SMALL MAMMAL ABUNDANCE WITHIN MEXICAN SPOTTED OWL HOME RANGES IN THE MANTI-LASAL NATIONAL FOREST, SAN JUAN COUNTY, UTAH

by

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TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Ecologists suspect that owls select specific areas based on prey availability. My objective was to determine and compare distributions and abundances of Mexican spotted owl prey species within different vegetation types in the canyons and mesas of the Manti-LaSal National Forest in Utah. I conducted live-trapping during summer and fall, 1994-95. Woodrat species (Neotoma spp.) are the Mexican spotted owls primary prey species as determined by percent biomass. White-footed mice (Peromyscus spp.) are also important in terms of frequency. Woodrats were only captured in the canyons and were primarily captured within the pinyon (Pinus spp.)-juniper (Juniperus spp.) vegetation type. The Mexican spotted owls (Strix occidentalis lucida) in southeastern Utah spend > 75% of their time within the canyons and forage within pinyon-juniper stands in the canyons. Maintaining the present state of pinyon-juniper stands within the canyons may benefit Mexican spotted owl populations in the Manti-LaSal National Forest.

INTRODUCTION

The Mexican spotted owl (Strix occidentalis lucida) was listed as a threatened species by the U.S. Fish and Wildlife Service in April 1993. Prior to its listing, involved state and federal agencies classified the Mexican spotted owl as a sensitive subspecies due to its habitat needs, rarity, and need of special management considerations.

Most Mexican spotted owl literature focuses on habitat features necessary for the owls direct needs, such as roosting, nesting, and perching trees or crevices within specific forest communities (Barrows 1981, Ganey 1994, Zwank et al. 1994). However, these components alone may not be enough to maintain Mexican spotted owls in a particular area. There are numerous habitat features that an animal may use in selecting areas to use. The factors involved in the decision-making process by an owl may include proximate factors such as the presence or absence of competitors or predators, temperature, or food or mate availability. All of these factors must be taken into consideration when evaluating the habitat needs of a species (Krebs 1985:58-67, Morrison et al. 1992:16-40).

Johnson (1980) depicted a hierarchical nature of habitat selection by a species or individual that consists of 4 orders. First-order selection describes the species' geographical range. The Mexican spotted owl inhabits southern Utah and Colorado, Arizona, New Mexico, and west Texas into the mountains of central Mexico (Forsman et al. 1984, Ganey et al. 1988). Within Utah, D. W. Willey (Movements and habitat ecology of Mexican spotted owls in southern Utah: final report, 1992, Utah Division of Wildlife Resources) found the Mexican spotted owl in Zion, Capitol Reef, and Canyonlands National Parks, and in the Manti-LaSal National Forest.

Within the geographic range of the species is the home range of an animal, termed second-order selection (Johnson 1980). In southern Utah, the mean home range size of 11 individual owls in 3 study areas ranged from 924 to 1487 ha (2,282 to 3,672 acres; USDI Fish and Wildlife Service 1995).

Third-order selection defines the use of habitat components within the home range (Johnson 1980). From telemetry locations obtained on foraging, nesting, and roosting sites, D. W. Willey (unpubl. data) defined general habitat components used by the Mexican spotted owls in southern Utah. In a study being conducted on Mexican spotted owls in the Manti-LaSal National Forest, D. W. Willey (unpubl. data) found that, in general, > 75% of owl telemetry locations occurred in steep canyons, while < 25% of the telemetry locations occurred on benches and mesa tops above the canyons. D. W. Willey (unpubl. data) also found that Mexican spotted owls are primarily foraging in the pinyon (Pinus edulis)-juniper (Juniperus osteosperma) vegetation community.

Finally, fourth-order selection is the consumption of food items within feeding sites determined to occur within specific habitat components. There are only a few studies that have examined the food items consumed by the Mexican spotted owl in Utah. These studies have found that the primary prey species of the Mexican spotted owls, in terms of percent biomass, is woodrats (Neotoma spp.)(Kertell 1977, Wagner 1982, USDI Fish and Wildlife Service 1995). In these same studies, Peromyscus spp. were frequently found in the Mexican spotted owl pellets. Results similar to these studies were found in Mexican spotted owl pellets collected from roost and nest sites of several pairs of owls in the Manti-LaSal National Forest (unpubl. data).

Ecologists suspect that spotted owls select habitats based partially on the availability of prey (Carey 1985, USDI Fish and Wildlife Service 1995). Thus, studies of prey species can provide insight into the ecology of a predator such as the spotted owl (Newton 1979, Carey 1985, Verner et al. 1992, Sakai and Noon 1993). For a pair of owls to avoid nest abandonment, the male must provide enough food for the female at the nest during the incubation and brooding period (Johnsgaard 1988). Reproductive success is often correlated with prey abundance (Craighead and Craighead 1956, Southern

1970, Wendland 1984, Korpimäki and Norrdahl 1991).

The USDI Fish and Wildlife Service (1995) proposed that an understanding of the ecology of primary prey species of the Mexican spotted owl is vital information needed for the owls recovery. This information can be another tool that managers can use for evaluating an area's ability to support and maintain spotted owls. Yet, I know of no published studies that have examined abundances of primary prey species of Mexican spotted owls in Utah. Accordingly, I developed this study to determine the distribution and relative abundance of Mexican spotted owl's primary prey species in home ranges found within the Manti-LaSal National Forest in southeastern Utah. Because temporal variation occurs in habitat use by small mammals (Rosenweig and Winakur 1969, Kelt et al. 1994), I examined relative abundances of prey items over 2 seasons within each of the 2 years of my study.

In consideration of the Mexican spotted owls second- and third-order habitat selection (home ranges and habitat components within home ranges, respectively; Johnson 1980), I focused on the areas primarily used (canyons) and primarily not used (mesas) by the owls within their home ranges (macro-scale). The primary objective of my study was to determine and compare the distribution and relative abundance of small mammals (specifically prey species of the

Mexican spotted owl) within different vegetation types in the canyons and the mesas of the Manti-LaSal National Forest. I tested the null hypothesis of no difference in small mammal relative abundances between the canyons and the mesas and between vegetation types.

A secondary objective of my study was to examine vegetation characteristics associated with the presence and abundance of small mammals in this area. This objective focused on the micro-scale level of the owls third-order selection (Johnson 1980). The information obtained at this level may help to determine habitat use by small mammals in this area. From the literature, I recognized that each of the small mammal species captured in my study may be associated with a specific vegetation type in terms of vegetation characteristics. However, I hope to find commonalities in vegetation variables between small mammal species at the micro-scale so that managers can use these variables to manage at the macro-scale, being the vegetation types and/or canyons and mesas. The results of my study will be incorporated in the development of management plans for the conservation and recovery of the Mexican spotted owl occurring in Utah.

STUDY AREA

My study occurred on the Monticello Ranger District of the Manti-LaSal National Forest, San Juan County, Utah. The area is part of the Canyonlands Section of the Colorado Plateau geographic province (Thornbury 1965: 417,426). Elevation ranged from approximately 1,830 to 2,680 m. Elk Ridge, the dominant topographic feature of the study area, was flanked to the west and east by steep-walled canyons (Arch, Texas, Hammond, Peavine, and Dark canyons). Because D. W. Willey (unpubl. data) radio-tagged Mexican spotted owls in Texas, Hammond, Peavine, and Dark canyons in 1992; in Texas and Hammond canyons in 1993; in Texas, Hammond, and Dark canyons in 1994; and in Texas canyon in 1995, these 4 canyons were the areas of focus in my study. Peavine and Dark canyons were surveyed only in 1995, whereas Texas and Hammond canyons were suveyed in 1994 and 1995.

My study area consists of extensive sandstone canyonlands, stair-step benchlands, alluvial valleys, high plateaus, and laccolithic mountains (Barnes 1978). Vegetation is distributed in discrete layers, corresponding to exposed sandstone strata and elevation zones. The vegetation types occurring in the study area include sagebrush (Artemisia tridentata), pinyon-juniper woodlands, mixed-conifer (Pinus ponderosa, Abies concolor, Pseudotsuga menziesii), aspen (Populus tremuloides), riparian, and ponderosa pine (P. ponderosa).

Climate is characterized as semi-arid to arid with hot, dry summers (temperatures range from approximately 8° to 34° C in spring and summer; Bair 1992:985-988). On average, precipitation and snowfall occur from October to May (temperatures range from approximately -4° to 16° C in fall and winter; average precipitation is approximately 30 cm; and average snowfall is approximately 2 m; Bair 1992:985-988).

METHODS

Grid Establishment

In each Mexican spotted owl home range, I set trapping grids within activity areas as determined by owl telemetry locations in Texas, Hammond, Peavine, and Dark canyons. In the canyons, I set trapping grids within the following dominant vegetation types as defined by the Monticello Ranger District of the U.S. Forest Service: riparian, mixed-mountain brush, mixed-conifer, and pinyon-juniper (B. Thompson, U.S. Forest Service, person. commun.). I also set trapping grids on the mesas in the following dominant vegetative types: ponderosa pine forests (Vegetative Structural Stages [VSS] 3, 4, and 5); grass-forb/shrub (VSS 1); and mixed aspen and ponderosa pine stands (VSS 2, 3, 4, and 5) as defined by the United States Department of Agriculture, Forest Service, Southwestern Region (Reynolds et al. 1992).

In April 1994, I randomly established 20 trapping grids in Texas and Hammond canyons (8 in Texas, 12 in Hammond). A trapping session consisted of 1 trapping grid within each of the 4 canyon vegetation types mentioned. Therefore, there were 2 trapping sessions in Texas Canyon and 3 in Hammond Canyon. On the mesas, I established 15 trapping grids, thus representing 5 trapping sessions consisting of 1 trapping grid within each of the 3 mesa vegetation types mentioned.

In May 1995, I established additional grids in Peavine and Dark canyons. Dark Canyon grids were represented by mixed-conifer, pinyon-juniper, and grass-forb/shrub vegetation types. Peavine Canyon grids were represented by 3 variations of ponderosa pine vegetation types: ponderosa with shrub understory, ponderosa with rocky understory, and ponderosa with oak understory. Only 1 trapping session in each season was conducted for each of these canyons.

I randomly placed a grid within each vegetation type by standing on the edge of the vegetation type of interest and spinning a compass. The last digit of the compass reading was multiplied by 15 to determine the number of meters paced for grid placement. If the compass bearing was outside of the vegetation type being sampled, the bearing 180° from the first bearing was used.

I set the trapping grids on the mesas in a 5 trapping station by 5 trapping station pattern. The canyon topography varies in width from approximately 100 to 300 m; therefore, to fit a grid completely within some of the designated vegetation types, I used grids of various lengths and widths within the canyons. The mixed-conifer, mixed-mountain brush, and pinyon-juniper vegetation types were more "block-like" than was the riparian vegetation type. The grids in the "block-like" vegetation types were arranged in as close to a 5 by 5 pattern as possible. The riparian vegetation type meandered through the canyon bottom; therefore, I modidfied the pattern of these grids to fit the vegetation type. I separated all trapping stations within each grid, in the canyons and on the mesas, by 15 meters. I used 41 grids in my study.

Trapping

I live-mammal trapped from May through November 1994 and 1995. Each trapping session ran for 4 nights and 3 days. O'Farrell (1974) found that the moon had a negative effect on nocturnal rodent activity. Travers et al. (1988) also noted that for nocturnal rodents there was greater activity on dark rather than bright nights and greater use of protected than exposed microhabitats. These behavioral responses have been interpreted to differences in risk of predation. Therefore, I trapped only on nights around a new moon (10 nights before, 10 nights after).

At the beginning of the study (first 2 weeks), each trapping station consisted of two live traps: one large Sherman live-trap (7.6 X 8.2 X 22.9 cm; Forestry Suppliers, Inc., Jackson, MS), and either one extra-large Sherman live-trap (10 X 12 X 37 cm) or one Tomahawk live-trap (13 X 13 X 35 cm; Forestry Suppliers, Inc., Jackson, MS). Two trap sizes were used to increase the probability of capturing woodrats and to minimize the potential bias of not capturing the larger mammals in the smaller traps. However, due to logistical problems in transporting the Tomahawk traps within the canyons, and the lack of woodrat captures in the Tomahawk traps, extra-large Sherman live traps were placed at every other trapping station and Tomahawk traps were no longer used. Therefore, for the remainder of the study, 13 trapping stations within each grid consisted of 1 extra-large Sherman trap and 1 large Sherman trap, with the remaining 12 trapping stations consisting of 2 large Sherman traps.

All traps contained rolled oats, peanut butter, and batting (Davis 1982). The bait was placed in the middle of a clump of polyester batting at the back of each trap. This method was chosen to be consistent in presentation of bait and to provide insulation (Willy 1992).

All traps were set before sunset and checked at sunrise by one or two technicians. Upon capture, all mammals were aged, sexed, weighed, and individually identified by toe-clipping. Age was differentiated between juvenile and adult. Reproductive condition was also recorded: non-reproductive, abdominal testes, or nipples.

Vegetation Sampling

Vegetation sampling was conducted on all trapping stations to determine microhabitat characteristics associated with small mammals captured. I centered a circular plot with a 5-meter radius on all trap stations. I used one 10-meter-diameter transect bisecting each plot to determine cover type, surface characteristics, canopy cover, and litter depth within each plot. The transect was obtained by a random spinning of the compass to determine direction. Vegetation structure was determined by using a point intercept sampling method along the transects (Bonham 1989). All items (Appendix A) and variables (Appendix B) were recorded at every 1.0 meter mark.

Analysis

Only grids from Texas Canyon, Hammond Canyon, and 2 grids from Dark Canyon were used in the analyses that follow because they contained vegetation types that were similar to each other (pinyon-juniper, mixed-conifer, mixed-mountain brush, and riparian). The Peavine Canyon vegetation types and 1 Dark Canyon vegetation type were not found in any other area and were thus excluded from small mammal-vegetation analyses.

I analyzed the vegetation data for 8 species of small mammals that are known prey species of Mexican spotted owls in Utah and have been found in the Mexican spotted owl pellets collected and analyzed from the Manti-LaSal National Forest. The 8 species used in the analyses were the deer mouse (Peromyscus maniculatus), canyon mouse (P. crinitus), brush mouse (P. boylei), pinyon mouse (P. truei), montane vole (Microtus montanus), mexican woodrat (Neotoma mexicana), least chipmunk (Tamias minimus), and Colorado chipmunk (T. quadrivittatus). Prey species predominantly found in Mexican spotted owl pellets in this area were the deer mouse, canyon mouse, brush mouse, and the Mexican woodrat (USDI Fish and Wildlife Service 1995). I included a small mammal species in the analyses based on if they were present in owl pellets, and if sample size was > 10 captures per season.

I estimated small mammal relative abundance as catch per unit effort (CE) which is the number of different animal captures per 100 trap-nights. Trap-nights is the number of traps per night times the number of nights in the field minus sprung-but-empty traps (Mills et al. 1991).

At the macro-scale, comparisons of small mammal relative abundances in different vegetation types and between the canyons and the mesas were analyzed using non-parametric tests. For ease of comparisons of results, I used non-parametric tests instead of parametric tests because all of the assumptions necessary for parametric tests could not be met for all species.

I used a Mann-Whitney test (Zar 1984:138-146) for 2 sampled comparisons to compare small mammal abundances between the canyons and the mesas. For comparisons between more than 2 groups, such as between vegetation types, I used the Kruskal-Wallis test for multiple comparisons (Zar 1984:201-202). If a significant difference was found between the vegetation types, I used a Dunn's test for multiple comparisons to determine where the difference occurred.

In addition, I analyzed the data between seasons and years to determine if there were any statistical differences in relative abundance of small mammals in the different vegetation types between the summer and fall and between 1994 and 1995. I used the same statistical tests as mentioned above for 2 group and multiple comparison analyses.

At the micro-scale, I evaluated relationships between small mammal numbers and vegetation variables, with a multivariate analysis of variance (MANOVA; $\underline{P} = 0.05$; Zar 1984:244-251) to determine if interaction occurred between seasons and years. If an interaction was found, I conducted further analyses of relationships between small mammals and vegetation characteristics based on the results specified by the MANOVA results. These analyses differed from the non-parametric analyses above in that in the MANOVA analyses I was looking at the vegetation variables and how they were associated with each species in either all grids grouped or by vegetation type. With the non-parametric tests I focused on the macro-scale. At this scale I only considered grouped species' abundance by vegetation type or canyons and mesas.

Prior to conducting the MANOVA's, I conducted a correlation matrix (Sokal and Rohlf 1981:561-572) on all vegetation variables, for each small mammal species, to determine if there was any high intercorrelation between the variables. If a pair of variables was found to be highly intercorrelated (> 0.7), one of the variables was removed from the anlaysis. The variable used was the one with the most biological meaning and the one that was easiest to measure (Morrison et al. 1992:306).

To determine which vegetative variables might assist in predicting a species' occurrence over the entire study area, I conducted a stepwise multiple regression (Zar 1984:328-30) on each species' abundance over all vegetation types. The variables used in the regression were the same ones used in the MANOVA analysis for each small mammal species. The criteria for entry and exclusion of a variable into the regression was 0.10 and 0.11, respectively. The adjusted R^2 was used to evaluate the goodness of fit of the final model. An adjusted R^2 value was used to correct the optimistic bias associated with the relationship between R^2 and the number of explanatory variables included in the regression model (Dillon and Goldstein 1984:209-242). In addition, I conducted a power analysis (Zar 1984:312) to determine the probability of correctly rejecting any vegetation variables that do not account for the variation in small mammal abundance.

I used a normal probability plot and a scatterplot to check the residuals against the predicted values to test for normality and equal variances of the data which are assumptions needed to conduct parametric tests (Morrison et al. 1992:280-283). All of the 8 small mammal species considered for further analyses met these assumptions and were used in the proceeding analyses. However, these assumptions were not met for all of the vegetation variables used in the MANOVA and multiple regression analyses. Therefore, I used stepwise multiple regression in a descriptive rather than predictive manner to help clarify habitat use by small mammals (Morrison et al. 1992:283-284).

To determine which vegetative variables might predict the presence or absence of a species, I conducted a stepwise logistic regression (Hosmer and Lemeshow 1989:87-88) for each species in each of the 7 vegetation types. The criteria for inclusion of a variable into the logistic regression model was $\underline{P} = 0.10$ and $\underline{P} = 0.11$ for exlusion of the variable from the model. Assesment of how well the model fits the data was evaluated by using a classification table to compare the observed outcomes to the predicted values. The Wald Chi-square (Hosmer and Lemeshow 1989), which is the square of the ratio of the coefficient to its standard error, was used to evaluate the variables selected in the regression.

Due to highly unequal sample sizes in presence and/or absence of a species, I randomly selected 30 subsamples and conducted a logistic regression on each of the 30 subsamples. The variable(s) that occurred in > 20% of the 30 models were entered into a logistic regression model. The model with the final variables was the model used to describe the vegetation features that may predict the presence of a species in a particular vegetation type.

RESULTS

Frequencies

I captured 2,893 different animals in 25,148 trap nights. White-footed mice (deer mouse, canyon mouse, brush mouse, pinyon mouse) were the most (80.7%) captured species throughout the study (Table 1). Other species captured were 3 species of woodrats: Mexican woodrat, whitethroat woodrat (N. albigula), and bushytail woodrat (N. cinerea); 2 species of chipmunks: least chipmunk and Colorado chipmunk; rock squirrel (Citellus variegatus); silky pocket mouse (Perognathus flavus); montane vole; shrew spp. (Sorex spp.); western harvest mouse (Reithrodontomys megalotus); and Ord kangaroo rat (Dipodomys ordii; Table 1).

Peromyscus spp. were the most frequently captured animals in all but the aspen vegetation type in the fall of 1994 (Table 1). Neotoma spp. were only captured in the canyons and were, overall, most frequently captured in the pinyon-juniper vegetation type within the canyons (Table 1).

The vegetation type on the mesas that had the highest number of different animals overall was the grass-forb/shrub vegetation type (n = 627), whereas in the canyons it was the pinyon-juniper vegetation type (462 different animals; Table 1). Similar results were also observed within each year, excluding 1994, where the mixed-mountain brush vegetation type in the canyons had a slightly higher number of different animals (n = 253) than did the pinyon-juniper vegetation type (n = 244; Table 1).

Table 1. Percent frequency of captures of small mammals by year, season, area, and vegetation type in the Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Year-Season / Area / Vegetation	n	No. new animals	*Peromyscus* spp.[a]	*Neotoma* spp.[b]	Other spp.[c]
1994-Summer					
Mesas	15	323	80.8		19.2
Aspen	5	77	80.5		19.5
Ponderosa	5	65	93.8		6.2
Shrub	5	181	76.2		23.8
Canyons	20	360	91.9	2.8	5.3
Mixed-conifer	5	70	94.3		5.8
Pinyon-juniper	5	115	86.1	7.0	7.0
Mixed-mtn.	5	96	91.7	2.1	6.3
Riparian	5	79	98.7		1.3
1994-Fall					
Mesas	15	249	71.9		28.1
Aspen	5	53	49.1		50.1
Ponderosa	5	35	71.4		28.6

Table 1. Continued.

Shrub	5	160	80.0		20.0
Canyons	20	532	91.0	5.8	3.2
Mixed-conifer	5	103	96.1	1.0	2.9
Pinyon-juniper	5	129	79.8	11.6	8.5
Mixed-mtn.	5	157	94.3	2.5	3.2
Riparian	5	143	89.5	6.3	4.2
1995-Summer					
Mesas	12	301	66.8		33.2
Aspen	4	93	54.8		45.2
Ponderosa	4	69	69.6		30.4
Shrub	4	139	73.4		26.6
Canyons	20	378	83.1	3.4	13.5
Mixed-conifer	5	78	78.2	2.6	19.2
Pinyon-juniper	5	107	85.0	4.7	10.3
Mixed-mtn.	3	65	81.5	4.6	13.9
Riparian	3	71	83.1	1.4	15.5
Shrub	1	25	92.0		8.0
Pond.-shrub	1	10	100.0		
Pond.-cliff	1	13	69.2	15.4	15.4
Pond.-oak	1	9	88.9		11.1
1995-Fall					
Mesas	9	328	72.9		27.1

Table 1. Continued.

Aspen	3	96	67.7		32.3
Ponderosa	3	85	68.2		31.8
Shrub	3	147	78.9		21.1
Canyons	18	422	77.5	1.4	19.4
Mixed-conifer	4	68	75.0		25.0
Pinyon-juniper	4	111	79.3	3.6	17.1
Mixed-mtn.	3	58	93.1		6.9
Riparian	3	54	79.6	1.9	18.5
Shrub	1	40	90.0		10.0
Pond.-shrub	1	34	64.7		35.3
Pond.-cliff	1	33	66.7	3.0	30.3
Pond.-oak	1	24	75.0		25.0

[a]*Peromyscus maniculatus*, *P*. *crinitus*, *P*. *boylei*, and *P*. *truei*.

[b]*Neotoma mexicana*, *N*. *albigula*, *N*.

[c]*Tamias minimus*, *T*. *quadrivittatus*, *Citellus variegatus*, *Perognathus flavus*, *Reithrodontomys megalotis*, *Dipodomys ordii*, *Sorex* sp., and *Microtus montanus*.

Relative Abundance - Canyons

Species.--The deer mouse was the most abundant species in the canyons in both seasons of 1994 and 1995 (Table 2 and 3, respectively). The deer mouse was found in all of the vegetation types in both seasons of 1994 and 1995 (Table 4, 5, 6, 7). Relative abundances of deer mice ranged from 2.5 in the pinyon-juniper vegetation type in the fall of 1994 (Table 5) to 18.3 in the grass-forb/shrub vegetation type in Peavine canyon (Table 7).

The pinyon mouse relative abundances ranged from 0.5 in several vegetation types in the summer of 1994 (Table 4) and in the fall of 1994 (Table 5) to 4.0 in the pinyon-juniper vegetation type in the fall of 1995 (Table 7). The canyon mouse relative abundances ranged from 1.6 in the pinyon-juniper vegetation type in the summer of 1995 (Table 6) to 6.3 in the pinyon-juniper vegetation type in the fall of 1994 (Table 5). The brush mouse relative abundances ranged from 0.5 in the mixed-mountain brush vegetation type in the summer of 1994 (Table 4) and also in the ponderosa-oak vegetation type in the fall of 1995 (Table 7) to 4.9 in the pinyon-juniper vegetation type in the fall of 1995 (Table 6).

The Mexican woodrat relative abundances ranged from 0.5 in the mixed-conifer vegetation type in the fall of 1994 (Table 5) and other vegetation types in both seasons of 1995 (Table 6 and 7) to 2.3 in the pinyon-juniper vegetation type in the summer of 1994 (Table 4). The montane vole relative abundances ranged from 0.5 in several vegetation types in the fall of 1994 (Table 5) and the summer and fall of 1995 (Table 6 and 7) to 0.8 in the riparian vegetation type in the fall of 1994 (Table 5).

The least chipmunk relative abundances ranged from 0.5 in several vegetation types in the fall of 1994 (Table 5) and in the fall of 1995 (Table 7) to 6.1 in the ponderosa-shrub vegetation type in the fall of 1995 (Table 7). The Colorado chipmunk relative abundances ranged from 0.5 in several vegetation types in the summer of 1994 (Table 4), the summer of 1995 (Table 6), and the fall of 1995 (Table 7) to 3.1 in the pinyon-juniper vegetation type in the summer of 1995 (Table 6).

Table 2. Relative abundance[a] (± SD) of each small mammal species within the mesas and canyons for each season in 1994, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

	Summer 1994		Fall 1994	
Species	Mesas	Canyons	Mesas	Canyons
Peromyscus maniculatus	8.7(5.2)	5.7(2.4)	7.0(6.6)	7.9(5.9)
P. boylei	0.5(0)	1.1(0.8)	0.5(--)	2.0(1.4)
P. crinitus	0.5(--)	3.2(2.3)		5.0(4.0)

Table 2. Continued.

P. truei	0.5(--)	1.5(1.6)		0.9(0.4)
Microtus montanus	1.0(0.7)		1.7(1.9)	0.7(0.3)
Neotoma mexicana		1.8(1.1)		1.0(0.7)
Tamias minimus	3.1(2.8)	2.5(--)	1.6(0.9)	0.8(0.4)
T. quadrivittatus		1.0(0.5)		1.6(1.0)

[a]Relative abundance = No. of different animals captured per 100 trap nights.

Table 3. Relative abundance[a] (± SD) of each small mammal species within the mesas and canyons for each season in 1995, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

	Summer 1995		Fall 1995	
Species	Mesas	Canyons	Mesas	Canyons
Peromyscus maniculatus	7.9(4.4)	4.6(2.8)	13.0(6.4)	6.8(4.3)
P. boylei	5.6(--)	3.6(2.3)	1.0(0.5)	2.4(1.6)
P. crinitus		3.5(2.2)	0.5(--)	
P. truei	1.0(0.7)	1.4(1.2)	0.5(0)	3.5(2.0)
Microtus montanus	2.1(1.0)	0.5(--)	2.4(2.4)	0.5(0)
Neotoma mexicana		0.6(0.3)		0.8(0.4)

Table 3. Continued.

Tamias minimus	3.0(1.9)	1.4(1.1)	3.7(3.3)	2.4(1.8)
T. quadrivittatus		1.8(1.5)		1.2(1.1)

[a]Relative abundance = No. of different animals captured per 100 trap nights.

Table 4. Relative abundances[a] of each small mammal speices within each vegetation type in the summer of 1994, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Area / Vegetation type / Species	N	X	±SD
Mesas			
Aspen			
Peromyscus maniculatus	61	6.3	4.3
P. crinitus	1	0.5	---
Montanus montanus	8	1.4	0.7
Tamias minimus	7	1.8	1.8
Ponderosa pine			
P. maniculatus	60	6.1	3.1
P. boylei	1	0.5	---

Table 4. Continued.

T. minimus	4	1.0	0.7
Grass-forb/shrub			
P. maniculatus	135	13.7	4.3
P. boylei	1	0.5	---
P. truei	1	0.5	---
M. montanus	2	0.5	0
T. minimus	38	4.9	2.9
Canyons			
Mixed-conifer			
P. maniculatus	48	4.8	2.4
P. crinitus	17	4.4	1.3
P. truei	1	0.5	---
T. quadrivittatus	3	0.8	0.4
Pinyon-juniper			
P. maniculatus	54	5.5	1.5
P. boylei	3	1.6	---
P. crinitus	31	3.9	2.8
P. truei	13	1.9	1.8
Neotoma mexicana	5	2.5	---
T. quadrivittatus	6	1.5	0
Mixed-mountain brush			
P. maniculatus	61	6.2	3.2

Table 4. Continued.

P. boylei	1	0.5	---
P. crinitus	25	3.2	2.9
P. truei	1	0.5	---
N. mexicana	2	1.0	---
T. minimus	5	2.5	---
T. quadrivittatus	1	0.5	---
Riparian			
P. maniculatus	61	6.1	2.8
P. crinitus	15	1.9	1.4
P. truei	2	1.0	---

[a] Relative abundance = No. of different animals captured per 100 trap nights.

Table 5. Relative abundances[a] of each small mammal speices within each vegetation type in the fall of 1994, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Area / Vegetation type / Species	N	X	±SD
Mesas			
Aspen			
Peromyscus maniculatus	26	3.4	2.7
Microtus montanus	19	2.5	2.5
Tamias minimus	5	2.5	---
Ponderosa pine			
P. maniculatus	25	3.2	2.4
T. minimus	9	1.5	1.4
T. quadrivittatus	1	0.5	---
Grass-forb/shrub			
P. maniculatus	127	13.0	7.1
P. boylei	1	0.5	---
M. montanus	7	0.8	0.4
T. minimus	5	2.5	---
Canyons			
Mixed-conifer			
P. maniculatus	76	7.7	3.6

Table 5. Continued.

P. boylei	6	1.5	0
P. crinitus	16	4.1	0
Neotoma mexicana	2	0.5	0
M. montanus	1	0.5	---
T. minimus	2	1.0	---
Pinyon-juniper			
P. maniculatus	14	2.5	0.6
P. boylei	20	2.2	1.0
P. crinitus	59	6.3	5.8
P. truei	9	0.9	0.4
N. mexicana	12	1.6	0.8
T. minimus	1	0.5	---
T. quadrivittatus	9	2.4	0.4
Mixed-mountain brush			
P. maniculatus	94	9.7	7.7
P. boylei	22	2.3	1.4
P. crinitus	41	5.2	4.0
P. truei	1	0.5	---
N. mexicana	4	0.7	0.3
T. minimus	4	0.8	0.6
T. quadrivittatus	1	0.5	---
Riparian			

Table 5. Continued.

P. maniculatus	94	9.6	6.7
P. boylei	4	1.0	0.7
P. crinitus	28	3.6	3.2
P. truei	2	1.0	---
N. mexicana	8	1.0	0.8
M. montanus	3	0.8	0.4
T. minimus	1	0.5	---
T. quadrivittatus	2	1.0	---

[a] Relative abundance = No. of different animals captured per 100 trap nights.

Table 6. Relative abundances[a] of each small mammal speices within each vegetation type in the summer of 1995, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Area / Vegetation type / Species	N	$\underline{X}$	±SD
Mesas			
Aspen			
Peromyscus maniculatus	51	6.4	4.2

Table 6. Continued.

Microtus montanus	17	2.2	0.5
Tamias minimus	24	4.8	2.9
Ponderosa pine			
P. maniculatus	47	5.9	4.7
P. truei	1	0.5	---
M. montanus	3	0.8	0.4
T. minimus	18	2.3	1.3
Grass-forb/shrub			
P. maniculatus	88	11.3	4.1
P. boylei	11	5.6	---
P. truei	3	1.5	---
M. montanus	13	3.3	0.4
T. minimus	23	2.9	1.6
Canyons			
Mixed-conifer			
P. maniculatus	31	3.2	2.1
P. boylei	19	2.5	1.5
P. crinitus	11	5.7	---
Neotoma mexicana	2	0.5	0
T. minimus	5	1.3	1.1
T. quadrivittatus	8	2.1	2.3
Pinyon-juniper			

Table 6. Continued.

P. maniculatus	35	4.5	2.0
P. boylei	38	4.9	3.3
P. crinitus	6	1.6	0.8
P. truei	12	1.5	1.3
N. mexicana	3	0.8	0.4
T. minimus	3	0.8	0.4
T. quadrivittatus	6	3.1	---
Mixed-mountain brush			
P. maniculatus	32	5.5	3.6
P. boylei	11	2.8	2.5
P. crinitus	10	5.1	---
N. mexicana	3	0.8	0.4
M. montanus	1	0.5	---
T. minimus	4	2.1	---
T. quadrivittatus	1	0.5	---
Riparian			
P. maniculatus	25	4.4	3.5
P. boylei	23	4.0	0.6
P. crinitus	11	5.1	---
N. mexicana	1	0.5	---
T. minimus	7	3.7	---
T. quadrivittatus	1	0.5	---

Table 6. Continued.

Grass-forb/shrub			
P. maniculatus	23	11.6	---
T. minimus	2	1.0	---
Ponderosa-shrub			
P. maniculatus	8	4.1	---
P. truei	2	1.0	---
Ponderosa-rock			
P. maniculatus	9	4.7	---
N. mexicana	1	0.5	---
T. minimus	2	1.0	---
Ponderosa-oak			
P. maniculatus	8	4.0	---

[a] Relative abundance = No. of different animals captured per 100 trap nights.

Table 7. Relative abundances[a] of each small mammal speices within each vegetation type in the fall of 1995, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Area Vegetation type Species	N	X	±SD
Mesas			
Aspen			
Peromyscus maniculatus	63	10.6	1.4
P. boylei	2	1.0	---
Microtus montanus	20	2.4	2.8
Tamias minimus	11	1.9	1.2
Ponderosa pine			
P. maniculatus	55	9.3	1.7
P. crinitus	1	0.5	---
P. truei	2	0.5	0
M. montanus	1	0.5	---
T. minimus	26	4.4	5.2
Grass-forb/shrub			
P. maniculatus	112	19.0	8.7
P. boylei	4	1.0	0.7
M. montanus	3	1.5	---
T. minimus	28	4.8	2.6

Table 7. Continued.

Canyons			
Mixed-conifer			
P. maniculatus	39	4.9	3.4
P. boylei	8	1.3	0.3
P. truei	4	2.0	---
M. montanus	1	0.5	---
T. minimus	9	2.5	0.5
T. quadrivittatus	1	0.5	---
Pinyon-juniper			
P. maniculatus	42	5.5	3.6
P. boylei	23	4.0	2.1
P. truei	23	4.0	1.6
Neotoma mexicana	2	1.0	---
M. montanus	1	0.5	---
T. minimus	10	2.6	2.3
T. quadrivittatus	7	1.2	1.3
Mixed-mountain brush			
P. maniculatus	34	6.8	3.2
P. boylei	14	2.4	1.6
M. montanus	1	0.5	---
T. minimus	2	0.5	0
T. quadrivittatus	1	0.5	---

Table 7. Continued.

Riparian			
P. maniculatus	23	3.9	1.3
P. boylei	20	2.4	1.6
N. mexicana	1	0.5	---
M. montanus	1	0.5	---
T. minimus	4	1.0	0.7
T. quadrivittatus	5	2.6	---
Grass-forb/shrub			
P. maniculatus	36	18.3	---
T. minimus	4	2.0	---
Ponderosa-shrub			
P. maniculatus	20	10.1	---
P. boylei	2	1.0	---
T. minimus	12	6.1	---
Ponderosa-rock			
P. maniculatus	22	11.7	---
T. minimus	10	5.3	---
Ponderosa-oak			
P. maniculatus	17	8.5	---
P. boylei	1	0.5	---
M. montanus	1	0.5	---
T. minimus	4	2.0	---

Table 7. Continued.

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[a] Relative abundance = No. of different animals captured per 100 trap nights.

Seasonal and yearly variation.--In 1994, there was a significant difference in small mammal relative abundance between summer and fall (P = 0.0003, Mann-Whitney) with the fall having the higher relative abundance than the summer (Table 8). No significant difference in small mammal relative abundance was found between the seasons in 1995 (P < 0.05). Comparisons of small mammal relative abundances for each season between years were not significantly different at the P < 0.05 level.

Vegetation type.--In 1994, both the pinyon-juniper and mixed-mountain brush vegetation types equally had the highest abundances of small mammals in the canyons (12.9; Table 8). In 1995, the shrub vegetation type in Peavine canyon had the highest abundance of animals (16.5) followed by the pinyon-juniper vegetation type with 12.6 (Table 8). Small mammal relative abundances did not differ significantly between the canyon vegetation types for any of the seasons or years (P = 0.1786, summer 1994; P = 0.0760, fall 1994; P = 0.2254, summer 1995; P = 0.2296, fall 1995;

Kruskal-Wallis).

Table 8. Mean relative abundances[a] and standard deviations of small mammals by year-season, area, and vegetation type, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Year-Season Area Vegetation	n	$\bar{X}$	SD
1994-Summer			
Mesas	15	11.2	6.6
Aspen	5	7.9	6.4
Ponderosa pine	5	6.6	3.1
Grass-forb/shrub	5	19.1	6.1
Canyons	20	9.1	2.2
Mixed-conifer	5	7.1	1.5
Pinyon-juniper	5	11.9	5.5
Mixed-mountain brush	5	9.7	9.9
Riparian	5	7.8	4.0
1994-Fall			
Mesas	15	8.5	9.2
Aspen	5	5.5	7.8
Ponderosa pine	5	3.6	4.6
Grass-forb/shrub	5	16.3	9.1

Table 8. Continued.

Canyons	20	13.6	7.9
Mixed-conifer	5	10.4	5.4
Pinyon-juniper	5	13.9	10.3
Mixed-mountain brush	5	16.1	14.1
Riparian	5	14.1	7.9
1995-Summer			
Mesas	12	12.8	5.2
Aspen	4	11.9	1.4
Ponderosa pine	4	8.7	5.3
Grass-forb/shrub	4	17.7	3.7
Canyons	20	9.8	4.0
Mixed-conifer	5	8.1	4.0
Pinyon-juniper	5	11.2	2.2
Mixed-mountain brush	3	11.1	3.6
Riparian	3	12.3	5.9
Grass-forb/shrub	1	12.6	NA
Ponderosa-shrub	1	5.1	NA
Ponderosa-rock	1	6.7	NA
Ponderosa-oak	1	4.5	NA
1995-Fall			
Mesas	9	18.4	2.9
Aspen	3	16.1	2.4

Table 8. Continued.

Ponderosa pine	3	14.4	7.0
Grass-forb/shrub	3	24.9	8.0
Canyons	18	12.3	4.5
Mixed-conifer	4	8.6	5.3
Pinyon-juniper	4	14.4	4.0
Mixed-mountain brush	3	9.9	2.3
Riparian	3	9.2	2.4
Grass-forb/shrub	1	20.3	NA
Ponderosa-shrub	1	17.2	NA
Ponderosa-cliff	1	17.6	NA
Ponderosa-oak	1	12.0	NA

[a] Relative abundance = No. of different animals captured per 100 trap nights.

Relative Abundance - Mesas

Species.--The deer mouse was the most abundant species on the mesas in both seasons in 1994 and 1995 (Table 2 and 3, respectively). The deer mouse was found in all of the vegetation types on the mesas in each season of each year (Table 4, 5, 6, 7). Deer mouse relative abundances ranged from 6.1 in the ponderosa pine vegetation type in the fall of 1994 (Table 5) to 19.0 in the grass-forb/shrub vegetation type in the fall of 1995 (Table 7).

The brush mouse, canyon mouse, and pinyon mouse all had low relative abundances on the mesas ranging from 0.5 in most of the vegetation types for each season in each year (Table 4, 5, 6, 7) to 5.6 for the brush mouse in the grass/forb-shrub vegetation type in the summer of 1995 (Table 6).

The montane vole had relative abundances that ranged from 0.5 in the ponderosa pine vegetation type in the summer of 1994 (Table 4) and also in the grass/forb-shrub vegetation type in the fall of 1995 (Table 7). The least chipmunk had relative abundances that ranged from 1.0 in the ponderosa pine vegetation type in the summer of 1994 (Table 4) to 4.8 in the grass-forb/shrub vegetation type also in the summer of 1994 (Table 4). The Colorado chipmunk was only captured in the poderosa pine vegetation type in the fall of 1994 (Table 5).

Seasonal and yearly variation.--No significant difference was found in small mammal relative abundances between the seasons in either 1994 or 1995 ($P < 0.05$). Comparisons of relative abundances of small mammals for each season between years were not significantly different at the $P < 0.05$ level, except for the fall mesa comparison ($P = 0.0083$, Kruskal-Wallis) with the fall of 1995 having a higher relative abundance of small mammals than the fall 1994 (Table 8).

Vegetation types.--Relative abundance between the 3 mesa vegetation types was significantly different during the summer of 1994 and 1995 and the fall of 1994. Significant differences occurred between the ponderosa pine vegetation type and the grass-forb/shrub vegetation type ($P < 0.05$, Dunn's; for each of the seasons) with the grass-forb/shrub vegetation having a higher relative abundance than the ponderosa pine vegetation (Table 8). In the fall of 1995, there were significant differences between the aspen-ponderosa pine and the grass-forb/shrub vegetation types ($P < 0.001$, Dunn's), and between the ponderosa pine and grass-forb/shrub vegetation types ($P < 0.001$, Dunn's) with the grass-forb/shrub vegetation having a higher relative abundance in both cases (Table 8). The vegetation type on the mesas with the highest abundance of animals was the grass-forb/shrub vegetation type in Peavine Canyon in the fall of 1995 (20.3; Table 8).

Relative Abundances - Canyons Versus Mesas

During the summer of 1994 and 1995, small mammal relative abundance in the canyons was not significantly different from small mammal relative abundance on the mesas ($P = 0.8113$, Kruskal-Wallis; $P = 0.0833$, Kruskal-Wallis; respectively). In the fall of 1994 and 1995, small mammal relative abundance was significantly different between the canyons and mesas ($\underline{P} < 0.0001$, Kruskal-Wallis; $\underline{P} = 0.0268$, Kruskal-Wallis; respectively). During the fall of 1994, small mammal relative abundances were higher in the canyons than on the mesas (13.6 to 8.5, respectively; Table 8). In the fall of 1995, the reverse was observed with the mesas having a higher relative abundance of small mammals than the canyons (18.4 to 12.3, respectively; Table 3). However, overall (years and seasons combined), there was no significant difference in relative abundances between the canyons and mesas ($\underline{P} = 0.5913$; Mann-Whitney).

MANOVA Results

MANOVA results for data grouped over vegetation types showed that no interaction occurred between seasons and years or in season and year main effects for 7 of the 8 small mammal species used in the analyses (Table 9). Therefore, data for the 7 species without interaction were grouped over seasons and years. The canyon mouse did have interaction between seasons and years (Table 9); however, due to the small sample size captured in 1995 in both seasons, multiple regression analyses were conducted only on data for the summer and fall of 1994.

Table 9. Results (significant P values) from MANOVA analyses for each small mammal species to determine if interaction between years (1994 and 1995) and seasons (summer and fall) was observed, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Species	Year	Season	Year by Season
Peromyscus maniculatus	0.890	1.000	1.000
P. crinitus	0.017	0.006	0.015
P. boylei	0.128	0.497	0.391
P. truei	0.317	0.795	0.904
Neotoma mexicana	0.993	0.988	0.990
Microtus montanus	0.802	0.866	0.970
Tamias minimus	0.750	1.000	0.983
T. quadrivittatus	0.960	0.922	0.922

MANOVA results by vegetation type indicated that 91.4% of the 8 species used in these analyses did not have interaction between years and/or seasons (Table 10). Interaction between years and seasons was observed with the Colorado chipmunk in the mixed-conifer vegetation type (P = 0.000) and with the brush mouse in the mixed-mountain brush vegetation type (P = 0.035). Main effect differences between years was observed with the deer mouse in the mixed-conifer vegetation type (P = 0.015), with the brush mouse in the mixed-mountain brush vegetation type (*P* = 0.012), and with the Colorado chipmunk in the mixed-conifer vegetation type (*P* = 0.001). Main effect differences between seasons was only observed with the Colorado chipmunk in the mixed-conifer vegetation type (*P* = 0.036). If sample size was small (≤5 cases for a species) it was excluded from the analysis for that particular vegetation type. Because only 8.6% of the small mammal species had interaction of some kind between years and/or seasons in each of the vegetation types, stepwise logistic regression was conducted on each species for each vegetation type on combined years and seasons.

Table 10. Results (significant *P* values) from MANOVA analyses for each small mammal species by each vegetation type to determine if interaction between years (1994 and 1995) and seasons (summer and fall) was observed, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Vegetation Type Species	Year	Season	Year by Season
Aspen			
Peromyscus maniculatus	0.589	0.635	0.472
P. crinitus	---	---	---
P. boylei	---	---	---

Table 10. Continued.

P. truei	---	---	---
Neotoma mexicana	---	---	---
Microtus montanus	0.839	0.343	0.581
Tamius minimus	0.285	0.498	0.079
T. quadrivittatus	---	---	---
Ponderosa pine			
Peromyscus maniculatus	0.521	0.964	0.506
P. crinitus	---	---	---
P. boylei	---	---	---
P. truei	---	---	---
Neotoma mexicana	---	---	---
Microtus montanus	---	0.669	---
Tamius minimus	0.746	0.312	0.880
T. quadrivittatus	---	---	---
Grass-forb/shrub			
Peromyscus maniculatus	0.769	0.128	0.685
P. crinitus	---	---	---
Pinyon-juniper			
Peromyscus maniculatus	0.176	0.485	0.976
P. crinitus	0.092	0.269	---
P. boylei	0.842	0.977	0.930
P. truei	0.413	0.548	0.929

Table 10. Continued.

Neotoma mexicana	0.829	0.951	0.829
Microtus montanus	---	---	---
Tamius minimus	0.570	0.708	---
T. quadrivittatus	0.333	0.322	0.942
Mixed-conifer			
Peromyscus maniculatus	0.015	0.690	0.427
P. crinitus	0.871	0.373	---
P. boylei	0.175	0.538	---
P. truei	0.123	---	---
Neotoma mexicana	---	---	---
Microtus montanus	---	---	---
Tamius minimus	0.236	0.806	0.934
T. quadrivittatus	0.001	0.003	0.000
Mixed-mountain brush			
Peromyscus maniculatus	0.530	0.669	0.949
P. crinitus	0.929	0.300	---
P. boylei	0.012	0.051	0.035
P. truei	---	---	---
Neotoma mexicana	0.920	0.920	---
Microtus montanus	---	---	---
Tamius minimus	0.137	0.635	0.626
T. quadrivittatus	0.810	0.950	0.893
Riparian			

Table 10. Continued.

Peromyscus maniculatus	0.873	0.955	0.944
P. crinitus	0.205	0.658	---
P. boylei	0.834	0.960	---
P. truei	---	---	---
Neotoma mexicana	0.930	0.217	---
Microtus montanus	---	---	---
Tamius minimus	0.897	0.949	0.766
T. quadrivittatus	0.829	0.953	0.843
P. boylei	0.962	0.849	0.641
P. truei	---	---	---
Neotoma mexicana	---	---	---
Microtus montanus	0.505	0.713	0.558
Tamius minimus	0.532	0.518	0.365
T. quadrivittatus	---	---	---

Multiple Regression

The significance level criteria was reached by the inclusion of ≤4 variables for the small mammal species analyzed over all vegetation types combined by stepwise multiple regression (Appendix C). The adjusted R^2 value ranged from 0.03 for the least chipmunk over all years and seasons combined to 0.66 for the canyon mouse in the fall of 1994 (Appendix C). All equations were significant at the *P*

≤ 0.10 level, and all but 2 equations were significant at the $P \leq 0.05$ level, least chipmunk ($P = 0.068$) and the Colorado chipmunk ($P = 0.099$; Appendix C). Only the multiple regression models for the deer mouse, cactus mouse, pinyon mouse, and montane vole exceeded the 0.17 R^2 value needed to achieve a power of 80% or greater (Appendix C).

The regression coefficients that comprised the final regression equation indicate the relative importance of each variable in the equation. The abundance of deer mice increased with an increase in evergreen shrubs in the 0 to 0.5 m height category (ERS1), a decrease in evergreen shrubs in the >1 to 2 m height category (ERS3), and an increase in forbs (D; Table 11).

The abundance of canyon mice in summer 1994 increased with an increase in rock cover and ERS1 cover (Table 11). In fall 1994, canyon mice abundance increased with an increase in rock cover, deciduous shrubs in the >0.5 to 1.0 m height category (DCS2), evergreen trees in the >0.5 to 1.0 m height category (ERT2), and with a decrease in litter depth (LDX; Table 11).

The abundance of brush mice increased with an increase in ERS3 and a decrease in forbs (Table 11). The abundance of pinyon mice increased with an increase in evergreen trees in the >1 to 2 m height category (ERT3; Table 11).

The abundance of woodrats increased with a decrease in forb cover (Table 11). The abundance of the montane vole increased with an increase in deciduous trees at the >15 to 30 m height category (DCT6) and an increase in evergreen shrubs at the >0.5 to 1 m height category (ERS2;Table 11). The abundance of least chipmunks increased with a decrease in mean litter depth, and the abundance of the Colorado chipmunk increased with an increase in ERS2 (Table 11).

Overall, with all species combined, abundance of small mammals increased with an increase in ERS2, and with a decrease in evergreen trees in the >5 to 15 m height category (ERT5) and with cactus (E; Table 11).

Table 11. Variables associated with increases in abundance of small mammal species based on multiple regression analysis over all vegetation types combined, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Species	Variable
Peromyscus maniculatus	+ evergreen shrubs 0 - 0.5 m
	- evergreen shrubs >1 - 2 m
	+ forb cover
P. crinitus	
1994 Summer	+ rock cover
	+ evergreen shrubs 0 - 0.5 m

Table 11. Continued.

1994 fall	+ rock cover
	+ deciduous shrubs >0.5 - 1 m
P. boylei	+ evergreen trees >1 - 2 m
Neotoma mexicana	- forb cover
Microtus montanus	+ deciduous trees >15 - 30 m
	+ evergreen shrubs >0.5 - 1 m
Tamias minimus	- mean litter depth
T. quadrivittatus	+ evergreen shrubs >0.5 - 1 m
Overall	+ evergreen shrubs >0.5 - 1 m
	- evergreen trees >5 - 15 m
	- cactus cover

Logistic regression

The significance level criteria was reached by the inclusion of 1-5 variables for all of the small mammal species within each of the vegetation types analyzed by stepwise logistic regression (Table 12). Correct classification of small mammals being present over all vegetation types ranged from 36.0% to 86.7%, with the lowest percentage occurring in the mixed-mountain brush vegetation type and the highest occurring in the grass-forb/shrub vegetation type (Table 12).

Aspen Vegetation Type.--Within the aspen vegetation type, correct classification for the presence of three of the eight small mammal species ranged from 78.8% for the deer mouse to 71.0% for the mountain vole (Table 12). The presence of deer mice was negatively associated with forb cover and ERT6 cover (Table 12). Forbs covered 15.3% of the area and ERT6 covered 5.0% of the area (Table 13). The presence of montane voles was positively associated with DCS1 and with DCT6 cover (Table 12). Deciduous shrubs in the 0 to 0.5 m height category covered 30.8% of the area and DCT6 covered 22.0% of the area (Table 13). Least chipmunks were negatively associated with ERT4 cover, positively associated with DCS4, and with deciduous trees in the >5 to 15 m height category (DCT5; Table 12). Evergreen trees in the > 2 to 5 m height category covered 6.7% of the area, DCS4 covered 8.0% of the area, and DCT5 covered 19.7% of the area where least chipmunks were present (Table 13).

Ponderosa Pine Vegetation Type.--Correct classification for the presence of 2 of the 8 species were 54.3% for the least chipmunk and 62.8% for the deer mouse (Table 12). The presence of deer mice was negatively associated with canopy cover (Table 12) which covered 26.8% of the area (Table 13). The presence of least chipmunks was negatively associated with canopy cover and positively associated with rock cover (Table 12). Canopy covered 27.9% of the area and rocks covered 4.8% of the area (Table 13).

Grass-forb/Shrub Vegetation Type.--Within the grass-forb/shrub vegetation type, correct classification for the presence of 4 of the 8 small mammal species ranged from 62.1% for the deer mouse to 86.7% for the mountain vole (Table 12). The presence of deer mice was negatively associated with grasses and positively associated with ERS1 (Table 12). Grasses covered 11.4% of the area and ERS1 covered 28.7% of the area (Table 13). The presence of brush mice was positively associated with litter cover (Table 12) which covered 81.8% of the area (Table 13).

The montane vole was negatively associated with deciduous shrubs in the >0.5 to 1.0 m height category (DCS2) and positively associated with ERS1 (Table 12). Deciduous shrubs in the >0.5 to 1 m height category covered 1.8% and ERS1 covered 38.5% of the area where mountain voles were present (Table 13). Grasses with a cover of 8.1% were negatively associated with the presence of least chipmunks (Table 12 and 13).

Pinyon-juniper Vegetation Type.--Correct classification of 7 out of the 8 small mammal species being present within the pinyon-juniper vegetation type ranged from 39.3% for the deer mouse to 76.8% for the Colorado chipmunk (Table 12). Deciduous shrubs in the 0 to 0.5 m height category (DCS1)and in the >1 to 2 m height category (DCS3), rock, and bareground were variables included in the logistic regression models for the 4 Peromyscus species (Table 12).

Both rock and DCS3 cover were positively associated with the presence of canyon mice (Table 12). Deciduous shrubs in this height category covered 16.9% of the area, 14.0% of the area was covered by rock (Table 13). Deer mice were negatively associated with rock cover and positively associated with DCS1 (Table 12). Rock covered 5.8% of the area and DCS1 covered 13.8% of the area where deer mice were present (Table 13). Pinyon mice were negatively associated with DCS3 (Table 12) that covered 5.5% of the area where they were present (Table 13). Brush mice were positively associated with bareground (Table 12) that covered 32.4% of the area where they were present (Table 13).

Mexican woodrats were negatively associated with canopy cover and positively associated with cacti and rock cover (Table 12). Mean percent canopy cover was 8.2%, cacti cover was 2.7%, and rock cover was 12.6% of the area where Mexican woodrats were present (Table 13).

The presence of least chipmunks was positively associated with litter, deciduous shrubs in the 0 to 0.5 m height category (DCS1), and litter depth (Table 12). Litter depth mean was approximately 26 mm, litter covered 61% of the area, and DCS1 covered 20.0% of the area where least chipmunks were present (Table 13). The presence of Colorado chipmunks was negatively associated with litter depth, and positevly associated with DCS3 and rock cover (Table 12). Mean litter depth was approximately 10 mm, rock cover was 15.7% of the area, and DCS3 was 16.4% of the area where Colorado chipmunks were present (Table 13).

Mixed-conifer Vegetation Type.--In the mixed-conifer vegetation type correct classification of 5 out of the 8 small mammal species being present ranged from 58.1% for the canyon mouse to 83.7% for the least chipmunk (Table 12). The deer mouse and brush mouse both had negative associations with all of the variable(s) in their models. The logistic regression model for the brush mouse included grass cover, rock cover, and evergreen trees in the >2 to 5 m height category (ERT4) and the >5 to 15 m height category (ERT5; Table 12). Rock and grass covered 3.5% and 2.3% of the area, respectively, while ERT4 covered 24.7% of the area, and ERT5 covered 16.6% of the area (Table 13). The variables associated with the deer mouse model were litter depth and evergreen trees in the >15 to 30 m height category (ERT6; Table 12). Mean litter depth was approximately 27 mm and ERT6 covered 3.6% of the area (Table 13).

Forb, rock, DCS3, ERS1, and ERS2 cover were associated with the presence of the canyon mouse (Table 12). Both the forb cover and DCS3 cover had a negative association with the presence of canyon mice (Table 12). Forbs covered 2.9%

of the area, and DCS3 covered 5.9% of the area (Table 13). Rock cover, ERS1, and ERS2 cover were all positively associated with the presence of canyon mice (Table 12). Rock covered 11.2% of the area, ERS1 covered 10.0% of the area, and ERS2 covered 2.9% of the area (Table 13).

The least chipmunk was negatively associated with rock (Table 12) covering 1.8% of the area (Table 13). The presence of Colorado chipmunks were positively associated with rock cover and negatively associated with litter and with deciduous shrubs in the >2 to 5 m height category (DCS4; Table 12). Litter covered 60.8%, rock covered 15.4%, and DCS4 covered 1.0% of the area where Colorado chipmunks were present (Table 13).

Mixed-mountain Vegetation Type.--Within the mixed-mountain brush vegetation type, the correct classification for the presence of 6 out of the 8 small mammal species ranged from 36.0% for the least chipmunk to 78.6% for the Colorado chipmunk (Table 12). The deer mouse and the brush mouse were associated with forb species. The deer mouse was positively associated with forb cover and negatively associated with rock cover (Table 12). Forbs covered 11.1% of the area and rocks covered 1.9% of the area where deer mice were present (Table 13). The brush mouse was negatively associated with forb and grass cover (Table 12). Forbs covered 2.3% and grasses covered 3.1% of the area where brush mice were present (Table 13). Canyon mice were negatively associated with grass cover and positively associated with rock and DCS3 cover (Table 12). Grasses covered 3.0% of the area, rocks covered 7.3% of the area, and DCS3 covered 48.6% of the area where canyon mice were present (Table 13).

The presence of Mexican woodrats was positively associated with ERS1 cover and DCS3 cover (Table 12) with ERS1 covering 13.6% of the area and DCS3 covering 62.7% of the area (Table 13). The least chipmunk was positively associated with evergreen trees in the >1 to 2 m height category (ERT3; Table 7) with ERT3 covering 10.5% of the area (Table 13). The presence of Colorado chipmunks was negatively associated with a mean litter depth (Table 12) of approximately 18 mm and forbs (Table 12) covering 3.5% of the area (Table 13).

Riparian Vegetation Type.--In the riparian vegetation type, correct classification for 4 out of the 8 small mammal being present ranged from 61.9% for the least chipmunk to 86.4% for the Colorado chipmunk (Table 12). The presence of deer mice was negatively associated with evergreen trees in the >1 to 2 m height category (Table 12) which covered 3.7% of the area (Table 13). The presence of canyon mice was negatively associated with a mean litter depth (Table 12) of approximately 13 mm (Table 13).

The presence of least chipmunks was negatively associated with forbs and positively associated with mean litter depth (Table 12). Forbs covered 3.2% of the area and mean litter depth was approximately 32 mm (Table 13). The presence of Colorado chipmunks was negatively associated with both a mean litter depth (Table 12) of approximately 7 mm (Table 13) and deciduous trees in the >1 to 2 m height category (DCT3; Table 12) which covered 1.3% of the area (Table 13).

Table 12. Results of the Wald Chi-square (X^2) for each habitat variable included in the logistic regression model for the presence/absence of each small mammal species within each vegetation type, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Vegetation type Species (n) Variable(s)	Coefficient	X^2	P
Aspen			
Peromyscus maniculatus (165)			
Constant	0.4166	5.9643	0.0146
Forb cover	-0.1200	3.0707	0.0797
Evergreen trees (>15-30 m)	-0.1977	10.0217	0.0015
* % correctly classified for presence/absence = 78.8/41.2			

Table 12. Continued.

Microtus montanus (62)			
Constant	-0.9057	9.0456	0.0026
Deciduous trees (>15-30 m)	0.1345	3.2088	0.0732
Deciduous shrubs (0-0.5 m)	0.2584	9.0294	0.0027
* % correctly classified for presence/absence = 71.0/67.7			
Tamias minimus (96)			
Constant	-0.1698	0.5950	0.4405
Evergreen trees (>2-5 m)	-0.1241	2.6076	0.1064
Deciduous shrubs (>2-5 m)	0.0535	0.3868	0.5340
Deciduous trees (>5-15 m)	0.1711	6.6263	0.0100
* % correctly classified for presence/absence = 47.9/63.5			
Ponderosa Pine			
P. maniculatus (148)			
Constant	0.5880	8.9827	0.0027
Canopy cover	-0.0182	14.0488	0.0002
* % correctly classified for presence/absence = 62.8/54.7			
T. minimus (70)			
Constant	0.2531	0.7170	0.3971
Canopy cover	-0.0141	3.7730	0.0521
Rock cover	0.7365	5.9795	0.0145
* % correctly classified for presence/absence = 54.3/67.1			
Grass-forb/shrub			

Table 12. Continued.

P. maniculatus (152)			
Constant	0.0183	0.0064	0.9261
Grass cover	-0.1655	10.6299	0.0011
Evergreen shrubs (0-0.5 m)	0.1336	4.9689	0.0258
* % correctly classified for presence/absence = 67.1/46.1			
P. boylei (19)			
Constant	-3.2416	4.6462	0.0311
Litter	0.4005	5.1640	0.0231
* % correctly classified for presence/absence = 73.7/63.2			
M. montanus (30)			
Constant	-0.1314	0.0387	0.8441
Deciduous shrubs (>0.5-1 m)	-0.8341	4.6931	0.0303
Evergreen shrubs (0-0.5 m)	0.1634	1.2451	0.2645
* % correctly classified for presence/absence = 86.7/53.3			
T. minimus (131)			
Constant	0.4826	8.8968	0.0029
Grass cover	-0.3461	18.0197	0.0000
* % correctly classified for presence/absence = 74.8/48.1			
Pinyon-juniper			
P. maniculatus (135)			
Constant	-0.0141	0.0068	0.9343
Deciduous shrubs (0-0.5 m)	0.1336	3.9788	0.0461

Table 12. Continued.

Rock cover	-0.1890	3.2267	0.0724
* % correctly classified for presence/absence = 39.3/71.9			
P. boylei (98)			
Constant	0.6644	5.2218	0.0223
Bareground	-0.1656	6.9521	0.0084
* % correctly classified for presence/absence = 65.3/53.1			
P. crinitus (65)			
Constant	-0.9675	11.5112	0.0007
Rock cover	0.3656	6.2013	0.0005
Deciduous shrubs (>1-2 m)	0.5282	12.1969	0.0128
* % correctly classified for presence/absence = 63.1/67.7			
P. truei (73)			
Constant	0.3351	2.7281	0.0986
Deciduous shrubs (>1-2 m)	-0.3707	7.7114	0.0055
* % correctly classified for presence/absence = 68.5/50.7			
Neotoma mexicana (23)			
Constant	-0.6555	1.3102	0.2524
Canopy cover	-0.0514	1.5368	0.2151
Cactus cover	2.6995	5.0474	0.0247
Rock cover	0.4551	2.4735	0.1158
* % correctly classified for presence/absence = 65.2/73.9			
T. minimus (35)			

Table 12. Continued.

Constant	-1.4612	5.2959	0.0214
Litter depth	0.0213	0.4603	0.4975
Litter	0.1059	0.4671	0.4943
Deciduous shrubs (0-0.5 m)	0.4290	4.2015	0.0404
* % correctly classified for presence/absence = 62.9/85.7			
T. quadrivittatus (56)			
Constant	0.4819	1.3806	0.2400
Litter depth	-0.0910	14.5434	0.0001
Rock cover	0.2820	3.0674	0.0799
Deciduous shrubs (>1-2 m)	0.2777	4.1081	0.0427
* % correctly classified for presence/absence = 76.8/64.3			
Mixed-conifer			
P. maniculatus (161)			
Constant	0.5634	5.4336	0.0198
Litter depth	-0.0125	2.9181	0.0876
Evergreen trees (>15-30 m)	-0.2944	12.2909	0.0005
* % correctly classified for presence/absence = 78.3/35.4			
P. boylei (60)			
Constant	0.6984	4.7548	0.0287
Grass cover	-0.4717	3.4076	0.0649
Evergreen trees (>2-5 m)	-0.0349	0.2347	0.6281
Evergreen trees (>5-15 m)	-0.1255	3.0309	0.0817

Table 12. Continued.

Rock cover	-0.2599	1.9515	0.1624
* % correctly classified for presence/absence = 63.3/58.3			
P. crinitus (31)			
Constant	-0.3747	0.7789	0.3775
Forb cover	-0.3110	1.1485	0.2839
Rock cover	0.2877	2.4616	0.1167
Evergreen shrubs (0-0.5 m)	0.6685	2.9595	0.0854
Evergreen shrubs (>0.5-1 m)	6.3363	27.1005	0.8151
Deciduous shrubs (>1-2 m)	-0.2902	1.1484	0.2839
* % correctly classified for presence/absence = 58.1/80.7			
T. minimus (49)			
Constant	0.0925	0.1826	0.6691
Rock cover	-0.3213	1.2584	0.2620
* % correctly classified for presence/absence = 83.7/20.4			
T. quadrivittatus (36)			
Constant	1.8494	3.1281	0.0770
Litter	-0.2183	3.8640	0.0493
Rock cover	0.1562	0.6221	0.4303
Deciduous shrubs (>2-5 m)	-0.9173	2.3851	0.1225
* % correctly classified for presence/absence = 58.3/66.7			
Mixed-mountain brush			
P. maniculatus (167)			

Table 12. Continued.

Constant	-0.0724	0.2336	0.6289
Forb cover	0.2099	5.7556	0.0164
Rock cover	-0.4088	7.9402	0.0048
* % correctly classified for presence/absence = 53.3/65.3			
P. boylei (56)			
Constant	0.9186	11.2538	0.0008
Forb cover	-0.9307	9.0868	0.0016
Grass cover	-0.5221	5.3839	0.0209
* % correctly classified for presence/absence = 75.0/67.9			
P. crinitus (51)			
Constant	-0.9080	3.4882	0.0618
Grass cover	-0.7120	8.9642	0.0028
Rock cover	0.6429	7.3225	0.0068
Deciduous shrubs (>1-2 m)	0.2078	6.3848	0.0115
* % correctly classified for presence/absence = 70.6/66.7			
N. mexicana (10)			
Constant	-1.2003	1.5084	0.2194
Evergreen shrubs (0-0.5 m)	0.1693	0.3486	0.5549
Deciduous shrubs (>1-2 m)	0.1727	1.4185	0.2337
* % correctly classified for presence/absence = 60.0/70.0			
T. minimus (25)			
Constant	-0.2192	0.4694	0.4933

Table 12. Continued.

Evergreen trees (>1-2 m)	0.2855	1.9899	0.1583
* % correctly classified for presence/absence = 36.0/80.0			
_T_. _quadrivittatus_ (28)			
Constant	1.6429	7.2878	0.0069
Litter depth	-0.0471	4.9149	0.0266
Forb cover	-0.8458	3.5078	0.0611
* % correctly classified for presence/absence = 78.6/53.6			
Riparian			
_P_. _maniculatus_ (146)			
Constant	0.0743	0.3208	0.5711
Evergreen trees (>1-2 m)	-0.1530	1.5558	0.2123
* % correctly classified for presence/absence = 74.7/29.5			
_P_. _crinitus_ (38)			
Constant	0.3031	0.9738	0.3237
Litter depth	-0.0185	2.1234	0.1451
* % correctly classified for presence/absence = 76.3/47.4			
_T_. _minimus_ (23)			
Constant	-0.8478	1.6999	0.1923
Forb cover	-0.1511	0.2455	0.6202
Litter depth	0.0364	3.4753	0.0623
* % correctly classified for presence/absence = 60.9/60.9			
_T_. _quadrivittatus_ (22)			

Table 12. Continued.

Constant	1.2139	5.8705	0.0154
Litter depth	-0.0775	4.3253	0.0376
Deciduous trees (>1-2 m)	-0.5596	0.9733	0.3239

* % correctly classified for presence/absence = 86.4/54.6

Table 13. Means, standard deviations, and percent cover of all used (P) and non-used (A) variables included in each logistic regression model for each small mammal species within each vegetation type, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Area / Species / Grouped variable (code) / Variable (code)	P $\bar{X}$(±SD) / A $\bar{X}$(±SD)	P % Cover / A % Cover
Aspen		
P. maniculatus		
Forb cover	1.68(1.44)	15.3
	2.20(1.99)	20.0
Evergreen trees (>15-30 m)	0.55(1.68)	5.0
	1.31(2.30)	11.9
Ponderosa pine	0.55(1.68)	5.0
	1.31(2.30)	11.9
Pinyon pine	---	

Douglas fir	---	

Juniper spp.	---	

Microtus montanus		

Table 13. Continued.

Deciduous trees (>15-30 m)	2.42(2.94)	22.0
	1.20(2.46)	10.9
Aspen	2.42(2.94)	22.0
	1.20(2.46)	10.9
Deciduous shrubs (0-0.5 m)	3.39(2.44)	30.8
	2.10(2.35)	19.1
Mahogany spp.	---	

Squawbush	---	

Wild rose	---	
	0.02(0.14)	0.2
Utah Serviceberry	---	

Gamble oak	0.11(0.48)	1.0
	0.08(0.37)	0.7
Snowberry	3.27(2.31)	29.7
	2.00(2.20)	18.2
Dogwood	---	

T. minimus		
Evergreen trees (>2-5 m)	0.74(1.58)	6.7

Table 13. Continued.

	1.41(2.47)	12.8
Ponderosa pine	0.74(1.58)	6.7
	1.41(2.47)	12.8
Pinyon pine	---	

Douglas fir	---	

Juniper spp.	---	

Deciduous trees (>5-15 m)	2.17(3.07)	19.7
	1.48(2.30)	13.5
Aspen	2.17(3.07)	19.7
	1.48(2.30)	13.5
Maple spp.	---	

Deciduous shrubs (>2-5 m)	0.88(1.86)	8.0
	0.42(1.21)	3.8
Mahogany spp.	---	

Squawbush	---	

Utah Serviceberry	---	

Table 13. Continued.

Gamble oak	0.88(1.86)	8.0
	0.42(1.21)	3.8
Dogwood	---	

Ponderosa pine		
P. maniculatus		
Mean canopy cover	26.87(25.60)	
	38.73(24.43)	
T. minimus		
Rock cover	0.53(1.02)	4.8
	0.25(0.70)	2.3
Mean canopy cover	27.93(24.83)	
	35.71(25.45)	
Grass-forb/shrub		
P. maniculatus		
Grass cover	0.78(1.85)	7.1
	0.46(1.32)	4.2
Evergreen shrubs (0-0.5 m)	3.16(2.37)	28.7
	1.97(1.88)	17.9
Holy sp.	---	

Table 13. Continued.

Buffaloberry	---	

Sagebrush	3.13(2.39)	28.5
	1.93(1.89)	17.5
Rabbitbrush	---	

Mormon tea	---	

Oregon grape	---	
	0.02(0.14)	0.2
Bitterbrush	0.03(0.18)	0.3
	0.02(0.14)	0.2
P. boylei		
Litter	9.00(1.73)	81.8
	7.20(2.35)	65.5
M. montanus		
Evergreen shrubs (0-0.5 m)	4.23(2.03)	38.5
	2.62(2.26)	23.8
Holy sp.	---	

Buffaloberry	---	

Table 13. Continued.

Sagebrush	4.20(2.06)	38.2
	2.59(2.27)	23.5
Rabbitbrush	---	

Mormon tea	---	

Oregon grape	---	
	0.01(0.09)	0.1
Bitterbrush	0.03(0.18)	0.3
	0.03(0.17)	0.3
Deciduous shrubs (>0.5-1 m)	0.20(0.55)	1.8
	1.33(1.73)	12.1
Mahogany spp.	---	
	0.08(0.42)	0.7
Squawbush	---	

Wild rose	---	

Utah Serviceberry	0.20(0.55)	1.8
	0.96(1.43)	8.7
Gamble oak	---	
	0.29(1.05)	2.6

Table 13. Continued.

Snowberry	---	

Dogwood	---	

T. minimus		
Grass cover	0.89(1.19)	8.1
	2.27(3.02)	20.6
Pinyon-juniper		
Peromyscus maniculatus		
Rock cover	0.64(1.06)	5.8
	0.96(1.37)	7.3
Deciduous shrubs (0-0.5 m)	1.52(2.32)	13.8
	1.01(1.63)	9.2
Mahogany spp.	0.36(0.93)	3.3
	0.24(0.63)	2.2
Squawbush	0.04(0.30)	0.4
	0.04(0.30)	0.4
Wild rose	0.01(0.09)	0.1
	0.01(0.05)	0.1
Utah Serviceberry	0.20(0.53)	1.8
	0.10(0.35)	0.9
Gamble oak	0.88(1.97)	8.0

Table 13. Continued.

	0.54(1.36)	4.9
Snowberry	0.10(0.34)	0.9
	0.08(0.32)	0.7
Dogwood	---	

P. boylei		
bareground	3.56(2.38)	32.4
	4.33(2.44)	39.4
P. crinitus		
Rock cover	1.54(1.63)	14.0
	0.76(1.20)	6.9
Deciduous shrubs (>1-2 m)	1.86(1.91)	16.9
	1.03(1.53)	9.4
Mahogany spp.	0.82(1.25)	7.5
	0.32(0.80)	2.9
Squawbush	0.03(0.17)	0.3
	0.03(0.20)	0.3
Utah Serviceberry	0.26(0.54)	2.4
	0.12(0.39)	1.1
Gamble oak	0.75(1.44)	6.8
	0.54(1.29)	4.9
Dogwood	---	

Table 13. Continued.

P. truei		
Deciduous shrubs (>1-2 m)	0.60(1.09)	5.5
	1.24(1.67)	11.3
Mahogany spp.	0.48(0.94)	4.4
	0.36(0.75)	3.3
Squawbush	0.33(0.80)	3.0
	0.05(0.26)	0.5
Utah Serviceberry	0.26(0.54)	2.4
	0.12(0.39)	1.1
Gamble oak	0.75(1.44)	6.8
	0.54(1.29)	4.9
Dogwood	---	

Neotoma mexicana		
Cactus cover	0.30(0.47)	2.7
	0.13(0.38)	1.2
Rock cover	1.39(1.23)	12.6
	0.84(1.29)	7.6
Mean canopy cover	3.44(5.53)	
	8.43(11.40)	
Tamias minimus		

Table 13. Continued.

Litter	6.71(2.87)	61.0
	4.96(2.92)	45.1
Mean litter depth	26.63(18.86)	
	16.87(15.97)	
Deciduous shrubs (0-0.5 m)	2.20(2.53)	20.0
	1.07(1.78)	9.7
Mahogany spp.	0.74(1.31)	6.7
	0.24(0.65)	2.2
Squawbush	0.09(0.51)	0.8
	0.03(0.27)	0.3
Wild rose	---	
	0.01(0.07)	0.1
Utah Serviceberry	0.34(0.73)	3.1
	0.09(0.34)	0.8
Gamble oak	0.91(2.04)	8.3
	0.62(1.52)	5.6
Snowberry	0.11(0.40)	1.0
	0.08(0.32)	0.7
Dogwood	---	

T. quadrivittatus		
Rock cover	1.73(1.66)	15.7

Table 13. Continued.

	0.75(1.20)	6.8
Mean litter depth	9.87(8.13)	
	18.62(16.92)	
Deciduous shrubs (>1-2 m)	1.80(1.88)	16.4
	1.06(1.56)	9.6
Mahogany spp.	0.89(1.30)	8.1
	0.33(0.80)	3.0
Squawbush	---	
	0.05(0.25)	0.5
Utah Serviceberry	0.14(0.40)	1.3
	0.14(0.42)	1.3
Gamble oak	0.77(1.58)	7.0
	0.54(1.27)	4.9
Dogwood	---	

Mixed-conifer		
P. maniculatus		
Mean litter depth	27.03(14.21)	
	32.99(19.73)	
Evergreen trees (>15-30 m)	0.40(1.09)	3.6
	1.20(2.24)	10.9
Ponderosa pine	0.11(0.55)	1.0

Table 13. Continued.

	0.39(1.09)	3.5
Pinyon pine	---	

Douglas fir	0.29(0.89)	2.6
	0.81(1.94)	7.4
Juniper spp.	---	

P. boylei		
Grass cover	0.25(0.63)	2.3
	0.61(1.20)	5.5
Rock cover	0.38(0.78)	3.5
	0.65(1.50)	5.9
Evergreen trees (>2-5 m)	2.72(2.73)	24.7
	3.39(3.28)	30.8
Ponderosa pine	0.10(0.35)	0.9
	0.44(1.24)	4.0
Pinyon pine	0.10(0.48)	0.9
	0.15(0.70)	1.4
Douglas fir	2.10(2.65)	19.1
	2.29(3.00)	20.8
Juniper spp.	0.38(1.04)	3.5
	0.51(1.16)	4.6

Table 13. Continued.

Evergreen trees (>5-15 m)	1.83(2.86)	16.6
	2.53(3.30)	23.0
Ponderosa pine	0.07(0.41)	0.6
	0.68(1.79)	6.2
Pinyon pine	---	
	0.09(0.81)	0.8
Douglas fir	1.68(2.64)	15.3
	1.61(2.82)	14.6
Juniper spp.	0.08(0.53)	0.7
	0.15(0.76)	1.4
P. crinitus		
Forb cover	0.32(0.95)	2.9
	0.70(1.07)	6.4
Rock cover	---	
	0.58(1.37)	5.3
Evergreen shrubs (0-0.5 m)	1.10(1.38)	10.0
	0.38(0.89)	3.5
Holy sp.	---	
	0.01(0.13)	0.1
Buffaloberry	0.19(0.75)	1.7
	0.01(0.20)	0.1
Sagebrush	---	

Table 13. Continued.

	0.04(0.33)	0.4
Rabbitbrush	0.03(0.18)	0.3
	0.01(0.07)	0.1
Mormon tea	0.03(0.18)	0.3
	0.01(0.07)	0.1
Oregon grape	0.84(1.29)	7.6
	0.31(0.81)	2.8
Bitterbrush	---	

Evergreen shrubs (>0.5-1 m)	0.32(0.70)	2.9
	0.05(0.26)	0.5
Holy sp.	---	
	0.01(0.07)	0.1
Buffaloberry	0.26(0.68)	2.4
	0.02(0.19)	0.2
Sagebrush	---	
	0.01(0.10)	0.1
Rabbitbrush	---	

Mormon tea	---	

Oregon grape	0.07(0.25)	0.6

Table 13. Continued.

	0.02(0.15)	0.2
Bitterbrush	---	

Deciduous shrubs (>1-2 m)	0.65(1.11)	5.9
	1.38(1.92)	12.5
Mahogany spp.	0.16(0.37)	1.5
	0.11(0.49)	1.0
Squawbush	---	
	0.02(0.27)	0.2
Utah Serviceberry	0.13(0.43)	1.2
	0.17(0.57)	1.5
Gamble oak	0.36(0.80)	3.3
	1.08(1.70)	9.8
Dogwood	---	

<u>T</u>. <u>minimus</u>		
Rock cover	0.20(0.50)	1.8
	0.67(1.50)	6.1
<u>T</u>. <u>quadrivittatus</u>		
Litter	6.69(3.74)	60.8
	8.57(2.70)	77.9
Rock cover	1.69(2.60)	15.4

Table 13. Continued.

	0.53(1.26)	4.8
Deciduous shrubs (>2-5 m)	0.11(0.32)	1.0
	0.64(1.46)	5.8
Mahogany spp.	0.03(0.17)	0.3
	0.02(0.13)	0.2
Squawbush	---	

Utah Serviceberry	---	
	0.02(0.22)	0.2
Gamble oak	0.08(0.28)	0.7
	0.60(1.46)	5.5
Dogwood	---	

Mixed-mountain brush		
P. maniculatus		
Forb cover	1.22(1.41)	11.1
	0.78(1.17)	7.1
Rock cover	0.21(0.64)	1.9
	0.52(1.12)	4.7
P. boylei		
Grass cover	0.34(0.77)	3.1

Table 13. Continued.

	1.06(1.34)	9.6
Forb cover	0.25(0.55)	2.3
	1.08(1.34)	9.8
_P_. _crinitus_		
Grass cover	0.33(0.79)	3.0
	1.05(1.46)	9.5
Rock cover	0.80(1.37)	7.3
	0.33(0.87)	3.0
Deciduous shrubs (>1-2 m)	5.35(3.17)	48.6
	4.23(2.85)	38.5
Mahogany spp.	1.20(1.48)	10.9
	0.54(1.21)	4.9
Squawbush	0.02(0.14)	0.2
	0.00(0.05)	0.0
Utah Serviceberry	0.53(1.14)	4.8
	0.38(0.93)	3.5
Gamble oak	3.61(2.93)	32.8
	3.31(2.73)	30.1
Dogwood	---	

_N_. _mexicana_		
Evergreen shrubs (0-0.5 m)	1.50(1.78)	13.6

Table 13. Continued.

	0.56(1.14)	5.1
Holy sp.	---	

Buffaloberry	---	
	0.03(0.21)	0.3
Sagebrush	0.10(0.32)	0.9
	0.29(0.79)	2.6
Rabbitbrush	---	

Mormon tea	---	
	0.01(0.07)	0.1
Oregon grape	1.40(1.84)	12.7
	0.24(0.89)	2.2
Bitterbrush	---	

Deciduous shrubs (>1-2 m)	6.90(3.48)	62.7
	4.31(2.87)	39.2
Mahogany spp.	1.30(1.49)	11.8
	0.61(1.26)	5.5
Squawbush	---	
	0.01(0.07)	0.1
Utah Serviceberry	0.60(0.70)	5.5

Table 13. Continued.

	0.39(0.97)	3.5
Gamble oak	5.00(3.20)	45.5
	3.30(2.73)	30.0
Dogwood	---	

T. minimus		
Evergreen trees (>1-2 m)	1.16(1.89)	10.5
	0.66(1.57)	6.0
Ponderosa pine	---	
	0.03(0.22)	0.3
Pinyon pine	0.40(1.12)	3.6
	0.11(0.53)	1.0
Douglas fir	0.16(0.80)	1.5
	0.04(0.41)	0.4
Juniper spp.	0.60(1.32)	5.5
	0.49(1.37)	4.5
T. quadrivittatus		
Forb cover	0.29(0.54)	2.6
	0.97(1.29)	8.8
Mean litter depth	18.42(12.51)	
	33.89(18.56)	
Riparian		

Table 13. Continued.

P. maniculatus		
Evergreen trees (>1-2 m)	0.42(0.88)	3.8
	0.67(1.14)	6.1
Ponderosa pine	0.03(0.22)	0.3
	0.10(0.42)	0.9
Pinyon pine	0.01(0.08)	0.1
	0.00(0.06)	0.0
Douglas fir	0.10(0.54)	0.9
	0.14(0.65)	1.3
Juniper spp.	0.27(0.68)	2.5
	0.43(0.86)	3.9
P. crinitus		
Mean litter depth	13.34(18.62)	
	22.26(23.04)	
T. minimus		
Forb cover	0.35(0.71)	3.2
	0.99(1.32)	9.0
Mean litter depth	32.22(18.76)	
	20.75(22.86)	
T. quadrivittatus		
Mean litter depth	6.59(5.56)	
	22.27(23.11)	

Table 13. Continued.

Deciduous trees (>1-2 m)	0.14(0.35)	1.3
	1.16(1.77)	10.5
Willow spp.	---	
	0.24(0.72)	2.2
Aspen	---	
	0.01(0.07)	0.1
Maple spp.	0.14(0.35)	1.3
	0.08(0.37)	0.7
Water birch	---	
	0.83(1.60)	7.5
Single-leaf ash	---	

DISCUSSION

Relative Abundances - Canyons and Mesas

The primary objective of my study was to examine at a macro-scale the Mexican spotted owls second- (home range) and third-order selection (habitat components within home ranges) based on its fourth-order selection (prey consumed in a foraging site). More specifically, I determined and compared relative abundances of small mammals (primarily Mexican spotted owl prey species) within Mexican spotted owls home ranges. Within these home ranges I surveyed between the canyons and mesas, and between vegetation types occurring in both of these areas.

I found significantly higher relative abundances of small mammals in canyons in 1994 compared to summer 1994, and annual differences in abundance occurred on the mesas between the fall of 1994 and the fall of 1995, with the fall of 1994 having a higher relative abundance of small mammals. Similar results related to differences in abundances (or densities) between seasons and years have been observed in small mammal populations (Rosenweig and Winakur 1969, O'Farrell 1974, Kelt et al. 1994, Skupski 1995). These observations may be influenced by any number of abiotic environmental factors, predator populations, or food availability in any particular season or year (O'Farrell 1974, Van Horne 1983, USDI Fish and Wildlife Service 1995).

Differences between the canyons and mesas were only observed in the fall seasons with 1994 having a higher abundance of small mammals in the canyons and 1995 having a higher abundance on the mesas. Even though the canyons and mesas are usually less than 3.2 km (2 miles) apart, the environmental factors, predators, and food availability may be quite different between the areas. Therefore, the factors that influence abundances between seasons and years may be affecting the canyons and mesas in different ways.

Differences between vegetation types in the canyons were not observed. On the mesas, however, differences were observed primarily between the grass-forb/shrub vegetation type and the ponderosa pine and aspen vegetation types, with the grass-forb/shrub vegetation type having a higher abundance of animals than the others. The absence of differences between canyon vegetation types may be due to the proximity of each of these vegetation types to each other, such that the home ranges of each species of small mammals may encompass more than one particular vegetation type. Neotoma species, the owls primary prey species, were predominantly captured in the pinyon-juniper vegetation type.

On the mesas, the grass-forb/shrub vegetation type consisted primarily of sagebrush and was heavily used by cattle. The deer mouse is described by Fitzgerald et al.

(1994) as being able to easily adapt and exploit disturbed areas such as areas that have been heavily grazed. Coincidentally, the deer mouse had its highest abundance in this vegetation type. The least chipmunk, which was also very abundant in this vegetation type, is typically associated with open, sunny areas (Fitzgerald et al. 1994) as is characteristic of the grass-forb/shrub vegetation type.

Relative Abundances - Species Specific

The deer mouse was the most abundant species in all of the 11 vegetation types sampled in my study, which corroborates with the literature describing the deer mouse as inhabiting a wide range of vegetation types and being the commonest small mammal in North America (Burt and Grossenheider 1976, Hoffmeister 1986, Fitzgerald et al. 1994). Fitzgerald et al. (1994) noted that where Peromyscus species' specialized to specific areas are present, deer mice will be locally scarce or absent. This was not the case in my study where in 9 of the vegetation types deer mice were more abundant than any of the other 3 more specialized Peromyscus species captured. However, Armstrong (1979) noted that it is not uncommon for Peromyscus species to co-occur in areas where the vegetation is broken, as is found within the canyons in my study area. For example, the mixed-conifer vegetation type within the canyons may have scattered pinyon pines or patches of gamble oak within them.

The brush mouse was most abundant in the pinyon-juniper vegetation type which is characteristic of the species when these areas consist of rough, broken terrain with boulders and heavy brush (Wilson 1968, Hoffmeister 1986, Fitzgerald et al. 1994). The brush mouse was also abundant in the riparian vegetation type where the stream beds consist of heavy brush and rocks.

Canyon mice were almost equally abundant in the mixed-conifer, pinyon-juniper, and mixed-mountain brush vegetation types in my study, however, these vegetative qualities contradict the characteristic rocky, slickrock, and cliff habitats associated with the species (Hoffmeister 1986, Johnson and Armstrong 1987, Fitzgerald et al. 1994). This observation may be explained by the proximity of these vegetation types to the cliff walls and slickrock. Also, the vegetation types in the canyons were rocky and broken, for example, the mixed-conifer vegetation type was always along the steep sides of the canyons and often consisted of large boulders within small drainages that ran through the vegetation type. Johnson and Armstrong (1987) noted that the vegetation in an area may have little or no effect on the the local distribution of this species, but instead the species is associated with the rocky substrate of the area rather than the plant association.

The pinyon mouse was most abundant in the pinyon-juniper vegetation type in my study as is characteristic of the species throughout its range (Wilson 1968, Burt and Grossenheider 1976, Armstrong 1979, Hoffmeister 1986, Fitzgerald et al. 1994).

The Mexican woodrat is generally found on rocky slopes, cliffs, and rock outcrops (Burt and Grossenheider 1976) and is also associated with pinyon-juniper woodlands (Cornerly and Baker 1979, Armstrong 1979, Fitzgerald et al. 1994). In my study, the Mexican woodrat was most abundant in habitats similar to previous observations (Armstrong 1979) that were characteristic of the pinyon-juniper stands in my study.

The montane vole was most abundant on the mesas in the aspen vegetation type. These observations agree with habitats typically associated with the montane vole, consisting of moist to wet areas with thick forb and grass cover, including aspen stands (Hoffmeister 1986, Fitzgerald et al. 1994).

The least chipmunk was abundant in all of the 11 vegetation types sampled in my study, being most abundant on the mesas, especially within the grass-forb/shrub vegetation type. Fitzgerald et al. (1994) noted that the least chipmunk ranges over a wide area and in many different habitat types including semi-desert shrublands, montane woodlands and shrublands, and forest edge. Within this range of vegetation types, the least chipmunk generally occupies relatively open sunny areas on the edge of escape cover (Fitzgerald et al. 1994) which is characteristic of the grass-forb/shrub vegetation type.

The Colorado chipmunk was most abundant in the pinyon-juniper vegetation type which typifies its general distribution. Best et al. (1994) describe a variety of habitats in which the Colorado chipmunk is found where woodlands represented 36% of the areas occupied by the species. Lechleitner (1969) associates the Colorado chipmunk with pinyon-juniper and spruce-fir forests, and open, rocky, brushy areas. In addition, Fitzgerald et al. (1994) associated the Colorado chipmunk with broken terrain and occuring within canyons.

Vegetative Characteristics - Micro-scale

Multiple regression.--Of the 8 species used to conduct stepwise multiple regression analyses, only 5 models exceeded an R^2 value 0.17 to achieve a power of at least 80%; therefore, the models that have powers < 80% will not be discussed further and the focus will be on those models above 80%. My results indicate that, in general, each of the variables making up the final models for each of the species corroborates with the literature. For example, the model for the pinyon mouse contained a vegetation variable that corresponds to the vegetative characteristics described in the literature with respect to its habitat: it increased in abundance with an increase in evergreen trees such as pinyon pines and junipers (Wilson 1968, Armstrong 1979, Fitzgerald et al. 1994).

The deer mouse model contains variables that are non-specific to a particular vegetation type which corresponds to its abundance in all of the vegetation types in my study. The montane vole does have more specific habitat characteristics which agree with the variables in its multiple regression model, such as deciduous trees (aspen) in the aspen vegetation type where it was most abundant, and evergreen shrubs such as sagebrush in the grass-forb/shrub vegetation type where it was also abundant. These habitat characteristics reflect or include the requirements presented in the literature for the occurrence of these species (Armstrong 1979, Hoffmeister 1986, Fitzgerald et al. 1994).

Logistic Regression.--As noted in the introduction, I expected species to respond to different vegetative characteristics within specific vegetation types, and this was the case. In general, only 1 vegetation type, the pinyon-juniper vegetation type, contained groups of variables that > 2 species of small mammals had in common. Within the rest of the vegetation types, vegetation variables could not be grouped for each vegetation type, therefore, species specific management would be necessary rather than vegetation type management. However, a group of variables would make management of an area for groups of species much easier than trying to manipulate vegetation for 1 or 2 speices.

One must remember, however, that the variables within each model associated with each species are only valid when in coexistance with the other variables in the model. What I was attempting to do, however, is develop a basis for managing each vegetation type for > 1 group of species. A problem with these models, that may jepordize the validity of our results, may be due to the small sample size of the dependent variable (e.g., < 20) compared to the number of independent variables (e.g., > 10; Johnson 1981, Morrison et al. 1992:329-330). These models should therefore be considered purely as descriptive, rather than predictive representations of habitat requirements for the small mammals used in these analyses.

Within the pinyon-juniper vegetation type, rocky and open areas generally describe the presence of 4 of the 7 species of small mammals. These species, the canyon mouse, brush mouse, Mexican woodrat, and the Colorado chipmunk, are all associated with rocky open areas (Wilson 1968, Armstrong 1979, Hoffmeister 1986, Johnson and Armstrong 1987, Fitzgerald et al. 1994). Deciduous shrubs in height categories 1 and 3 (0 to 0.5 m and >1 to 2 m, respectively) were also associated with 4 of the 7 species of small mammals, the canyon mouse, deer mouse, Colorado chipmunk, and least chipmunk. Within these categories, mountain mahogany and gamble oak covered between 3.3 to 8.3% of the area where these species were present. In summary, open and rocky areas along with deciduous shrub cover ≤ 2 m high within pinyon-juniper stands are positively associated with most of the prey species in this vegetation type.

In consideration of the 4 predominant prey species consumed by owls in this area, 3 species, the deer mouse, canyon mouse, and brush mouse were represented in the mixed-conifer vegetation type. In general, 2 of these species (deer and brush mouse) were negatively associated with evergreen trees between the >5 to 30 m height categories, whereas the canyon mouse was positively associated with evergreen shrubs between 0 and 1 m in height.

In the mixed-mountain brush vegetation type, 3 of the 4 predominant prey species have somewhat similar vegetative characteristics. Both the brush mouse and the canyon mouse are negatively associated with grass and/or forb cover, while the Mexican woodrat and canyon mouse are positively associated with shrub cover between 0 and 2 m in height.

Within the riparian vegetation type, neither the deer mouse nor the canyon mouse shared any vegetative characteristics, therefore, management of this area would need to be at the species level.

On the mesas, only the deer mouse was found in all three vegetation types. Because this species is a generalist, vegetative characteristics varied within each vegetation type on the mesas. The brush mouse was the only other predominant prey species analyzed on the mesas and it was only captured in the grass-forb/shrub vegetation type. Within this vegetation type, it was positively associated with grass cover.

Prey Species and Mexican Spotted Owls

The deer mouse, brush mouse, and Mexican woodrat are consumed regularly by Mexican spotted owls throughout most of its range, and in Utah, canyon mice are also likely to be consumed (USDI Fish and Wildlife Service 1995). In my study, the canyon and brush mouse were primarily captured within the canyons, and the woodrats were only captured in the canyons. As mentioned earlier, the Mexican spotted owls studied in this area were primarily (> 75%) located within the canyons. D. W. Willey (unpubl. data) found that the owls within the canyons I was sampling in were primarily foraging in the pinyon-juniper vegetation type. This correlates with the woodrat being predominantly captured in the pinyon-juniper vegetation type. The other prey species of the owl were also abundant in this vegetation type.

Management Implications

My study showed that the 4 predominant prey species of the Mexican spotted owl (i.e., deer mouse, canyon mouse, brush mouse, and Mexican woodrat), were predominantly found in the pinyon-juniper vegetation type within the canyons. I have also found that these prey species are also fairly abundant in the other vegetation types within the canyons. Perhaps by maintaining the current mixture of vegetation types within the canyons it may at sometime be used as a buffer against the effects of small mammal cycles in any particular vegetation type (USDI Fish and Wildlife Service 1995). For example, small mammal populations are known to fluctuate around seed and/or cone-crop production (Boutin and Larson 1993). If a certain tree species produces cones one year, small mammal species that are not extreme habitat specialist (as most of the owls primary prey species are not) may temporarily move into the food abundant areas, thus maintaining viable populations.

In regards to the owls fourth-order selection (Johnson 1980), I recommend that current management practices at the macro-scale be maintained as is within the canyons. The Monticello Ranger District does not practice timber harvesting in the canyons and only allows cattle grazing on alternate years (J. Forrest, U.S. Forest Service, pers.

commun.). I base this recommondation on my results along with D. W. Willey's (unpubl. data) observations of Mexican spotted owls foraging behavior.

At the micro-scale level, I found that rock cover and open areas among deciduous shrubs between 0 and 2 m high within the pinyon-juniper vegetation type, along with the other variables in each of the prey species models, described the presence of 3 of the 4 predominant prey species of the owls during my study. It is very difficult to manage at this scale. However, these models can give managers a better understanding of the small mammals' associations within specific areas. If environmental factors in subsequent years are similar to those I experienced during my 2 year study, managers could use my models as starting points if small mammal abundances decrease by seeing which vegetative characteristics were associated with a higher abundance or with the presence of each species.

Skupski (1995) comments, however, on the drawbacks of short-term studies (2 or 3 years) in that they are unlikely to reflect the variation in population dynamics that is found in response to normal ranges of environmental variation. In this light, my study may actually only be revealing a small part of the natural fluctuations that may be present within these areas. Because prey abundance has been correlated with the reproductive success of owls, a better understanding of small mammal fluctuations within the canyons may be an assest to management of the owls. If managers have some idea of these fluctuations, they may be able to adequately evaluate an area's ability to support owls.

Currently, there are no timber harvesting practices conducted in the canyons within my study area, however, as mentioned earlier, cattle grazing practices are allowed in alternate years (J. Forrest, U.S. For. Serv., pers. commun.). The USDI Fish and Wildlife Service (1995) gave examples of studies having been conducted in grazed and non-grazed areas, primarily within meadows and riparian areas. These studies showed that, in general, grazing areas had an increase in deer mouse populations and a decrease in species diversity. Grandison (1994) suggests that livestock grazing would not have an affect on woodrat numbers due to their xeric habitats. However, within the canyons in the Manti-LaSal National Forest, the woodrats were also using other vegetation types that were not characteristic xeric habitats, therefore, livestock grazing may have a negative effect on woodrat numbers. Future studies within the Manti-LaSal Forest may involve studying the effect that grazing has on the abundance of small mammals within the canyon vegetation types.

In conclusion, the correlation between woodrats and Mexican spotted owls is extremely interesting. This suggests that the pinyon-juniper vegetation type is an important component of the owls home range during the summer and fall seasons based on owl foraging behavior studies, owl diet, and prey abundance of key species. Future research might address this further by assesing whether the amount of pinyon-juniper vegetation type within the hom range of individual owl pairs influences owl survival and reproductive success. Until then, maintaining the current management practices within the canyons may assist in the recovery and conservation of Mexican spotted owls in the Manti-LaSal National Forest.

APPENDIX A. Items recorded along line intercept and foliage height categories used in vegetation sampling in the Manti La-Sal National Forest, San Juan Co., Utah, 1994-1995.

Items:

-bareground
-litter=detached forbs and grasses; leaves, cones, and twigs <1 cm diameter
-gravel
-small rock ($\geq$1 cm-10 cm)
-medium rock (>10 cm-50 cm)
-large rock (>50 cm)
-boulder (rock outcrop, immovable)
-water=creek, pond, seep, wet meadow
-moss
-lichen (not in trees)
-small log (1m X $\geq$15 cm-30 cm)
-medium log (1m X >30 cm-60cm)
-large log (1m X >60 cm)
-stump=tree species $\geq$5 cm dbh and <3 m tall
-tree species=$\geq$5 cm dbh
-shrub=tree species <5 cm dbh and $\geq$1/4 m tall (<1/4 m tall=tree seedling)
=shrub species $\geq$0.5 m diameter
-tree seedling=<5 cm dbh, no dbh, <1/4 m tall
-forb species (alive or dead, but attached)
-grass species (alive or dead, but attached)

Foliage height categories:

1=0.0-0.5 m
2=>0.5-1.0 m
3=>1-2 m
4=>2-5 m
5=>5-15 m
6=>15-30 m
7=>30 m

APPENDIX B. Descriptions and sampling methods for variables to be used in measuring each plot in the Manti La-Sal National Forest, San Juan Co., Utah, 1994-1995.

Variables	Methods
Habitat Structure	
Percent canopy cover[a]	Percentage of points with woody vegetation $\geq$5 cm dbh; ocular tube (James and Shugart 1970).
Vertical structure[a]	Live foliage and limb heights of each species; estimate heights into foliage height categories (see Appendix 1).
Litter depth	Measure to mm at each meter mark; tape measure.
All items[a]	Identify items (see Appendix 1) at each meter mark.
Environmental Data	
UTM	UTM coordinates; topography map.
Slope	Degrees; compass.
Aspect	Degrees; compass.
Elevation	Meters; topography map.
Slope position	Slope location of plot relative to top and bottom of slope; estimate, 0.0 (bottom) to 1.0 (ridge of hill).
Vegetation strata	Number of distinct vegetation strata within the plot, considered a layer if strata covers >33% of plot area; estimate presence (1) or absence (0).
Vegetation type	Visual estimate of dominant plants.

APPENDIX B. Continued.

Vegetation change	Nearest major break in vegetation; visual or maps.
Distance to vegetation change.	Distance in meters; pace or map.
Water type	Nearest water type.
Distance to water type.	Distance in meters; pace or map.
Ephemeral water	Nearest ephemeral water.
Distance to ephemeral water.	Distance in meters; pace or map.
Rock outcrop	Nearest rock outcrop (boulder or cliff).
Distance to nearest rock outcrop.	Distance in meters; pace or map.
Dirt road	Distance to nearest dirt road.
Distance to nearest in-service dirt road.	Distance in meters; pace or map.

[a]sample on line intercept

APPENDIX C. Multiple regression equations, adjusted R^2 values, and significance values describing small mammal abundances based on small mammal-vegetation relationships over all vegetation types combined, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Species	Equation	Adjusted R^2	P
Peromyscus maniculatus	0.43 + 0.32(ERS1) -1.36(ERS3)+ 0.13(D)	0.37	0.0000
P. crinitus			
1994 summer	-0.02 + 0.18(ROCK) + 0.24(ERS1)	0.43	0.0132
1994 fall	0.18 + 0.14(ROCK) + 0.16(DCS2)- 0.02(LDX) + 0.25(ERT2)	0.66	0.0038
P. boylei	0.39 + 0.75(ERS3) - 0.15(D)	0.14	0.0107
P. truei	0.04 + 0.13(ERT3)	0.17	0.0163
Neotoma mexicana	0.10 - 0.05(D)	0.13	0.0469
Microtus montanus	0.05 + 0.14(DCT6) + 0.12(ERS2)	0.41	0.0001
Tamias minimus	0.52 - 0.01(LDX)	0.03	0.068
T. quadrivittatus	0.18 + 0.28(ERS2)	0.07	0.0987
Overall	1.32 + 0.92(ERS2) - 0.11(ERT5) - 1.72(E)	0.23	0.0000

ERS1 = Evergreen shrubs in the 0 - 0.5 m height category.
ERS3 = Evergreen shrubs in the > 1 - 2 m height category.
D = Forb cover.
ROCK = Rock cover.
DCS2 = Deciduous shrubs in the > 0.5 - 1 m height category.
LDX = Mean litter depth.
ERT2 = Evergreen trees in the > 0.5 - 1 m height category.
DCT6 = Deciduous trees in the > 15 - 30 m height category.
ERS2 = Evergreen shrubs in the > 0.5 - 1 m height category.
ERT5 = Evergreen trees in the > 5 - 15 m height category.
E = Cactus cover.

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