class II	58.8 ± 0.9, N = 4	58.0 ± 0.0, N = 2
Adult	101.8 ± 5.96, N = 6	103.5 ± 1.5, N = 2
Reproductively active voles (mean %)		
Class I	0.57, N = 5	0.42, N = 7
Class II	0.60, N = 15	0.62, N = 8
Adult	1.00, N = 14	1.00, N = 4

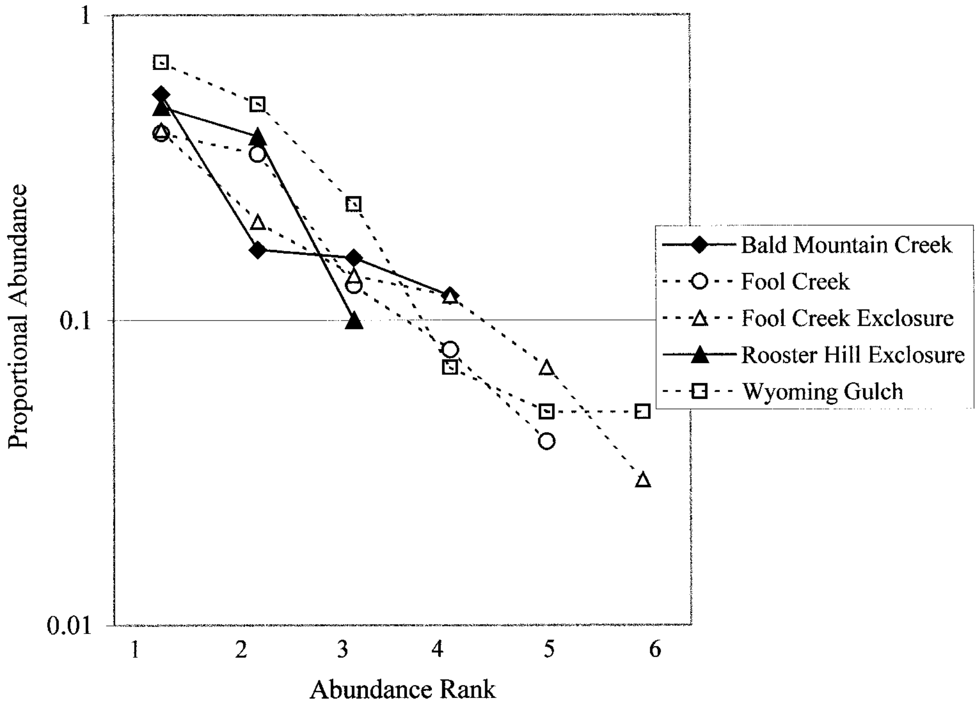

FIGURE 2. Relative abundance of all captured species at each location. While more water voles were captured at the Rooster Hill Exclosure and Bald Mountain Creek sites, fewer small mammal species were captured and the small mammal community was less diverse at these locations, as indicated by the shorter solid lines. The steep lines indicate that one species of small mammal dominated the captures at each location.

Riparian classification for the Rooster Hill exclosure seep and Bald Mountain Creek was a willow/wet *Carex* community type that is found on seeps and swales with limestone parent materials (Girard et al., 1997; Bischoff, pers. comm., 2001; Table 2). This community type stays wet throughout the growing season and its topographic features help hold the moisture. Duncum Creek was classified between the *Deschampsia cespitosa*/Forb type, a common early seral community, and the *Carex microptera*/*Deschampsia cespitosa* transition type (Girard et al., 1997; Bischoff, pers. comm., 2001). Fool Creek, both in and out of the exclosure, was classified as *Carex microptera*/*Deschampsia cespitosa* type with a potential natural community of the *Carex rostrata* ecological type due to the Type B stream channel at that location (Girard et al., 1997; Beard, pers. comm., 2001). Wyoming Gulch has a *Poa pratense*/*Taraxacum officinale* and *Deschampsia cespitosa*/forb riparian classification (Girard et al., 1997; Bischoff, pers. comm., 2001). Wyoming Gulch dries up late in August or September of some years (Bischoff, pers. comm., 2001).

Discussion

In the Big Horn Mountains, water voles were captured at only 33% of the streams they were expected to occupy. In comparison, they were captured at 71% of the streams they were expected to occupy in the Beartooth Mountains (Luce, 1995). A total of only 18 adults and 37 juvenile water voles were captured during the 5 yr of this study and fewer water voles were captured when precipitation levels were lower.

Whereas the percent cover by ferns and thallophytes was a

TABLE 5

Mean percent cover ±SE, dry weight biomass, and linear regression coefficient of water vole relative abundance and plant life form

Plant Life Form[a]	Bald Mountain Creek (grazed)	Duncum Creek (grazed)	Fool Creek (grazed)	Fool Creek Exclosure (ungrazed)	Rooster Hill Exclosure (ungrazed)	Wyoming Gulch (grazed)	Coefficient of Determination[d] (r^2)
Thallophytes[b]	16.7 ± 0.2	12.0 ± 4.1	19.9 ± 12.4	15.8 ± 15.6	34.7 ± 27	2.0 ± 0.7	0.80
Horsetails	0.1 ± 0.1	5.3 ± 3.3	0.0	0.13 ± 0.125	0.3 ± 0.2	4.6 ± 3.5	0.30
Ferns	0.0	0.0	0.0	0.0	0.02 ± 0.2	0.0	0.87
Graminoids	17.9 ± 10.5	5.25 ± 2.6	22.5 ± 9.5	34.6 ± 13.3	6.5 ± 6.2	1.7 ± 0.8	0.01
Forbs	7.7 ± 4.8	9.4 ± 4.3	16.0 ± 7.5	37.1 ± 19.2	24.7 ± 10.3	11.3 ± 6.5	0.20
Shrubs	54.2 ± 17.6	4.6 ± 3.5	0.0	0.0	63.3 ± 24.2	22.6 ± 21.6	0.50
Litter	33.0 ± 13.8	20.6 ± 5.6	21.0 ± 12.2	47.0 ± 18.6	31.2 ± 28.2	16.7 ± 16.2	0.20
Bare ground or rock	2.5 ± 2.5	3.8 ± 3.8	2.3 ± 2.12	0.13 ± 0.1	0.0	0.4 ± 0.4	0.25
Mean[c] dry weight biomass (g)	148.6	58.5	40.7	47.4	194.7	66.9	0.25

[a] Whittaker, 1975.
[b] Mosses and liverworts.
[c] Mean of means.
[d] Linear regression of water vole relative abundance and plant life form (Zar, 1996).

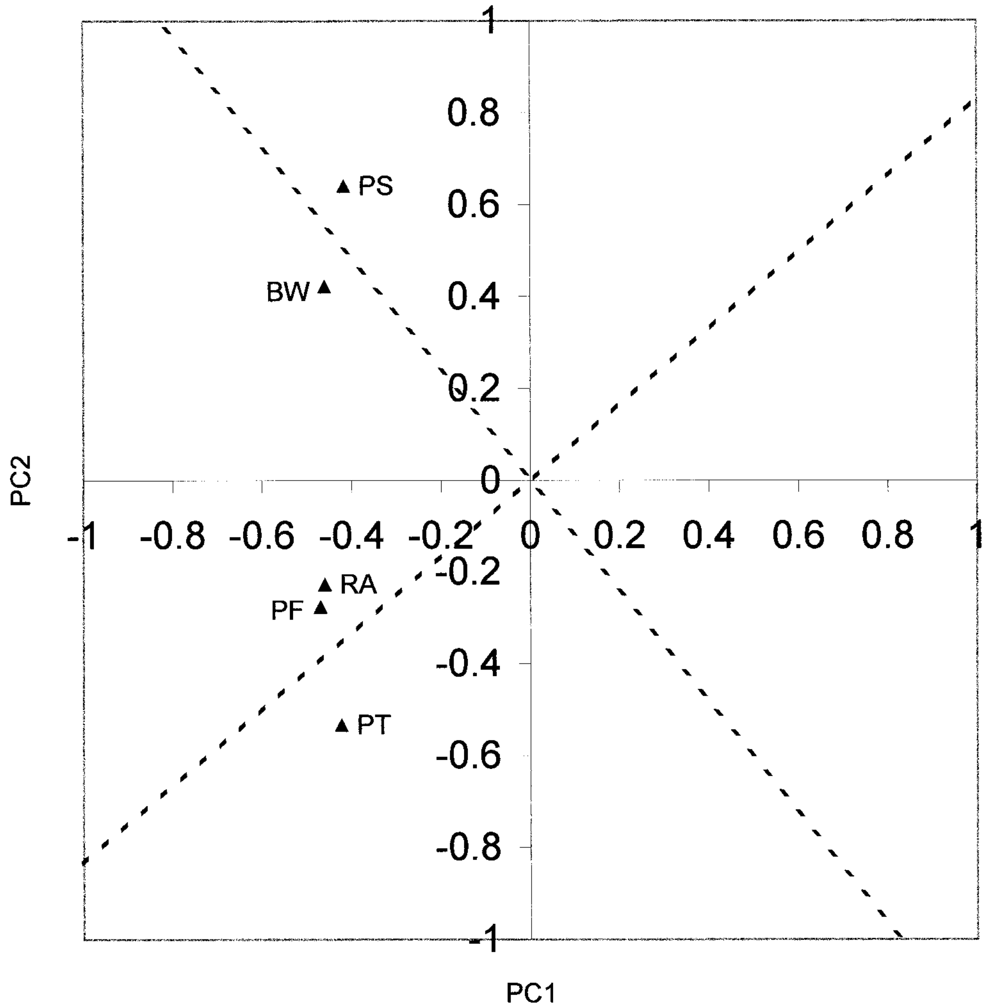

FIGURE 3. Principal components analysis of the four variables most likely to explain the relative abundance of water voles. PC1 is principal component number one; PC2 is principal component number 2; RA is the relative abundance of water voles; PF is percent cover by ferns; PT is the percent cover by thallophytes; PS is the percent cover by shrubs; and BW is the dry weight biomass (Graph by R. Smith).

significant predictor of water vole abundance, water voles are not known to use these plants for food (Anderson et al., 1976; Ludwig, 1981), and these plants are too low in stature at these latitudes and elevations to be used for cover. Because these plants require external water for reproduction, they may indicate that the amount of available water is an important habitat component. Grazing has been shown to reduce water availability to plants. The Rooster Hill Exclosure was the only site where ferns were found. Willow cover was not statistically significant, but willows provided protective cover for the water voles and were important for their survival at this location (Fig. 4). This site had the second highest relative abundance of small mammals, but the lowest diversity index because the majority of the captures were water voles. Belsky et al. (1999) stated that diversity estimates may be higher in grazed locations where the landscape is more homogeneous, as riparian specialists decline and more mesic species move into the site.

Bald Mountain Creek is grazed, but it had the greatest relative abundance of small mammals and more water voles were captured here than at any other site (Table 4). Like the Rooster Hill Exclosure, Bald Mountain Creek has a relatively high percent cover by willows (Fig. 4). At this site, cattle were observed to trail around willows and the uneven ground where the willows grew. Livestock accessed the creek only at locations where willows were absent. The cattle did not appear to enter into or feed on these willows, thus cover was not reduced and the stream bank was not trampled. Cattle were observed to access this site later in the season. Only the Rooster Hill Exclosure seep and Bald Mountain Creek had a willow/wet *Carex* riparian classification (Table 2). This type of community is found on relatively undisturbed sites with stable, well-developed soil and bank structure (Girard et al., 1997), important habitat components for water voles.

The Fool Creek Exclosure was an effective exclosure for only 1 yr of this study. Belsky et al. (1999) found it takes 2 to 15 yr to initiate recovery on a grazed site depending on climate conditions and soil fertility. Nevertheless, the relative abundance of both small mammals and water voles captured in the exclosure was double that outside the exclosure (Table 4). Small mammals are known to congregate inside exclosures where food and cover are abundant (Belsky et al., 1999). While willows were not found at any of the sampled sites in or out of the Fool Creek exclosure, a few were caged within the exclosure. The *Carex microptera*/*Deschampsia cespitosa* community at Fool Creek is found in disturbed areas on moist but not saturated riparian sites on soils with granitic or sedimentary parent materials (Girard et al., 1997).

Duncum Creek had the lowest abundance of small mammals and Wyoming Gulch had the lowest relative abundance of water voles (Table 4). These have a drier community type found on disturbed soils that tend to become compacted and have less moisture holding capacity (Girard et al., 1997). The plants at Duncum Creek do not stabilize the bank, and trailing, trampling, and compaction are evident. This site had the highest percentage of bare ground. The Wyoming Gulch community type is found in highly disturbed areas where potential vegetation has been

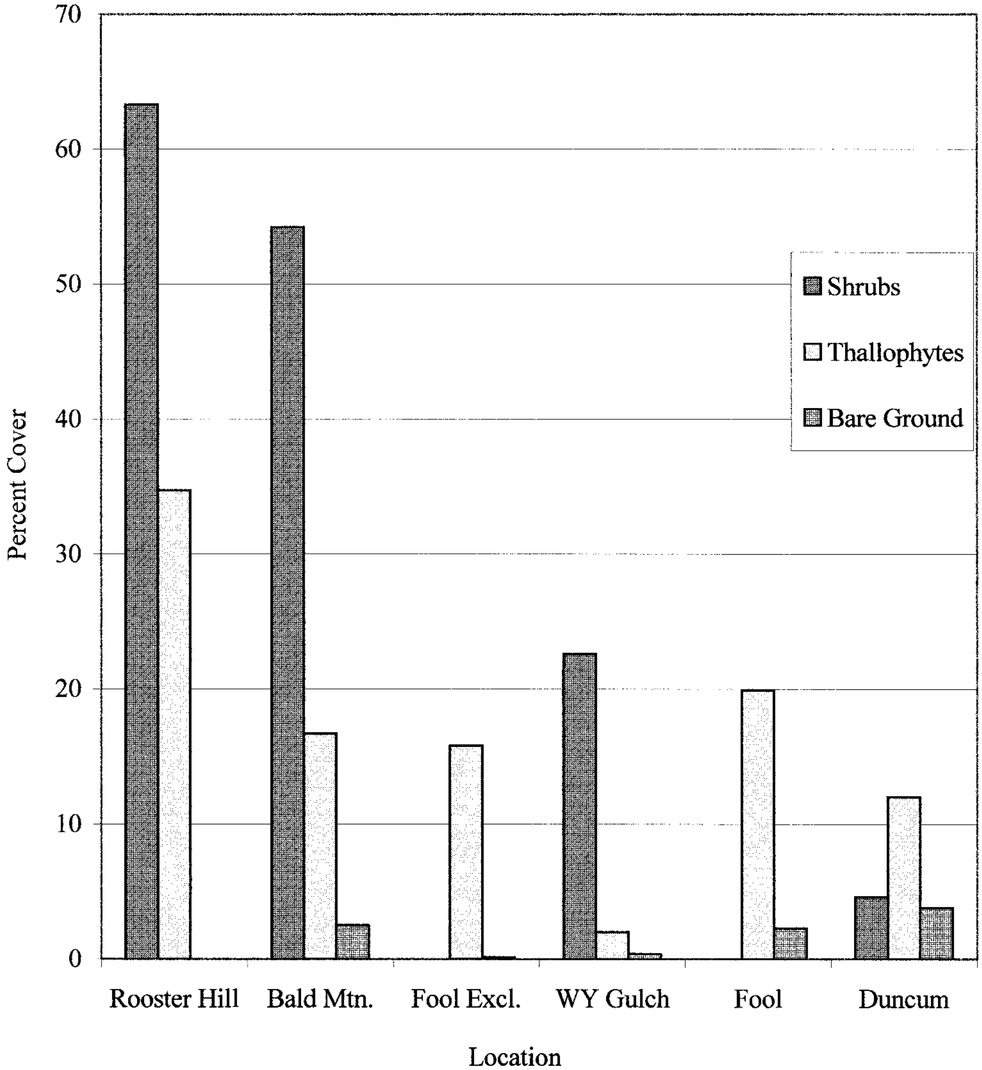

FIGURE 4. Shrub, thallophyte, and bare ground cover percentages at each location. The two best sites for water vole captures, Rooster Hill Exclosure and Bald Mountain Creek, had the highest percent cover by shrubs (willows). The willows provided escape cover for water voles and protected stream banks from trampling by cattle.

reduced or eliminated; this community type results when any of the other ecological types are severely disturbed (Girard et al., 1997). Water voles were captured here some years, but not others. As rare riparian specialists, fewer water voles were captured on riparian types typical of disturbed sites.

At their montane sites, Grant et al. (1982) found that microtine rodents dominated their ungrazed grids while cricetine rodents dominated their grazed grids. In this study, one species dominated the captures at each location and the Shannon-Wiener indices generally appear to result from similar evenness and richness patterns at the various locations (Fig. 2). However, more water voles were captured at the Rooster Hill Exclosure and Bald Mountain Creek sites, but fewer small mammal species were captured and the small mammal community was less diverse at these locations (Fig. 2). *Clethrionomys gapperi, Microtus montanus,* and *Microtus richardsoni* dominated Fool Creek (both inside and outside the exclosure), the Rooster Hill Exclosure, and Wyoming Gulch. *Zapus princeps* dominated Bald Mountain Creek and *Peromyscus maniculatus* did not dominate any of the sites (Table 5).

The Big Horn Mountains are one of two island mountain ranges in the northern Great Plains where water voles are found. Water voles were probably isolated here by following tundra-like vegetation into high elevations after the Pleistocene glaciations (Hoffmann and Koeppl, 1985). This suggests water voles cannot disperse across lowland barriers to reach suitable habitat and have low colonization rates as well as high extinction rates (Brown, 1971). Low populations in the Big Horn Mountains may therefore be cause for concern. Their narrow habitat range and low population densities result in small populations that are not buffered against habitat degradation and local extinction. Livestock can impact water vole populations when water availability in riparian ecosystems is reduced, cover is reduced or eliminated, the soil is compacted, and the banks eroded.

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