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HABITAT OF THREE RARE SPECIES OF SMALL MAMMALS IN JUNIPER WOODLANDS OF SOUTHWESTERN WYOMING

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ABSTRACT.—Southwestern Wyoming constitutes the northern limit of the ranges of the cliff chipmunk (*Tamias dorsalis*), pinyon mouse (*Peromyscus truei*), and canyon mouse (*P. crinitus*). In addition to trying to determine their presence in the region, we wanted to identify habitat characteristics commonly used by each of these species. We used Sherman live-traps to sample 14 sites representing 2 distinct habitat types in 1998 and 1999: juniper-rocky slopes and juniper cliffs. Seventeen habitat characteristics were measured at capture locations for each species and compared with randomly located points. Best subsets multiple logistic regression was used to construct models that distinguish between used and available habitat for each species. The cliff chipmunk occurred in both rocky slopes and cliffs. The pinyon mouse was also captured in rocky slopes and cliffs and was most often captured in locations in the interior of the juniper woodland with high tree canopy cover, high forb cover, and low density of rock outcrops. The canyon mouse was captured only in cliffs at sites consisting of high forb cover, high rock cover, and high tree density.

Key words: juniper, cliff chipmunk, Tamias dorsalis, *pinyon mouse,* Peromyscus truei, *canyon mouse,* Peromyscus crinitus, *habitat, logistic regression, information theory.*

Effective wildlife management and conservation rely on biologists' understanding factors that influence the distribution of species including those at the periphery of their range. Research focusing on the ecology of game species has given biologists considerable knowledge of the factors affecting their numbers and distribution, thus enabling managers to make informed decisions on management. However, this information is largely unavailable for many nongame species. For instance, small mammals are an important prey component of most ecosystems in which they occur (Vaughan 1986), but we often do not have adequate information on such species to make informed management decisions (Gibson 1988). The cliff chipmunk (*Tamias dorsalis*), pinyon mouse (*Peromyscus truei*), and canyon mouse (*P. crinitus*) are found throughout the Great Basin (Burt and Grossenheider 1980). While populations of these species are considered stable throughout their geographical distribution, they are considered rare in Wyoming, the northern extent of their range (Fertig 1997, Luce and Oakleaf 1998), which constitutes the northern limit of their geographical distribution (Burt and Grossenheider 1980, Clark and Stromberg 1987). The species are known to occur only in Sweetwater County in southwestern Wyoming (Clark and Stromberg 1987), and they may have experienced some habitat loss as a result of construction of Flaming Gorge Dam and the subsequent creation of Flaming Gorge Reservoir in the early 1960s.

Our objectives were to determine occurrence of the cliff chipmunk, pinyon mouse, and canyon mouse in the juniper (*Juniperus osteosperma*) woodlands of southwestern Wyoming and provide data on habitat association. To do this we measured variables representing microhabitat characteristics at capture locations and compared them with randomly located sites. The results provided information on their distribution and factors influencing the distribution of these 3 small mammal species at the edge of their range.

MATERIALS AND METHODS

The study area is in southwestern Wyoming in south central Sweetwater County. Trapping took place south of Rock Springs, Wyoming, to the east of Flaming Gorge Reservoir and north of the Utah and Wyoming border. A "naturally patchy" juniper woodland and sagebrush-grassland mosaic characterize the landscape. In general, big sagebrush (*Artemisia tridentata*) dominates the lower elevations (1860 m, near

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Flaming Gorge Reservoir), with juniper woodlands occupying ridges and slopes. Pinyon pine (*Pinus edulis*) occurs at very low densities in the southern portion of the study area. In addition to sagebrush, true mountain mahogany (*Cercocarpus montanus*) is another common shrub species found throughout the study area. The primary land use is cattle grazing and recreation activities such as hunting and camping.

Juniper-dominated rocky slopes and cliff areas were identified as 2 dominant habitat components of the probable landscape for these species. Low-gradient slopes characterize the rocky slopes with their moderate to high juniper tree canopy cover and variable amounts of herbaceous understory ground cover. Isolated rock outcrops are found throughout the rocky slope habitat. Cliffs occur in areas characterized by high-gradient slopes, with juniper as the dominant vegetation component, and shrubs, grasses, and forbs common in the understory. After an initial review of the area, we selected the sites so that they represented the habitat groups and the area.

From May through August 1998 and 1999, we conducted small mammal surveys. Mammal trapping was conducted at 7 rocky slopes and 7 cliff sites using 7-cm × 9-cm × 23-cm Sherman-live traps, arranged in grids consisting of 49 traps with 15-m spacing between traps. The exact configuration of the trapping grid often depended on size and shape of the habitat patch being sampled. In general, we established 7 × 7-m grids; however, cliff sites often were too narrow for such configurations. In these areas, to maintain a more or less equal effort at all sites, our grids consisted of 3 rows of 12 traps and 1 row of 13 traps. Trap grids ranged from 0.74 ha to 0.81 ha because of this variation in trap grid configuration.

Traps were baited with a combination of rolled oats and peanut butter, and to each trap we added polyester bedding for thermal insulation to decrease the mortality rate of captured individuals exposed to low overnight temperatures. Each trapping session consisted of 4 consecutive nights. Traps were opened in the evening at approximately 1900 hours and checked and closed beginning at 0700 hours. Trapping was performed at 4 sites (2 of each habitat type) simultaneously with 1 session of 2 grids only. Two trapping sessions were conducted at each site: 1 between 18 May and 30 June, and again between 7 July and 12 August. Traps that we found closed but without a capture were considered half a trap night. Traps remained closed during the daylight to prevent small mammals from being captured during periods of high temperatures.

We identified captured animals to species; each was sexed, examined for reproductive status, weighed, and marked with a uniquely numbered ear tag (Monel size 1, National Band and Tag). All captured individuals were released at the point of capture.

We measured 17 habitat variables (Table 1) at 21 randomly located points within each trapping grid and at the 1st trapping location of each individual cliff chipmunk, pinyon mouse, and canyon mouse. Locations of 3 random points were determined on each row of traps within the grid. A 3-digit random number was used to determine the location of the random point along the length of the row of traps, and a 2-digit random number indicated direction and distance of the point from the row. Even numbers placed the random points to the right of the row, and odd numbers to the left. This point, marked using a fluorescent flag, indicated the center of a circular sampling plot with an 8-m radius encompassing 0.02 ha.

We used the criteria of Dueser and Shugart (1978) to select habitat variables that were measured: (1) each variable should provide a measure of the structure of the environment which is either known or reasonably suspected to influence the distribution and local abundance of small mammals; (2) each variable should be quickly and precisely measurable with nondestructive sampling procedures; (3) each variable should have intraseason variation that is small relative to interseason variation; and (4) each variable should describe the environment in the immediate vicinity of the capture. The variables selected represent 3 strata: tree overstory, understory, and ground cover.

From the center of each habitat sampling plot, we measured distance to the nearest log, diameter of that log, distance to nearest barren expanse of rock, and distance to the nearest edge of juniper vegetation type. Tree and shrub density as well as average tree diameter for the random point and capture location was determined using the point-quarter method described by Cottam and Curtis (1956). Height of the nearest shrub in each quarter was also measured to estimate average shrub height.

TABLE 1. Mean values for each habitat variable measured at random points in rocky slope and cliff habitat types and at cliff chipmunk, pinyon mouse, and canyon mouse capture locations in southwestern Wyoming in 1999. Values with the same superscsript letter are significantly different ($P < 0.05$).

Variable	Random plots	Cliff chipmunk	Pinyon mouse	Canyon mouse
% tree canopy cover	17.0^{b}	17.0	25.9	13.1
% grass cover	5.6^{a,b}	3.5^{a}	3.2^{b}	4.1
% forb cover	2.2^{a,b}	1.7^{a}	1.0^{b}	3.7
% shrub cover	4.6	4.8	2.9	5.3
% litter cover	19.1	20.5	21.4	13.6
% bare ground	56.3^{a,c}	50.8^{a}	58.0	42.2^{c}
% rock cover	13.1^{a,c}	18.2^{a}	13.9	35.6^{c}
Shrub density (no. ha^{-1})	2879	1981	2563	2052
Average shrub height (cm)	48.3^{a}	58.9^{a}	46.9	62.4
Tree density (no. ha^{-1})	251	310	386	232
Distance to nearest tree (m)	4.6^{a,b}	3.6^{a}	2.7^{b}	3.8
Distance to nearest shrub (m)	2.4^{b}	2.2	1.8^{b}	2.1
Distance to nearest log (m)	7.8^{a,b,c}	4.6^{a}	3.0^{b}	3.5^{c}
Diameter of nearest log (cm)	17.0^{a}	17.9^{a}	19.2	21.8
Distance to nearest rock outcrop (m)	10.9^{a,b}	6.6^{a}	15.8	2.1^{c}
Distance to juniper woodland edge (m)	47.8^{a,b}	68.7^{a}	237.7^{b}	77.4

Two transects, 1 going north–south and the other east–west, were established through each plot center point. Along each transect we established Daubenmire quadrats at the center point and at 4 m and 8 m from the center point for a total of 9 quadrats (Daubenmire 1959). On each quadrat we estimated the proportion of ground cover by grass, forbs, shrubs, litter, bare ground, and rock. Because of the small stature of juniper trees, we were unable to use an ocular tube to measure tree canopy cover. Instead, we used a 5-m pole placed perpendicular to the ground at 1 m apart along both transects. Tree canopy cover was measured in 3 strata (Gilbert and Allwine 1991; 0–2, 2–4 and 4+ m) using the pole marked in 2-m segments. Tree canopy cover in any of the 3 strata was recorded when a tree branch touched the pole within the respective 2-m intervals.

Habitat data collected at random points were combined across grids for each habitat type. In addition, data collected at all capture locations were combined across grids for each rodent species. To eliminate multicollinearity in multivariate analyses, we used Pearson product moment correlation analysis to test for linear correlation between all possible pairs of variables measured. In cases where the correlation coefficient (CC) was >0.625, the variable perceived as having the least biological significance was eliminated subjectively from further analyses. Univariate binary logistic regression analysis was used to further reduce the number of variables to be used in multivariate analysis. Variables with a univariate significance of $P < 0.25$ were considered significant and were included in the full model while the others were discarded. Hosmer and Lemeshow (1989) suggested using this level of significance because lower levels of significance may eliminate variables that may increase the goodness-of-fit of a reduced model to the data.

Best subsets multiple logistic regression was used to determine which combinations of the variables identified in the univariate analyses provided the best model for predicting the occurrence of each rodent species. Best subsets is an effective model-building technique that identifies collections of variables, all of which could possibly be weakly associated with the response variable but are important predictors when taken together (Hosmer and Lemeshow 1989). We used the Akaike's Information Criterion (AIC) to determine the best model from the larger set. The AIC scored each model according to number of parameters and goodness-of-fit of the model, the model with the lowest AIC value being considered the most efficient. However, final model selection was also based on biological interpretability.

RESULTS

In 5397.5 trap nights, we captured 113 individual cliff chipmunks, 19 pinyon mice, and 13 canyon mice. The cliff chipmunk was captured in 13 of 14 sites sampled, the pinyon

TABLE 2. Univariate significance (*P*-values) of each habitat variable measured in predicting cliff chipmunk, pinyon mouse, and canyon mouse occurrence in rocky slope and cliff habitat types in southwestern Wyoming in 1999. Significant at $P \leq 0.05$.

	Species		
Variable (*n*)	Cliff chipmunk (119)	Pinyon mouse (19)	Canyon mouse (13)
DISCRETE			
Shrub density			
Low			
Medium	0.98	0.84	0.43
High	0.57	0.57	0.36
Tree density			
Low			
Medium	0.02*	0.64	0.30
High	0.09	0.63	0.23
Average tree size			
Small			
Medium	0.95	0.47	0.47
Large	0.59	0.89	0.89
CONTINUOUS			
Canopy cover	0.25	0.00*	0.58
% grass cover	0.00*	0.10	0.60
% forb cover	0.08	0.02*	0.00*
% shrub cover	0.77	0.37	0.77
% litter cover	0.44	0.41	0.22
% bare ground cover	0.02*	0.66	0.02*
% rock cover	0.01*	0.51	0.00*
Average shrub height	0.00*	0.50	0.32
Distance to nearest tree	0.04*	0.05*	0.33
Distance to nearest shrub	0.71	0.66	0.66
Distance to nearest log	0.08	0.05*	0.30
Diameter of nearest log	0.63	0.21	0.23
Distance to nearest rock outcrop	0.03*	0.04*	0.07
Distance to juniper woodland edge	0.00*	0.00*	0.16

*Significant values at 0.05 level.

mouse in 5 sites in both habitats, and the canyon mouse in only 2 of 7 cliff habitat sites. Habitat data were collected at 294 random plots, and 113, 19, and 13 centered plots for cliff chipmunks, pinyon mice, and canyon mice, respectively (Table 1).

Pearson product moment correlation analysis showed that 4 variables exhibited linear correlation: tree canopy cover in low strata, tree canopy cover in middle strata, and tree canopy cover in upper strata were highly correlated (CC > 0.725) to overall tree canopy cover. Therefore, the 3 strata of canopy cover were removed and only overall canopy cover was included in further analysis. Height of the nearest shrub was also eliminated, which was correlated (CC = 0.644) to average shrub height.

From the remaining variables, univariate binary logistic regression analysis was used to determine which microhabitat variables were significant (univariate significance < 0.25) predictors of the occurrence of cliff chipmunks, pinyon mice, and canyon mice. This was accomplished by comparing used sites (capture locations) with available habitat (random plots). These analyses indicated that 12 variables were significant predictors of the occurrence of the cliff chipmunk, 8 for the pinyon mouse, and 7 for the canyon mouse (Table 2). These variables were then used to construct full regression models for each species.

Best subsets logistic regression constructed 14 reduced models for the cliff chipmunk, 9 for the pinyon mouse, and 8 for the canyon mouse. For the cliff chipmunk there were 3 models within 2.5 AIC units. The lowest-AIC model (296.7) was a 4-variable model. The 2nd best model included 5 parameters, and the 3rd model consisted of 3 parameters. The 1st model was discarded because the data did not fit the logistic regression model ($P < 0.05$).

TABLE 3. Parameter estimates (β), standard error, and odds ratios for the best multivariate model for distinguishing between cliff chipmunk, pinyon mouse, and canyon mouse capture locations and random sites in the rocky slope and cliff habitat types in southwestern Wyoming in 1999.

Species	β	$s_{\bar{x}}$ (β)	Odds ratios
Cliff chipmunk			
% grass cover	–0.133	0.017	0.876
% bare ground cover	–0.023	0.002	0.977
Average shrub height	0.013	0.060	1.013
Pinyon mouse			
% canopy cover	0.029	0.014	1.030
% forb cover	–0.482	0.167	0.618
Distance to nearest rock outcrop	0.050	0.031	1.051
Distance to juniper woodland edge	0.016	0.004	1.016
Canyon mouse			
% forb cover	0.362	0.178	1.436
% rock cover	0.076	0.024	1.078
High tree density	1.186	0.415	3.275

Ultimately, the model consisting of 3 parameters was chosen (Table 3) because it was the simplest with regard to the fewest parameters, and the data fit the logistic regression model ($P > 0.05$). Once this model was selected, tests were conducted for interaction effects between variables included in the reduced model. All potential 2-way interactions (%Grass cover * %Bare ground cover, %Ground cover * Average shrub height, and %Bare ground cover * Average shrub height) were tested, and none were found to be significant (Ramsey and Schafer 1997). The final model indicates that cliff chipmunk capture locations consisted of lower grass cover, lower bare ground cover, and taller shrubs than random sampling plots.

Of the 9 models constructed by best subsets logistic regression for the pinyon mouse, 3 combinations of variables had AIC values within 1 unit of each other. The model with the lowest AIC value (109.85) was reduced to a 4-parameter model. The other models consisted of 3 parameters and 5 parameters with AIC values of 110.65 and 110.70, respectively. Once this model was selected (Table 3), we tested for all possible 2-way interactions that were considered biologically important (%Canopy cover * %Forb, %Canopy cover * Distance to juniper woodland edge, and %Forb cover * Distance to juniper woodland edge) between the variables included in the model (Ramsey and Schafer 1997). None of these interactions were found to be significant ($P > 0.05$). The final model indicates that greater canopy cover, lower forb cover, and greater distances to rock outcrops and the woodland edge best distinguished pinyon mouse capture locations from random sites.

The model that best distinguished canyon mouse capture locations from random sites was a 3-parameter reduced model with an AIC value of 80.63 (Table 3). According to the AIC, the next best model had a value of 82.32 and 4 parameters. While this 2nd model had a slightly better goodness-of-fit ($P = 0.32$ compared with 0.29), the predictability between the 2 was virtually identical (88.5% for the 3-parameter model compared with 88.4% for the 4-parameter model). It appears that the additional variable in the 2nd model does not increase its predictability over the 1st model. The 3-parameter model was selected as the better model for distinguishing between canyon mouse capture locations and random plots. Tests were conducted for all possible 2-way interactions (%Forb cover * %Rock cover, %Forb cover * High tree density, %Rock cover * High tree density) between the variables included in the model (Ramsey and Schafer 1997). None of these interactions proved to be significant ($P < 0.05$). The final model indicates canyon mouse capture locations are characterized by greater forb cover, rock cover, and bare ground than random plots in the cliff habitat type.

DISCUSSION

The cliff chipmunk, pinyon mouse, and canyon mouse were considered rare in Wyoming because there were fewer than 5 documented occurrences of each species in the state (Fertig 1997) prior to our study. Clary (1917) first described the cliff chipmunk and canyon mouse in Wyoming as "among the characteristic Upper Sonoran mammals of the Green River Valley." The canyon mouse was known to occur only in northeastern Arizona, southeastern Utah, and adjacent parts of Colorado and New Mexico (Osgood 1909). In 1929, Svihla and Svihla (1929) collected 1 cliff chipmunk in Wyoming near the Utah border. At the same time they collected 3 canyon mice near the Utah border (Svihla and Svihla 1929, 1931). The earliest published account of the pinyon mouse in Wyoming appears to be 1942 (Hoffmeister 1951). During an expedition through the area in 1959, Durrant and Dean (1960) collected 3 cliff chipmunks and 5 pinyon mice in Utah but found none in Wyoming.

Surveys have also been conducted in more recent years. During an intensive sampling effort in 1979, cliff chipmunks were captured at 1 site located approximately in the center of our study area (Belitsky 1981). Canyon mice also were captured north of our study area (Belitsky 1981).

We found that the cliff chipmunk is distributed throughout the juniper woodland in our study area. Of 14 juniper woodland, rocky slope, and cliff sites, this species occurs in 13 of them. The cliff chipmunk is commonly associated with cliffs and rocky outcrops in juniper woodlands throughout its distribution (Hart 1971, Belitsky 1981). Apparently, it uses cliff structures for den sites and some foraging, primarily in the early spring.

The cliff chipmunk's diet comprises almost exclusively vegetation, primarily forbs and grasses. We found grasses and forbs to be more abundant in the rocky slope habitat type. Juniper tree density was also higher in the rocky slope habitat type than in cliffs; thus, foraging may require less effort to harvest more juniper berries.

Our analysis suggests that habitat in southwestern Wyoming may be suboptimal for the pinyon mouse. Pinyon mice commonly occurred in sites of higher canopy cover and lower forb cover than was available throughout the rocky slope and cliff habitat types. Pinyon mice selected against proximity of rock outcrops and avoided the edge of the juniper woodland. Rocky slope habitat type may be better suited for the pinyon mouse. However, rocky slopes have greater amounts of forb cover and a shorter distance to the woodland edge, both of which the pinyon mouse selected against. Thus, neither rocky slopes nor cliffs provide an optimal combination of microhabitat characteristics for the pinyon mouse. This is consistent with Brown's (1984) theory that the limit of a species distribution occurs where environmental requirements for that species are not met.

During our investigation the canyon mouse was found only in the cliff habitat type, which is consistent with the common description of canyon mouse habitat (Hardy 1945, Hall and Hoffmeister 1946, Baker 1968, Clark and Stromberg 1987, Johnson and Armstrong 1987). Our results contradict Egoscue's (1964) idea of the importance of vegetation on the distribution of canyon mice. On average, canyon mice were captured at sites in the cliff habitat type with higher tree canopy cover and very dense trees, along with higher rock cover. While cliff sites in the study area consisted of high rock cover, the rocky slope type had higher canopy cover and tree density. Similar to the results of the pinyon mouse, this may indicate that available cliffs provide only marginal canyon mouse habitat. However, because it was found to occur only in the cliff habitat type, and assuming Johnson's (1986) suggestion regarding interspecific effects applies to this part of its range, it is likely that a combination of competition and habitat quality is important in determining the canyon mouse distribution in this area. It is also likely that cliffs provide some other requirement or that slopes lack the factor.

Hedderson (1992) suggested that "peripheral populations may include genotypes which are unique for any given species. Protection of such populations is thus thought to deserve priority equaling that granted other types of rare species." These comparisons may provide insight into which habitat or environmental factors are influencing the distribution and abundance of these species, particularly as they approach the limit of their range.

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