Interaction between deermice, antelope bitterbrush, and cattle in southwest Montana

by Stephanie Jo Matlock-Cooley

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Biological Sciences
Montana State University

Abstract:
Antelope bitterbrush (Purshia tridentata) stands appear to be non-reproductive via seed in southwestern Montana. Deermice (Peromvscus maniculatus) association with bitterbrush was observed to determine the role they have in the germination of bitterbrush plants. Deermice habitat variable selection was compared between two bitterbrush communities in the Mt. Haggin Wildlife Management Area using radio telemetry. This study area was located 6.2 km southeast of Anaconda, Montana. One site, Railroad Gulch, appeared to be more heavily used by domestic cattle (Bos taurus) in the past than the other site, Willow Creek. Cattle were grazed at the Willow Creek site for a one-day experiment in 1991 and 1992 . Habitat use changes were compared between the two sites following the grazing activity. Deermice were found to utilize bitterbrush at 1 to 50 cm above ground, at both sites, more than any other available vegetation type, indicating a close association between the deermice and the bitterbrush plants. Cattle grazing at Willow Creek did produce significant differences in habitat variable use by the mice. Mice were found to leave the bitterbrush and utilize the recently grazed grassy areas. This short-term grazing appeared to have a positive effect on the deermice by creating new resources. Few differences in habitat variable use were noted at the Railroad Gulch site, which had no cattle grazing. Artificial bitterbrush seed caches were planted inside and outside enclosures to compare germination with and without deermice presence. Caches germinated both inside and outside enclosures indicating germination was possible. Natural bitterbrush seed caches and germinating seedlings were never observed at either site. Deermice were found to remove and hoard seed in their burrows, but not scatter hoard as typically observed south of Montana. Relying on deermice for aiding in germination of bitterbrush seed appears to be unpredictable in this area.

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APPROVAL

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Stephanie Jo Matlock-Cooley

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date December 17, 1993

To Nancy Jane Matlock and Betty Jo Matlock, the matriarchs who influenced my life.

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ABSTRACT

Antelope bitterbrush (Purshia tridentata) stands appear to be non-reproductive via seed in southwestern Montana. Deermice (Peromyscus maniculatus) association with bitterbrush was observed to determine the role they have in the germination of bitterbrush plants. Deermice habitat variable selection was compared between two bitterbrush communities in the Mt. Haggin Wildlife Management Area using radio telemetry. This study area was located 6.2 km southeast of Anaconda, Montana. One site, Railroad Gulch, appeared to be more heavily used by domestic cattle (Bos taurus) in the past than the other site, Willow Creek. Cattle were grazed at the Willow Creek site for a one-day experiment in 1991 and 1992. Habitat use changes were compared between the two sites following the grazing activity. Deermice were found to utilize bitterbrush at 1 to 50 cm above ground, at both sites, more than any other available vegetation type, indicating a close association between the deermice and the bitterbrush plants. Cattle grazing at Willow Creek did produce significant differences in habitat variable use by the mice. Mice were found to leave the bitterbrush and utilize the recently grazed grassy areas. This short-term grazing appeared to have a positive effect on the deermice by creating new resources. Few differences in habitat variable use were noted at the Railroad Gulch site, which had no cattle grazing. Artificial bitterbrush seed caches were planted inside and outside enclosures to compare germination with and without deermice presence. Caches germinated both inside and outside enclosures indicating germination was possible. Natural bitterbrush seed caches and germinating seedlings were never observed at either site. Deermice were found to remove and hoard seed in their burrows, but not scatter hoard as typically observed south of Montana. Relying on deermice for aiding in germination of bitterbrush seed appears to be unpredictable in this area.

INTRODUCTION

The goal of this research was to examine interactions among deermice (Peromyscus maniculatus), antelope bitterbrush (Purshia tridentata) reproduction, and domestic cattle grazing by using radio telemetry on deermice in two similar bitterbrush shrub communities. The objectives were to determine: 1) whether patterns of habitat use by deermice, as estimated from radiotelemetry, suggest a close association between deermice and bitterbrush; 2) whether there are differences in habitat utilization by deermice following cattle grazing; and 3) whether there are losses of bitterbrush seeds, from rodent predation that result in caches and germination of bitterbrush. This research was conducted on the Mount Haggin Wildlife Management Area (MHWMA) south of Anaconda, Montana during 1991 and 1992.

Bitterbrush is an important winter forage for many wild ungulates. Mule deer (Odocoileus hemionus), elk (Cervus elaphus), pronghorn antelope (Antilocapra americana), bighorn sheep (Ovis canadensis), and moose (Alces alces) consume bitterbrush (Cliff 1939; Dasmann 1949; Mason 1952; Harry 1957; Wilkins 1957; McCullough and Schneegas 1966; and Stuth and Winward 1977). It is especially important for big game in winter because it is nutritious and palatable (Guinta et al. 1978).

The MHWMA was purchased in 1976 by the Montana Department of Fish, Wildlife, and Parks for big game winter range

(Frisina and Canfield 1987). The available bitterbrush stands within the management area make it very attractive to mule deer and elk. Recent studies of bitterbrush stands in the MHWMA have indicated little to no recruitment (Guenther 1989, and Fraas 1992). Therefore managers are interested in understanding factors affecting maintenance of these stands.

In addition to large mammals' preference for bitterbrush, deermice, yellow-pine chipmunk (Eutamias amoenus), chipping sparrow (Spizella passerina), and blue grouse (Dendragapus obscurus) all utilize bitterbrush for both food and shelter (Gordon 1943; Mussehl 1960; Everett et al. 1978). Nelson et al. (1970) credits deermice as the major consumer of artificially planted bitterbrush seed. Deermice, yellow-pine chipmunks, and chipping sparrows, all present at the study area in the MHWMA, are presumed to be the main vertebrate bitterbrush seed predators.

Deermice are found in higher numbers in bitterbrush communities than surrounding habitats (Douglass, 1989). The low recruitment rate of bitterbrush in the MHWMA inspired the need to determine the specific use by deermice in the bitterbrush community, and to evaluate the effect of caching on bitterbrush germination.

An interesting aspect of bitterbrush ecology is its apparent coevolution with rodents. Deermice and yellow-pine chipmunks consume and cache bitterbrush seed (Gordon 1943; Sanderson 1962; West 1968; Everett et al. 1978; Evans et al.

1983). The seeds are high in carbohydrates and are preferred by deermice over other native seeds (Everett et al. 1978, and Kelrick et al. 1986). Simultaneously, the caching behavior is an important factor in germination of bitterbrush, because rodents remove outer husks that contain a germination inhibitor (Fraas 1992). Most bitterbrush stands are established due to this caching behavior of rodents (Hormay 1943; Stanton 1959).

The role that cattle grazing activities may play on the behavior and abundance of deermice is another factor involved in the bitterbrush-deermice interaction. Cattle grazing has been shown to increase deermice numbers in mesic habitats and decrease their abundance in xeric habitats (Black and Frischknecht 1971; Grant et al. 1982; Page et al. 1977; Hanley and Page 1982; Medin and Clary 1989; Samson et al. 1989). This effect on deermice abundance, and consequently on their activities, can potentially affect the interaction between deermice and bitterbrush.

Because MHWMA has low bitterbrush recruitment, cattle grazing, and deermice activity, it is an ideal location to study these interactions.

STUDY AREA

This study was conducted in the Mount Haggin Wildlife Management Area (MHWMA), approximately 6.2 km southeast of Anaconda, Montana (Figure 1). This is a semiarid area located east of the Anaconda mountain range and near the Continental Divide. Annual precipitation was 362 mm in 1991 and 312 mm in 1992.

Heavy human use of this area in the past has affected the areas present appearance and vegetative structure. In the late 1800s, the area was extensively logged for timber used by mining and smelter operations in both Butte and Anaconda (Monninger 1992). It was also heavily grazed by cattle, sheep, horses, and mules for the mining operations and thousands of inhabitants in the area (Guenther 1989). The subsequent smelting activities added to the initial impacts. In 1902, the Washoe Smelter was built south of Anaconda and operated until 1980; published data from 1955 indicate copper, zinc, sulfuric acid, and arsenic products were generated (Kelly 1983). Present use is limited to some seasonal livestock grazing in portions of the MHWMA, and recreational fishing and hunting.

Two sites, Willow Creek (WC) and Railroad Gulch (RRG), were chosen for this study, in the MHWMA, for their abundance of bitterbrush stands and relatively similar vegetative compositions, aspects, slopes, and elevations. The Willow Creek site is approximately 100 m northwest of Willow Creek on a grassy slope bounded by a drainage dominated by Douglas fir

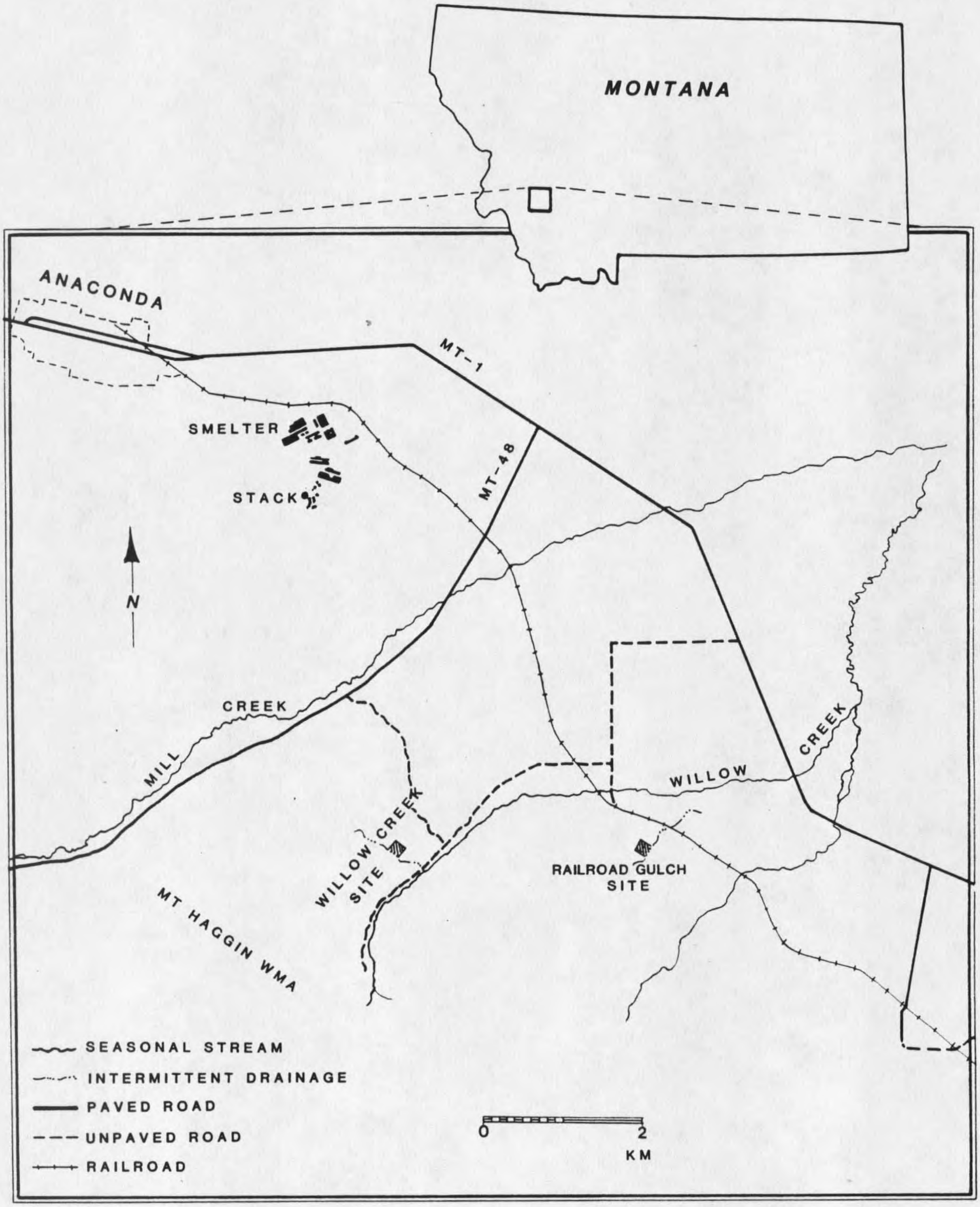

Figure 1. Map of the project area on Mt Haggin Management Area.

(Pseudotsuga menzeisii) to the northeast. It is 1707 m (5600 ft) in elevation with an eastern aspect. Vegetation at this site should be in a seral stage of Mueggler and Stewart's (1980) bitterbrush-bluebunch wheatgrass (Agropyron spicatum) habitat type; however, non-native species have persisted and the plant community is in a seral stage with leafy spurge (Euphorbia esula) dominating. Other plants dominating this site are Kentucky bluegrass (Poa pratensis), lupine (Lupinus wyethii), and Wood's rose (Rosa woodsii), all of which indicate past disturbance of the area, (Guenther 1989). For a complete list of species at this site see Table 6 in the Appendix. This site is not presently grazed and has been rested since 1980 (Frisina pers. com.).

The Railroad Gulch site is situated in a drier, rockier area 3.2 km (2 miles) east of the Willow Creek site. There is a drainage to the north dominated by Douglas fir. Elevation of this site is 1616 m (5300 ft) and the aspect is northeast. Vegetation is in a similar state as Willow Creek, but the dominant species in this community are spotted knapweed (Centaurea maculosa), Kentucky bluegrass, and Wood's rose, again indicating past disturbance of the area. Both sites are being invaded by Douglas fir and Rocky Mountain juniper (Juniperus scopulorum) trees (complete species list in Table 6 in Appendix). Possible past smelter influences and overgrazing practices make this site appear more heavily disturbed than the Willow Creek site. Occasional, light cattle grazing occurs at this site in early spring and late fall.

METHODS

Experimental Design

The habitat use, activity, and home ranges of deermice were determined using radiotelemetry. The effects of cattle-grazing activity on these aspects of deermouse ecology were investigated in two manners: 1) by comparing habitat use in two areas, one of which appears to have been more heavily disturbed in the past than the other; and 2) by using cattle introduced into home range areas of radio- collared deermice.

Along with the telemetry-based habitat selection, the ecological relationship between deermice and bitterbrush was determined by examining artificial bitterbrush seed cache survival, and determining seed removal rates by deermice.

Procedures

Study sites were chosen for similar aspects, slope and bitterbrush density. Within both sites, WC and RRG, grids 170 m x 170 m, were constructed with dimensions of 10 columns and 10 rows.

Live Trapping

One hundred Sherman live traps, baited with peanut butter and oats, were placed at each site along staked columns 19 m apart for 600 trap nights, May 17-20 1991, and 200 trap nights, May 15, 1992. Traps were checked each morning. Captured animals were weighed and individually marked with numbered fish fingerling tags clipped into the right ear.

Species, sex, age class, and reproductive condition were recorded for each animal. After a two-week period, traps were placed at both grids to recapture resident deermice. Deermice captured with an ear tag (from the May trapping) and weighing over 20 g (adult weight) were considered residents.

Radio Tracking

Four resident deermice at each site were fitted with 1.8 g to 2.5 g radio collars. Radio collars contained SM-1 transmitters (AVM Instrument Co.) and were attached to the necks of animals with nylon wire ties. Mice were released and thereafter tracked nightly from 2100 h to 0100 h for a two-week period. Signals were detected using an AVM LA-12 DS receiver and a three element Yagi antenna. Signals were detected within 50 m, and exact location of collared animals was determined to within 0.5 m. Deermice positions, when animals were immobile for 1 minute or more, were marked with small numbered surveyor's flags placed 1 m south of the exact location of the animal. Each animal was located from 3-25 times per night at one site. Tracking was alternated from site to site unless a field assistant was available and then tracking was done concurrently at both sites. At the end of the two-week tracking period, mice were recaptured with live traps near day burrows and collars removed. This procedure was repeated throughout the summer of 1991 with different mice and terminated August 12, 1991. These procedures were repeated again in the summer of 1992 with a set of five mice tracked from May 16 to June 4, 1992 (Table 7 in the Appendix).

Habitat Analysis

A point frame (Figure 2) was used to analyze a representative sample of the habitat cover at both sites (Barbour et al. 1987). A one-meter point frame was placed directly over 40 chosen locations, and two perpendicular sets (five points north-south and five points east-west) of analyses were performed for a total of 400 habitat variable points. The habitat was analyzed at three levels; surface, 20 cm above the surface, and 50 cm above the surface. Percent cover for each strata was determined using the equation:

$$\% \text{ cover} = \frac{\text{no. of pins hitting plant type A} \times 100}{\text{total no. pins}}$$

Percent cover was examined by separating habitat into various variables. These variables were: ground (including rocks and bare ground), club-moss (*Selaginella densa*), litter (including dead plant material and animal feces), grasses, forbs, bitterbrush (btt), rabbitbrush (rbt) (*Chrysothamnus* spp.), rose, open spaces (no hits by points), gooseberry (goose) (*Ribes* spp.), and trees (including juniper, Douglas fir and maple (*Acer glabrum*)).

Deermouse habitat use is defined as the percent cover at each level for every flagged mouse location. The point frame was used, as in the representative sample, over each mouse location.

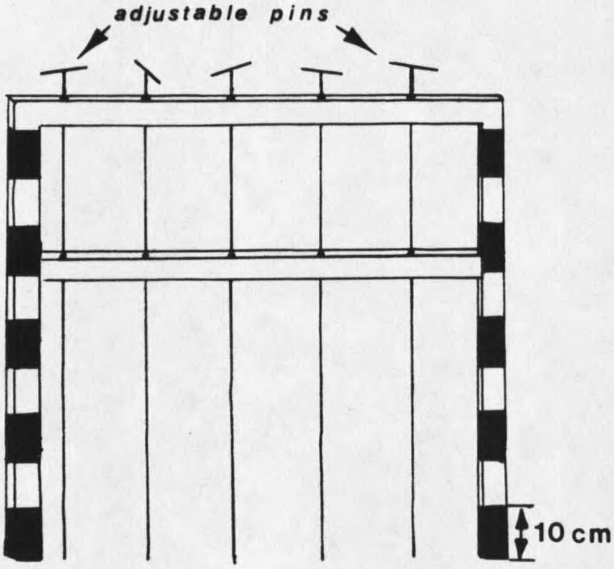

Figure 2. A point frame with five movable pins.

Cattle Introduction

Of the eight initially collared animals, five surviving mice (2 at WC and 3 at RRG) were followed from June 3-7, 1991. On June 8, 1991, 130 Hereford/Angus hybrid cows and calves were brought into the WC grid and allowed to graze for a period of one hour at different sections of the grid and then moved, via human hazing and horseback riders, to a new section of the grid. Cattle were contained by humans and riders surrounding each section. After five hours cattle were removed from the site.

The same procedures were utilized in 1992. Five new mice were tracked from May 29-June 1, 1992, and 30 Charolais yearling bulls were introduced and grazed in the same method as in 1991.

After cattle were removed, the previously collared set of mice were tracked from June 9-10 in 1991 and June 2-4 in 1992. Mice were followed during the same time period at the RRG site as a control. Deermouse habitat use for both sites was measured prior to and after cattle introduction.

Habitat Modification Measurement

Grass heights were measured in 1991 as an indication of habitat modification by cattle. Four 100 m transects (two north-south and two east-west through grid) were established and grass height was measured at every 1 m interval. Grass heights were measured prior to and after cattle introduction. Grass height measurements were not taken in 1992.

Seed Removal Comparisons

Four bitterbrush were randomly chosen at WC, and four at RRG. If the plant was dead or larger than 2 m long and 1 m high another was randomly chosen due to the constraints of enclosure size. A trench 15 cm deep was dug around each bush to set enclosures below ground. Each bush was enclosed with 6 mm mesh hardware cloth structures which were sewn together with fishing line. Once the enclosures were positioned around the bush, the bases were buried and enclosures were wired to rebar set into the trenches. Each enclosure had an entrance lid closed with twist ties for accessibility. Sherman live traps were placed inside enclosure to capture any confined mice. Ten 15 cm diameter paper plates were placed around the base of the enclosed bush to determine fallen seed abundance. Two bushes exterior to and nearest the enclosed bush, for each of the four bushes at each of the sites, were chosen to determine possible seed removal by deermice, and plates were also placed under those bushes. Seeds were counted in situ on enclosed bushes and also on two outer bushes to determine initial seed numbers. This was done just prior to complete ripening, July 6-10, 1991. Fallen seeds were counted on the plates inside and outside of the enclosures after ripening of seed was completed, August 11-12, 1991, and few remaining seeds were still attached to bushes.

Simulated Caches

Bitterbrush seed was acquired in three manners: 1) 1,000 seeds were purchased in 1991, from Native Seeds, Inc. in Lehi, Utah; 2) seeds were hand collected from both sites in 1991; and 3) seeds were collected in 1990, from surrounding local bitterbrush sites by another researcher. Simulated caches were planted both inside and outside enclosures during the late summer, August 12-13, 1991. Ten caches were planted inside the enclosures, and five caches each were planted at each of the two outside bushes (Table 8 in the Appendix). Caches were planted 2.5 cm to 3 cm deep to simulate deermouse bitterbrush cache depths (Hormay 1943). Caches were marked with metal tabs and two caches were planted at each tab. Ten seeds were cached in one pile on the north side of the tab and 20 seeds were cached in one pile on the south side. Caches were checked one month later on September 14, 1991 to determine disturbances. All discarded hulls from disturbed caches were collected.

Caches were monitored during the summer of 1992. The first seedlings were observed on May 16, 1992 and surviving seedlings were counted. Surviving seedlings were counted again on June 4, 1992, and June 21, 1993.

Statistical Methods and Analyses

Statistical analysis was completed with the use of the SAS statistical package (SAS Institute, Inc. 1988). Deermouse habitat use means and the representative sample of vegetation means were compared by using the Student's t-test. Mouse habitat use comparisons for post grazing June, July, and August periods between sites and years were analyzed with t-tests, as were the pre/post cattle grazing mouse habitat use differences between sites and years.

RESULTS/DISCUSSION

Deermice Habitat Use vs. Representative Vegetation

Mice locations were used from the pre-cattle grazing period to compare with the representative vegetation sample measured prior to cattle grazing. A total of 3 mice at RRG, and 4 at WC were tracked during this period in 1991, and 1 at RRG and 4 at WC in 1992. A total of 63 mice locations were compared to 40 representative sample locations at WC in 1991, and 113 mice locations to 40 representative locations in 1992. At RRG, 85 mice locations were compared to 40 representative sample locations in 1991, and 52 mice locations to 40 representative locations in 1992 (means and standard deviations in Table 9 in the Appendix).

Willow Creek vs. Railroad Gulch Habitats

The significant differences between the representative habitat variable means at the two sites are listed in Table 1. In 1991, the significant differences at the two sites for the surface level were between litter ($P=0.0139$), forbs ($P=0.0077$), and bare ground ($P=0.0345$). In 1992, litter and ground at the surface were also significantly different ($P<0.0001$) between the two sites. The trend for these differences is similar for both years (Figure 3). In both years, litter was more abundant at WC than RRG, and bare ground was more abundant at RRG than WC. WC had more

Table 1. t-test significance levels for mean differences between Railroad Gulch (RRG) and Willow Creek (WC) habitats, between deermice habitat use at each site and the representative habitat at each site, and between deermice habitat use at RRG and WC. (Btt=Bitterbrush, Rbt=Rabbitbrush, Moss=Club-moss, Open=No hits by points, Goose=Gooseberry)

Habitat Variable	RRG vs.WC Vegetation		WC Mice vs. WC Veg.		RRG Mice vs. RRG Veg.		RRG vs WC Mice	
	91	92	91	92	91	92	91	92
Surface								
Litter	***	***	***	***	***	***		
Forb	***			***		***	***	
Btt				***		***	**	
Rbt		***		**		***	**	
Grass		***		***	***		***	
Moss		***	**		***	***		
Ground	**	***			***	***		
20 cm Above Ground								
Litter	***	**			***	**	***	***
Forb	***	**			***		***	**
Btt		***	***	***	***	***	**	**
Rbt					***		***	**
Grass	**	***		***	***	***	***	
Rose								
Rock								
Open		***	***	***	***	***		
Goose						***		***
Tree								
50 cm Above Ground								
Litter		***						***
Forb				***			**	***
Btt			***	***	***	***	***	
Rbt					**		***	
Grass		**	***				***	
Open			***	***	***	***		**
Goose						**		***
Tree								

*** = $P \leq 0.01$
** = $P = 0.01$ to 0.05
Blank = $P > 0.05$

grass and litter covering the ground, and RRG was largely bare ground with grass and litter located sporadically (Figures 4 and 5).

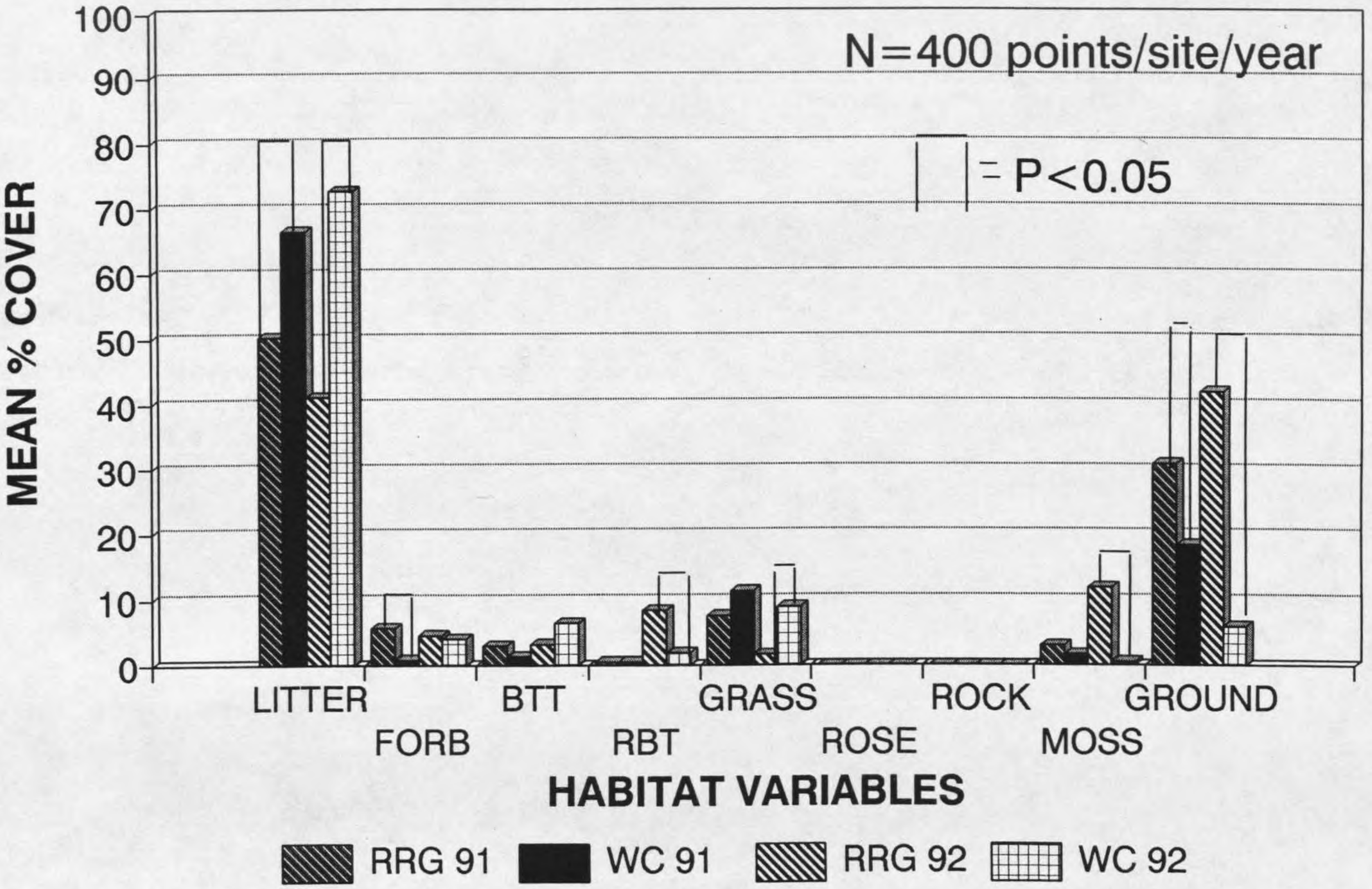

Figure 3. Comparison of mean % cover of surface habitat variables at representative points on Willow Creek and Railroad Gulch for 1991 and 1992.

Figure 4. Surface characteristics of the Railroad Gulch site.

Figure 5. Surface characteristics of the Willow Creek site.

In 1992, other significant differences in vegetation at the surface level were rabbitbrush, grass, and club-moss ($P<0.001$). Rabbitbrush and club-moss are both more abundant at RRG, and grass is more abundant at WC (Figure 3). RRG has more rabbitbrush and club-moss at the ground level, and grass is more abundant at WC. Litter was the dominant habitat variable at the surface of WC (66.5% in 1991 and 72.6% in 1992) and at RRG in 1991 (50.2%), but in 1992, bare ground was dominant at RRG (42%). These habitat characteristics at RRG may be an indication of heavy past or present disturbance. Club-moss has been found to increase in abundance in areas that are disturbed (Beetle 1956 and Campbell et al. 1962) and RRG does have higher amounts of club-moss than WC. This abundance of club-moss and bare ground, and lack of dense grass and litter at RRG indicates a history of disturbance.

At the 20 cm level, in 1991, litter, forb ($P<0.001$), and grass ($P=0.0349$) were all significantly different between sites (Table 1). These same habitat variables were also significantly different in 1992 ($P<0.01$ for grass and $P<0.05$ for litter and forbs). Forbs and grass at the surface level were more abundant at WC than RRG both years (Figure 6). Litter at the 20 cm level did not follow the same trend as the surface. Litter was more available at RRG than WC in 1991, but more available in WC than RRG in 1992. Bitterbrush and open space were significantly different ($P<0.001$) in 1992 between the sites. Bitterbrush was more abundant in WC in 1992, and

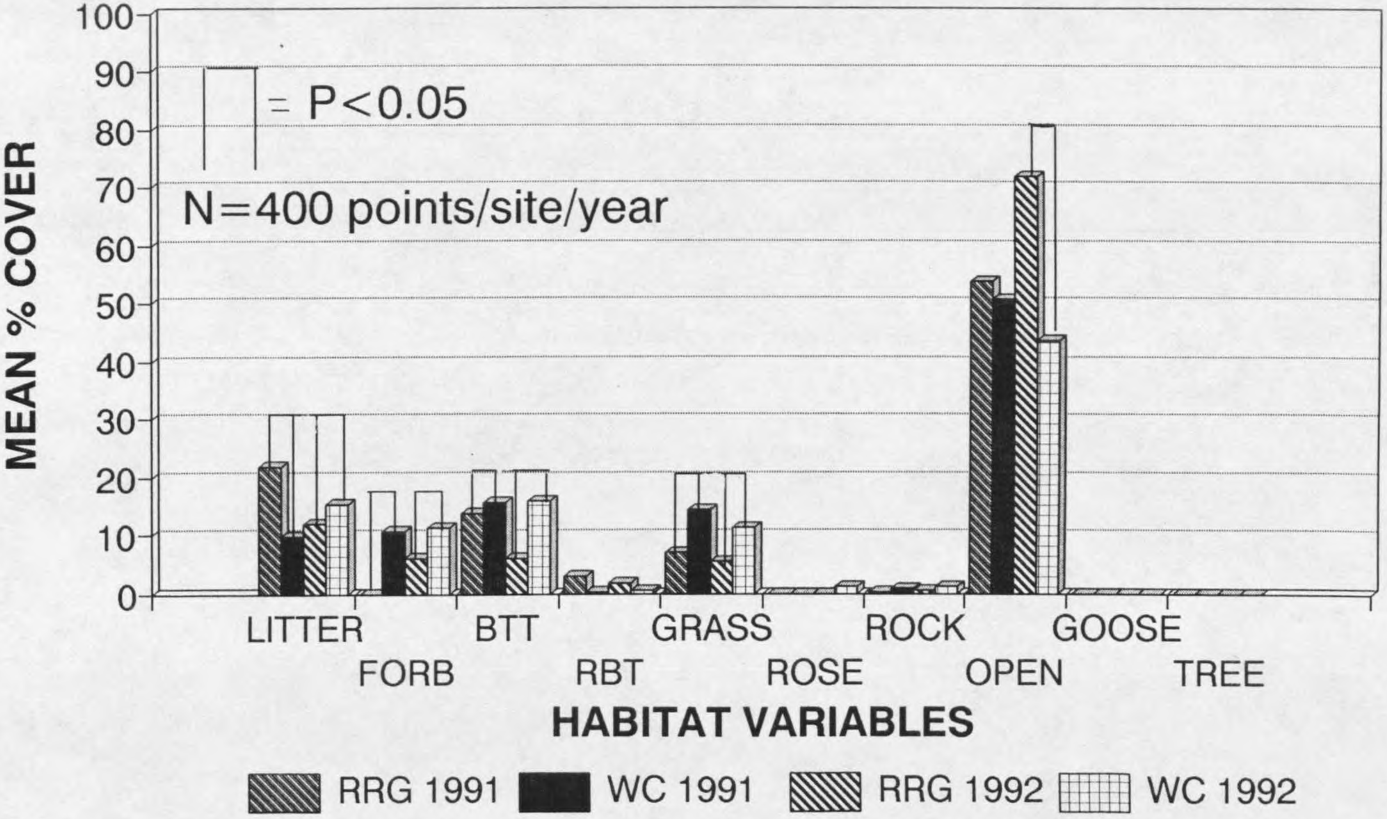

Figure 6. Comparison of mean % cover of the 20 cm level habitat variables at representative points on Willow Creek and Railroad Gulch for 1991 and 1992.

open space was more abundant in RRG in 1992. In 1991, both of these habitat variables were similar, with 15% of the total cover in bitterbrush and 50% in open space (Figure 6). The marked drop of availability in litter, forbs, and bitterbrush at RRG, from 1991 to 1992, may be due to an increase of highly competitive non-native vegetation in 1992. At RRG, more bitterbrush was dead, less ground cover (litter or grass) was available, and open spaces were more prominent due to the increase in dead bitterbrush and spotted knapweed. Spotted knapweed reduced forb cover due to its typically open growth form, and its ability to out compete other forbs. At WC, the vegetation was denser both years, with an abundance of litter, grass, forbs, and bitterbrush. Leafy spurge blanketed the WC area in 1992, and was a factor in the increase of forb cover.

At the 50 cm level, the only significant differences between sites were for grass and litter in 1992 (Table 1). The rest of the habitat variables were fairly consistent between the two sites (Figure 7). The difference in grass abundance between the two sites, while statistically significant ($P=0.0234$), is biologically only slightly different (0% cover at RRG and 1.2% at WC). However, it does indicate more grass availability at WC compared to RRG.

Litter (in the form of dead grass mostly) was more abundant at WC (10%) than RRG (3%) at this higher level ($P<0.01$). Again, the difference is biologically fairly small between the two sites. Bitterbrush, which is very important to

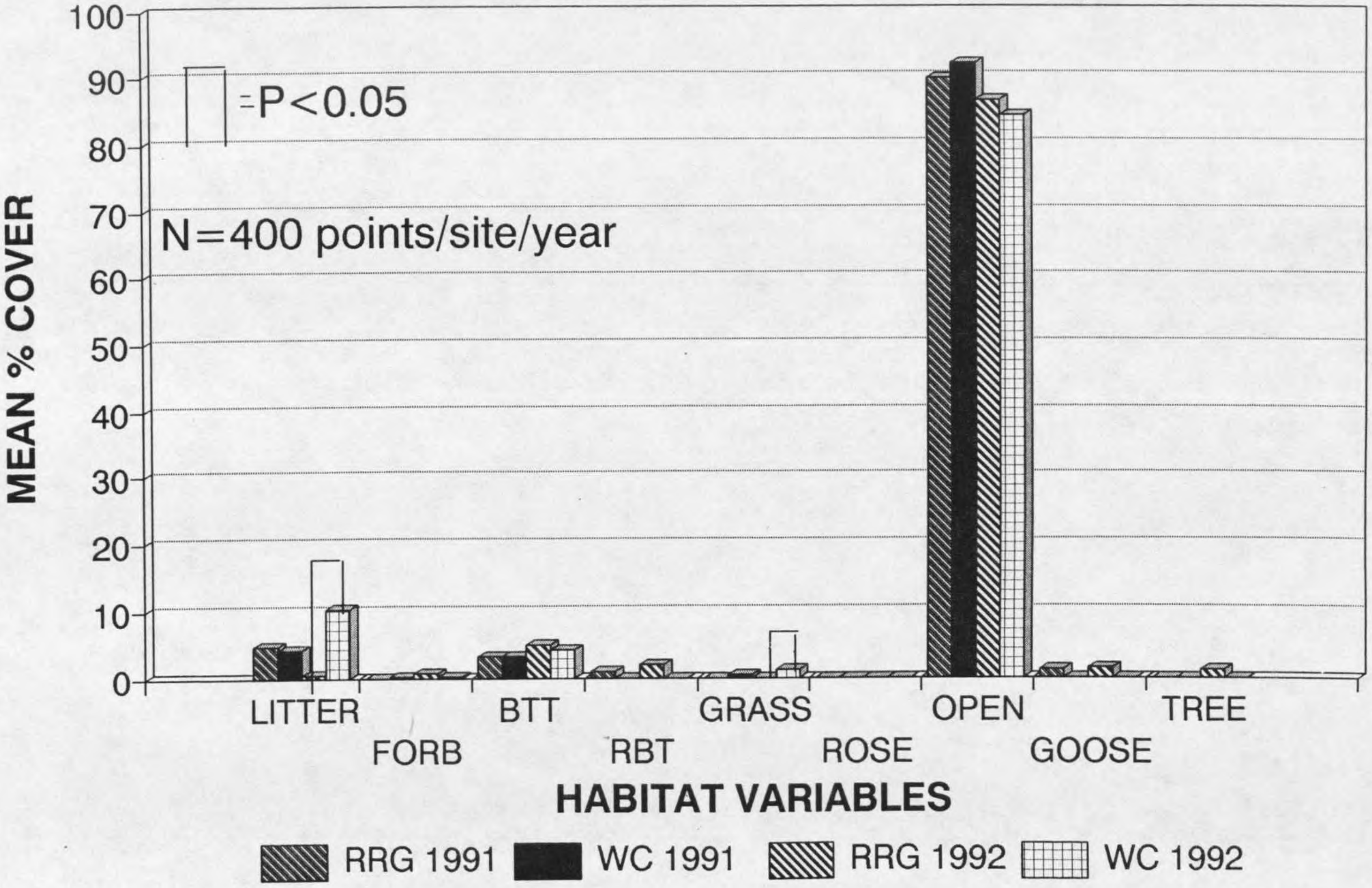

Figure 7. Comparison of mean % cover of the 50 cm level habitat variables at representative points on Willow Creek and Railroad Gulch for 1991 and 1992.

deermice, at this 50 cm level, was only 3-5% of the total vegetative cover available at RRG and 3-4% at WC. The overall dominant habitat variable at both sites and both years for this level was open space (approx. 90% and 87% at RRG, and 92% and 84% at WC), indicating these sites have an overall low vegetation height, with open spaces in the shrubs and between the habitat variables.

Deermice Habitat Use vs. Representative Vegetation

For both sites and both years, the trends for deermice selection versus the representative samples are similar at the surface level (Table 1 and Figure 8, 9, 10, and 11). Litter use by the mice versus the representative samples was significantly greater for both sites and both years ($P<0.001$). Interestingly, litter selection remained fairly constant regardless of the amount of litter available (84% and 91% for WC, and 87% for both years at RRG for mice selection, and 67% and 73% for represented litter at WC, and 50% and 41% for RRG) at either site. Litter selection by deermice at RRG was basically the same as WC, except the amount of litter available to the mice was approximately 30-50% less.

The slight increase in use at WC in 1992 may be due to the subsequent increase in availability of litter that year. Litter, at this level, must have been important to the mice since their selection was constant regardless of the amount available. Litter at the surface may provide an area for mice to forage since seeds, other plant parts, and insects may all

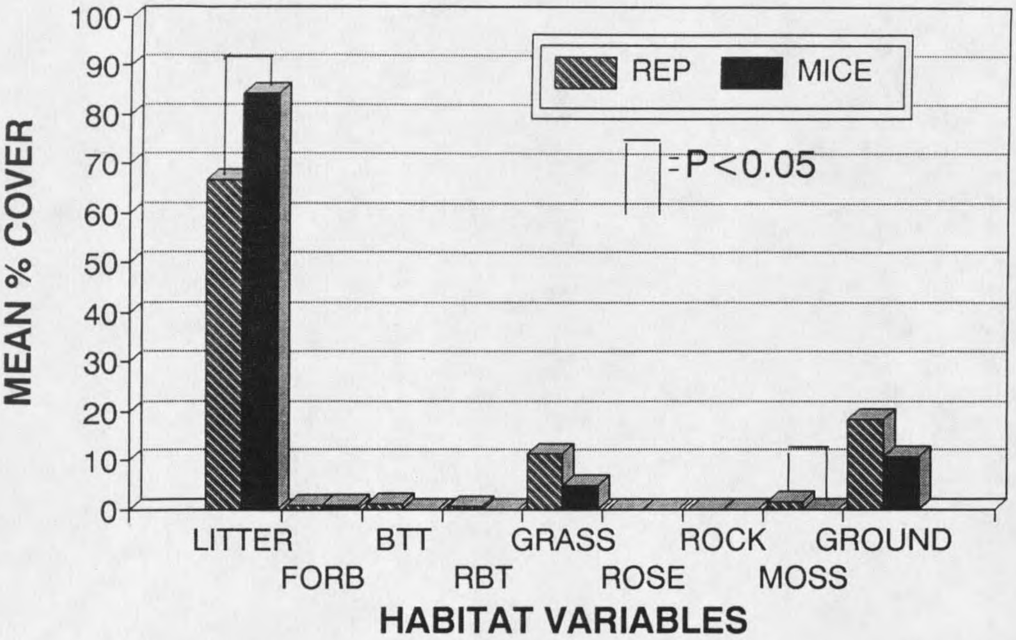

Figure 8. Mean % cover of surface habitat variables at representative points versus deermouse locations on the Willow Creek site in 1991.

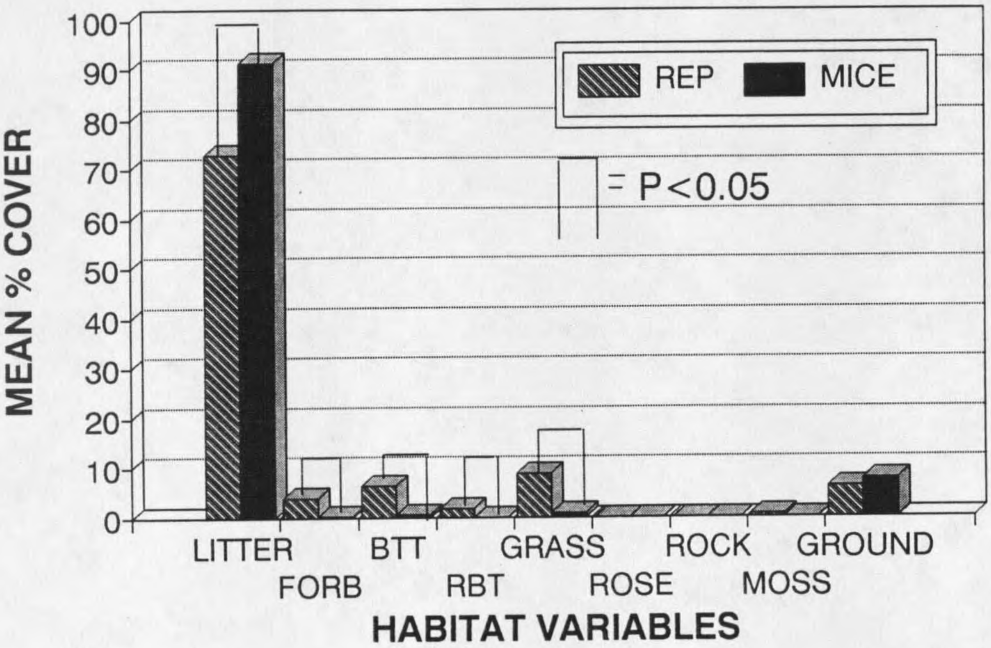

Figure 9. Mean % cover of surface habitat variables at representative points versus deermouse locations on the Willow Creek site in 1992.

be located in that substrate.

Deermice avoided grass at the surface level. Significant differences between grass use occurred only at WC in 1992 (P<0.0001) and RRG in 1991 (P<0.0001), but the pattern was similar for all years at both sites (Figures 8, 9, 10, and 11). Since this data was collected during the pre-grazing period, grass had not been used by cattle at this time. Grass composed approximately 10% of the total cover on the sites (except for RRG 1992, which was 1.5%), and was either completely avoided by the mice or only rarely selected (4.8% selection by mice at WC in 1991). This avoidance of grassy areas by deermice has been noted by other researchers (Getz 1961; Hansen and Warnock 1978; Barnum et al. 1992).

Significant differences occurred between mice selection of bare ground and the representative sample (P<0.0001) of ground at RRG for both years. There were no significant differences for ground use at WC, but that may have been due to the decreased amount of bare ground available at WC. For both sites, mice selected approximately 10% of the bare ground habitat variable regardless of bare ground availability fluctuations. Bare ground provides areas for unrestricted travel for mice, perhaps, because dense grass hampers movement (Hansen and Warnock 1978). The other significant differences, at both sites and years, for the other habitat variables at the surface level were not addressed due to insignificant amount of selection by mice, regardless of availability.

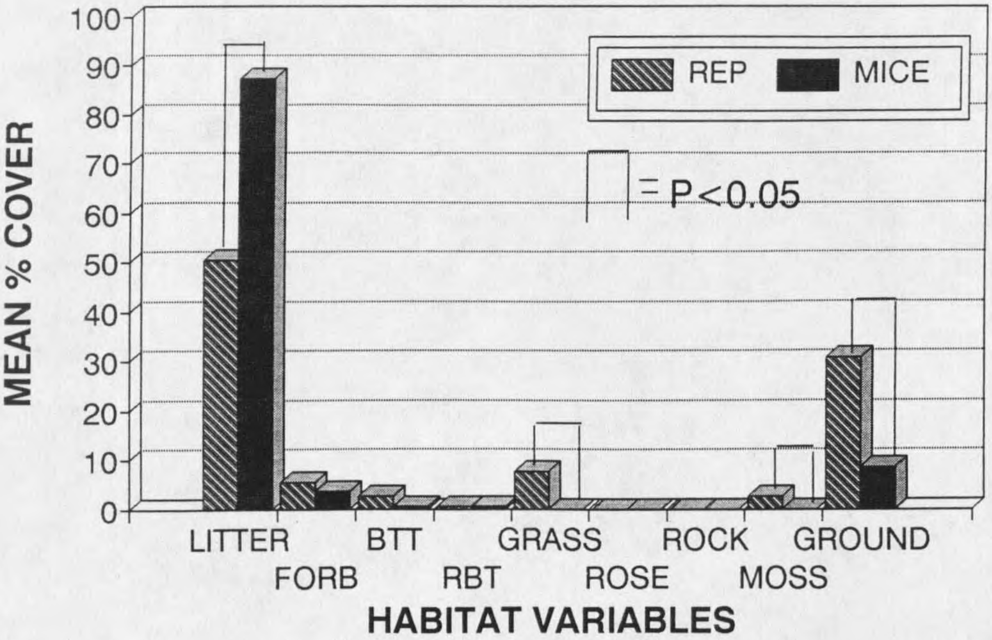

Figure 10. Mean % cover of surface habitat variables at representative points versus deermouse locations on the Railroad Gulch site in 1991.

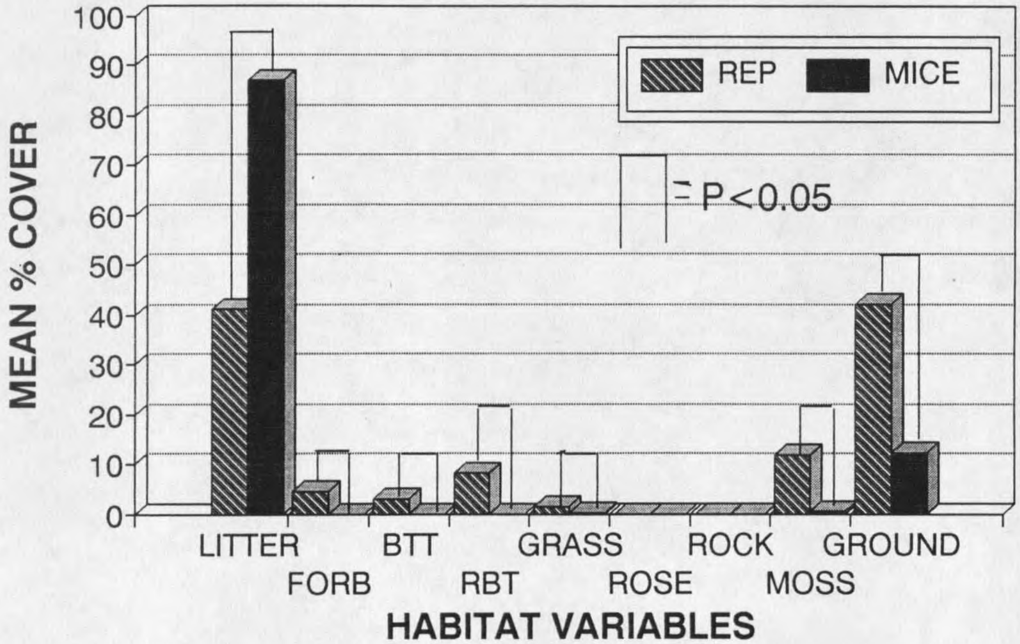

Figure 11. Mean % cover of surface habitat variables at representative points versus deermouse locations on the Railroad Gulch site in 1992.

Comparisons with the vegetation present at the 20 cm level produce similar trends. Selection of grass was significantly lower for RRG in 1991 ($P<0.01$) and 1992 ($P=0.0221$), and WC in 1992 ($P<0.001$), but not for WC in 1991; however, the trend for grass selection at WC in 1991 was similar to 1992 (Table 1 and Figures 12, 13, 14, and 15). In all cases, the amount of grass present was greater than actually was selected by the mice, indicating an avoidance of grass, as at the surface level. The other significant differences in habitat use at WC were for bitterbrush and open spaces ($P<0.0001$). Deermice locations had over 3 times as much bitterbrush as the representative sample at WC. Consequently, deermice avoided open space in nearly the same proportion. Observations of the mice support the conclusion that mice preferred the cover bitterbrush provided at this level, since mice were found under bitterbrush more often than under other vegetation. Douglass (1989) found similar results in his radio telemetry study in the same area; deermice used 3 times as much bitterbrush, at a 1-10 cm above ground level, than was represented at that site. The same results were found at RRG, with mice use for both bitterbrush and open space significantly different from the representative sample by 5 to 7 times ($P<0.0001$). Mice use at both sites and years was consistent for this 20 cm level. Selection of bitterbrush by mice was 64% and 51% at WC, and 74% and 65% for RRG (Figures 12, 13, 14, and 15). This high degree of selection was the

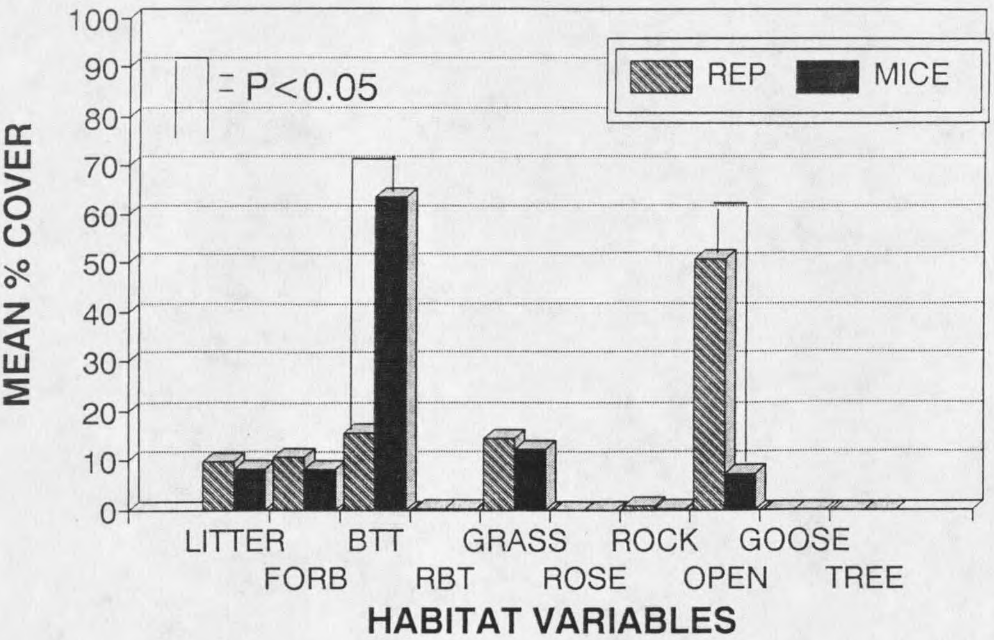

Figure 12. Mean % cover of 20 cm level habitat variables at representative points versus deermouse locations on the Willow Creek site in 1991.

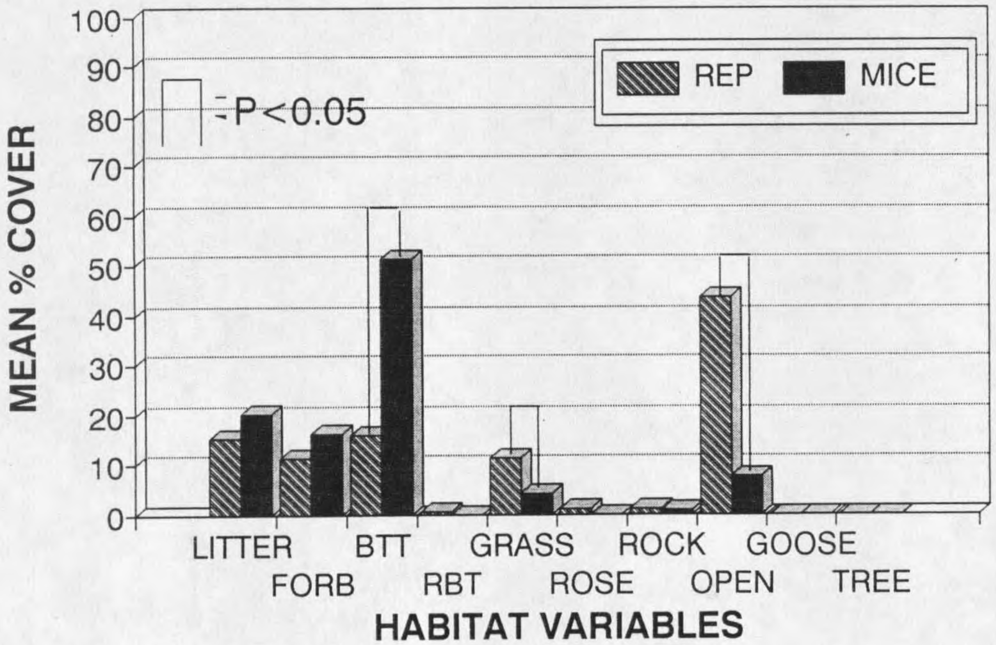

Figure 13. Mean % cover of the 20 cm level habitat variables at representative points versus deermouse locations, on the Willow Creek site in 1992.

same despite fluctuations in amount of bitterbrush represented for both sites. Avoidance of open spaces was also consistent between sites and years. Open space was represented between 45% and 50% at WC, and 54% to 70% at RRG. Mice selected only approximately 5% open spaces at both sites and years.

Cover, especially in the form of bitterbrush, at the 20 cm level, appears to be extremely important to the mice. Mice occurred under bitterbrush at some point during tracking every night, and would dart from one bush to the next. They were observed digging in the litter under the bitterbrush, and sitting on their haunches consuming food under the bushes. Broome (1988), in her radio telemetry study, found that deermice preferred shrub communities because shrubs provided attractive forage areas, with seeds accumulating at their bases. The cover bitterbrush shrubs provide decreases the risk of predation (Broome 1988; Parmenter and MacMahon 1983). It is possible that while mice foraged at other places, such as in open grassy areas, they stored food particles in their mouths until they were safely under cover before consuming the food.

There were significant differences at the 20 cm stratum for other habitat variables at RRG. For both years, selection of litter was significantly different ($P<0.0001$ and $P<0.01$). Although litter covered 10% to 20% of the representative sample, the mice only selected less than 5% litter, indicating an avoidance of litter at this level. This was not the case at

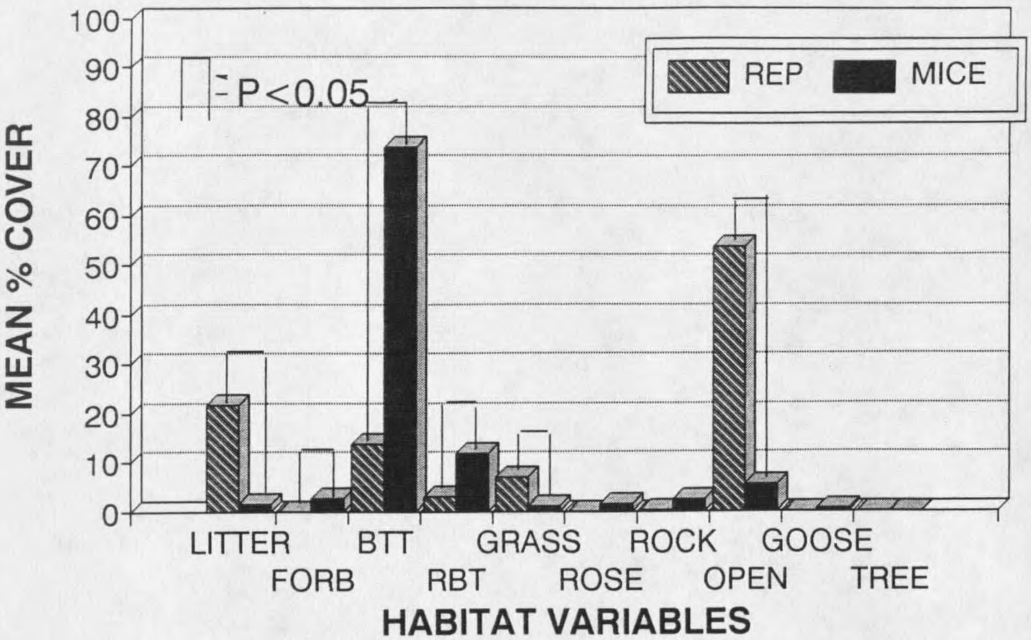

Figure 14. Mean % cover of the 20 cm level habitat variables at representative points versus deermouse locations on the Railroad Gulch site in 1991.

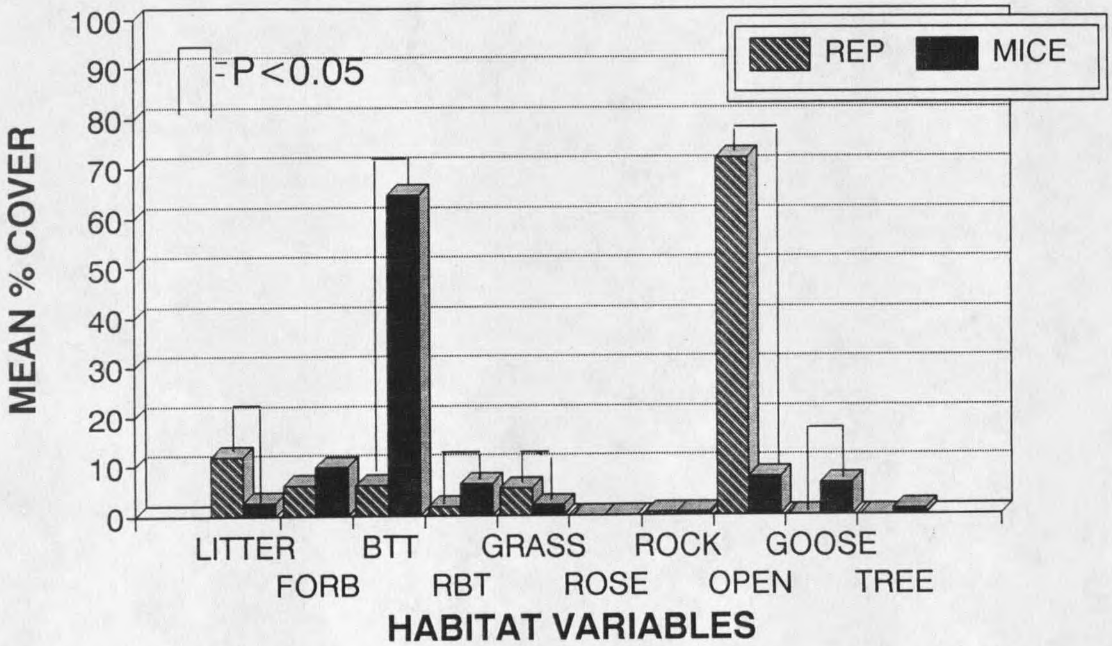

Figure 15. Mean % cover of 20 cm level habitat variables at representative points versus deermouse locations on the Railroad Gulch site in 1992.

WC, since mice selected litter about as much as was represented. The possible reason for mice avoiding litter at this level at RRG is not known. Mice at RRG, in 1991, selected forbs and rabbitbrush significantly more than what was available ($P<0.01$). For both years, deermice selection of forbs and rabbitbrush was higher than what was represented. Deermice at RRG appeared to be less selective of the habitat variables they used, as this site has only limited amounts of various cover types, and the higher population of mice at this site (70% trap success) probably increases competition for habitat.

Bitterbrush appears to be the most preferred variable for the 20 cm level, and probably affords the best protection for the mice from both raptors and terrestrial predators. This level is the most complicated and has the most diverse habitat variables (Figures 12, 13, 14, and 15). The 20 cm level surrounds the mouse, and is the area where mice were most selective. Barnum et al. (1992) also found that the vegetation in the 0-7.6 cm high range was most important to deermice. Wywialowski (1987) noted that deermice spent 25% more time in areas with increased cover, and that deermice responded more to horizontal cover rather than vertical cover. He also noted that horizontal cover may be a better defense against avian predators (Wywialowski 1987).

Mice at both sites tended to dart from one bush to the next, or from dense forbs directly into adjoining bitterbrush.

Great horned owls were heard at both sites on many occasions, and may have captured two radio-collared animals at RRG, in the open areas, where the animals were last observed. Rodents are more susceptible to predation with the increased light of the full moon (Clarke 1983; Kotler 1984). Wywialowski (1987) suggested that mice prefer thick cover since moonlight intensity is decreased at ground level with dense cover. Barnum et al. (1992) also suggested that mice travel in shaded or sheltered areas to avoid predation. Swainson's hawks have been observed searching for prey in areas of low vegetative cover (Bechard 1982). When deermice were under a bitterbrush shrub it was difficult to see them, even when the radio signal was very strong. These shrubs would make effective protection from predators, especially avian predators.

At the 50 cm level, again a pattern is very similar between sites for both years. Significant differences for mice selection versus the representative samples existed for bitterbrush and open space ($P<0.0001$) at both sites and years (Table 1 and Figures 16, 17, 18, and 19). Although bitterbrush was only 5% of the total representative cover at this level, for both sites and years, deermice use was higher at both sites. Deermice selection of bitterbrush at WC was 48% and 49% while selection at RRG was 34% and 45%. Consequently, the selection of open space by deermice was less than what was available at both sites and years. Open space at both sites ranged from 85% to 90%, but mice used open space only a third

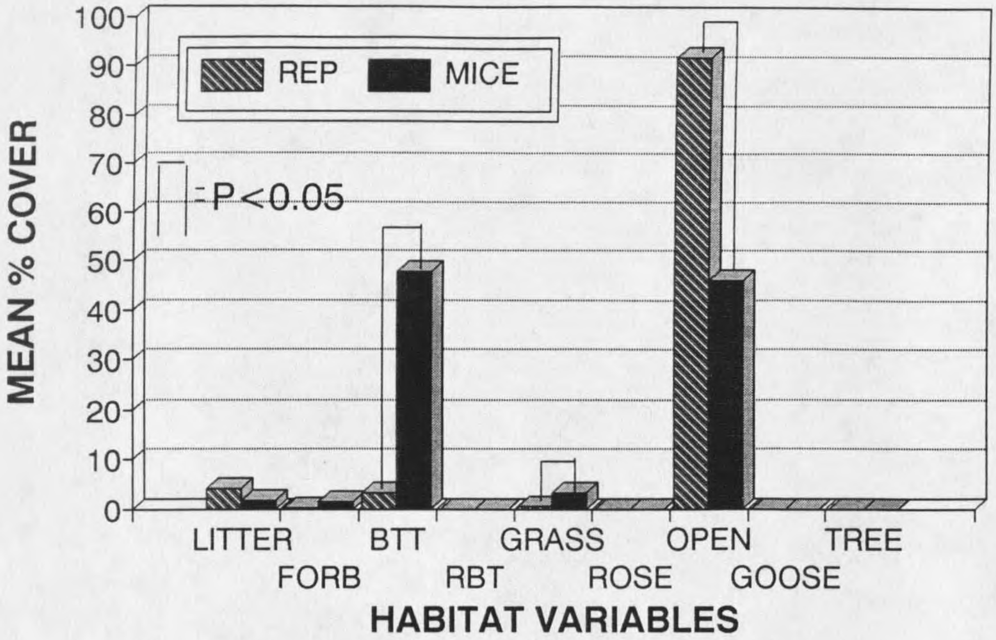

Figure 16. Mean % cover of the 50 cm level habitat variables at representative points versus deermouse locations on the Willow Creek site in 1991.

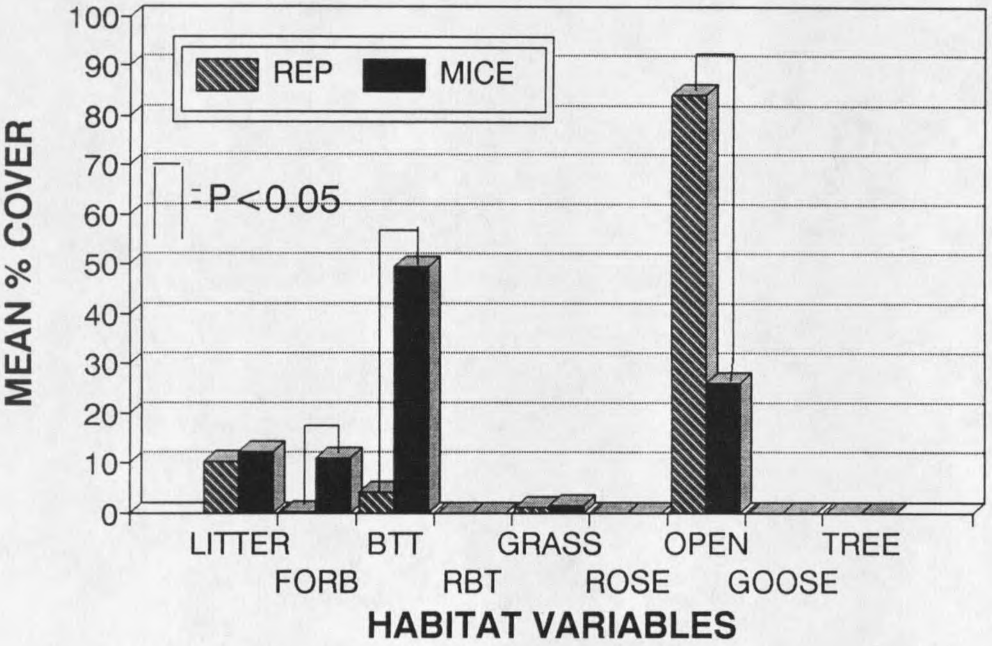

Figure 17. Mean % cover of the 50 cm level at representative points versus deermouse locations on the Willow Creek site in 1992.

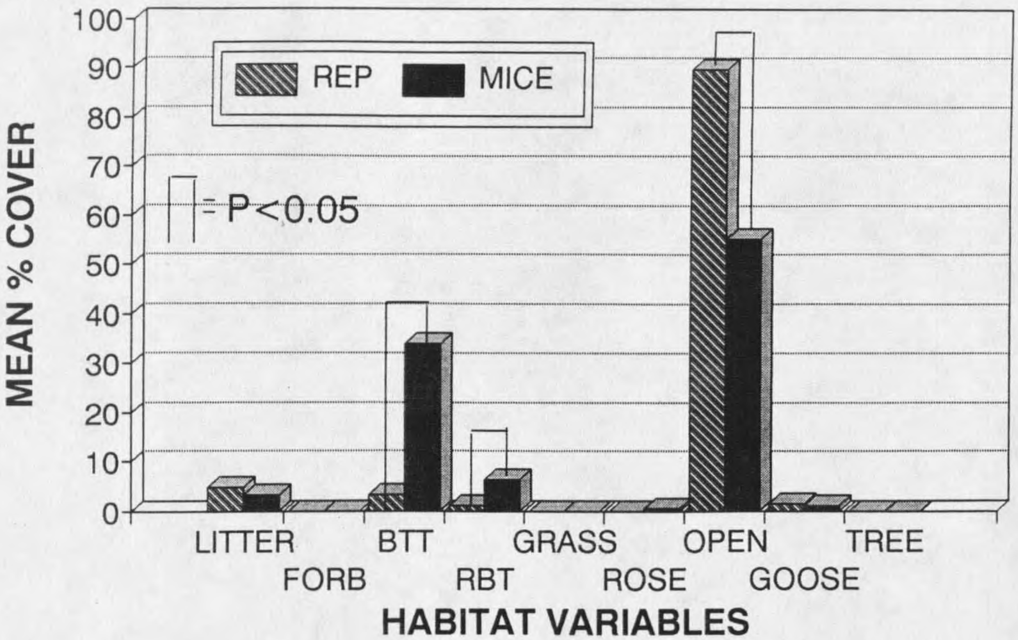

Figure 18. Mean % cover of the 50 cm level at representative points versus deermouse locations on the Railroad Gulch site in 1991.

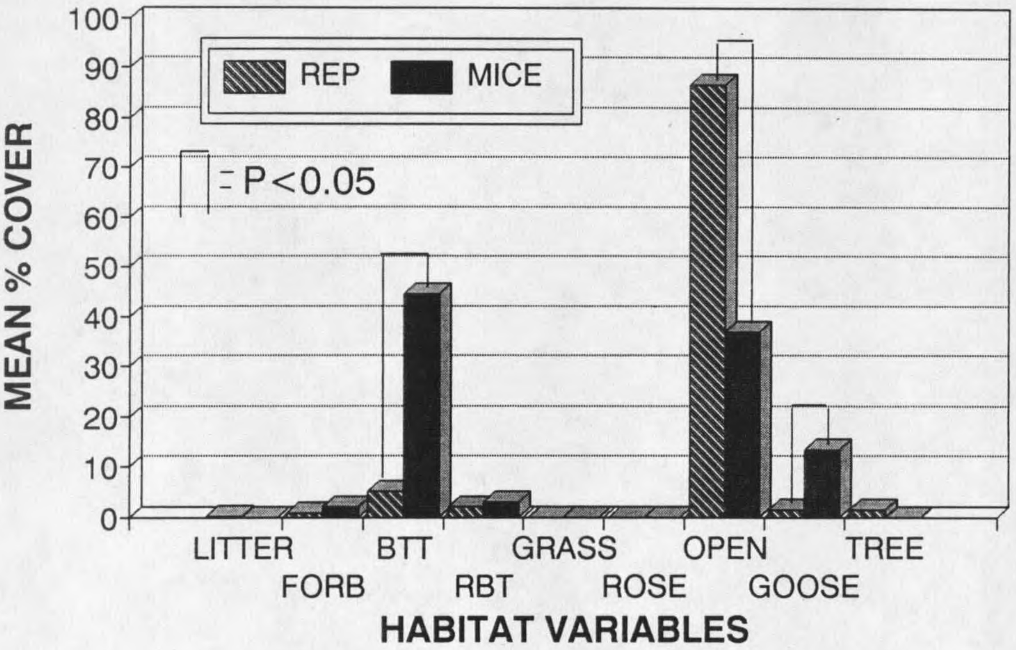

Figure 19. Mean % cover of the 50 cm level at representative points versus deermouse locations on the Railroad Gulch site in 1992.

to half as much as was available. Differential selection of both of these habitat variables indicate the preference of deermice for bitterbrush as overhead cover and the avoidance of open areas. Although the mice did use open spaces 25%-55% of the time, this may be due to the nature of both sites having sparse shrubs scattered in a mosaic throughout the site. In order for deermice to move from one patch of shrubs to another, open areas could not be avoided. Douglass (1989), also found deermice preferred bitterbrush at the 11-50 cm stratum by nearly 3 times its representation. Preference for shrubs by Peromyscus spp. has been found by many other researchers (Rosenzweig and Winakur 1969; Merkt 1981; Kaufman et al. 1983; Broome 1988).

Grass use in 1991 ($P<0.01$), and forb use ($P<0.0001$) in 1992, by mice at WC were also significantly different. Mice selected more of these habitat variables than were represented, and may indicate selection of tall grass and forbs for both cover and food. At RRG, the other significant selections were for rabbitbrush in 1991, and gooseberry in 1992 ($P<0.02$). At the 50 cm level at WC, the variables available were bitterbrush, forbs, grass, trees, and rose bushes. At RRG, they were bitterbrush, rabbitbrush, gooseberry, trees, and some forbs. Mice were frequently seen under bitterbrush at this level at both sites, and under forbs and grass at WC, and rabbitbrush and gooseberry at RRG.

Deermice nest locations were associated with habitat variables of 50 cm or higher above them. At WC, nests were found in dense, high (>50 cm above ground), leafy spurge patches, rose bushes, and bitterbrush shrubs. At RRG, nests were commonly found under bitterbrush shrubs greater than 1 m high, but also under gooseberry bushes, mountain maple saplings, rabbitbrush shrubs, and rose bushes, all of which were greater than or equal to 50 cm high. Elton (1939, p.335) writes, "Cover may also give seclusion, or an environment that is psychologically satisfactory in other ways, for the undisturbed prosecution of mating activities, for rest and sleep, or for social life and play." Mice were observed resting, nesting, and associating with others under the bitterbrush at both sites. Elton mentions the importance of cover in providing a food source and protection, but he notes that cover is most important in protection from enemies (Elton 1939).

Deermice Habitat Use Compared between Sites

Deermouse habitat use was similar at the two sites in both years. Although there are statistically significant selections for individual habitat variable choice, percent differences between variable use was small (Table 1 and Figures 20, 21, and 22). This was especially true at the surface level.

At the 20 cm level, the differences between sites is consistent between years. Selection of litter, forb, and grass variables was consistently higher at WC than RRG, and

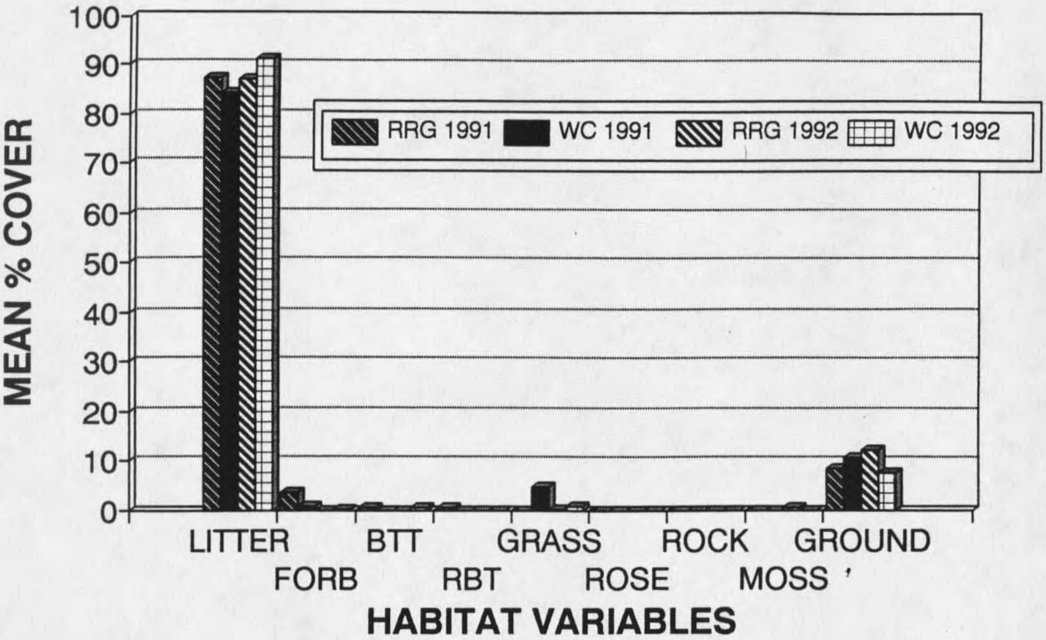

Figure 20. Mean % cover of surface habitat variables at deermouse locations on Willow Creek and Railroad Gulch in 1991 and 1992.

selection of rabbitbrush and bitterbrush was consistently lower at WC.

Patterns of deermice preference were similar for both sites. Deermice selected surface habitat variables consisting of litter and bare ground. At the 20 cm level mainly bitterbrush was preferred, and at the 50 cm level it was bitterbrush and open space. Variation in significance of deermice selection relative to other habitat variables was due to variable availability differences, and grazing differences at the two sites. Differences between sites in selection of litter, grass, forbs, and bitterbrush by deermice can be attributed to factors similar to those described below for the

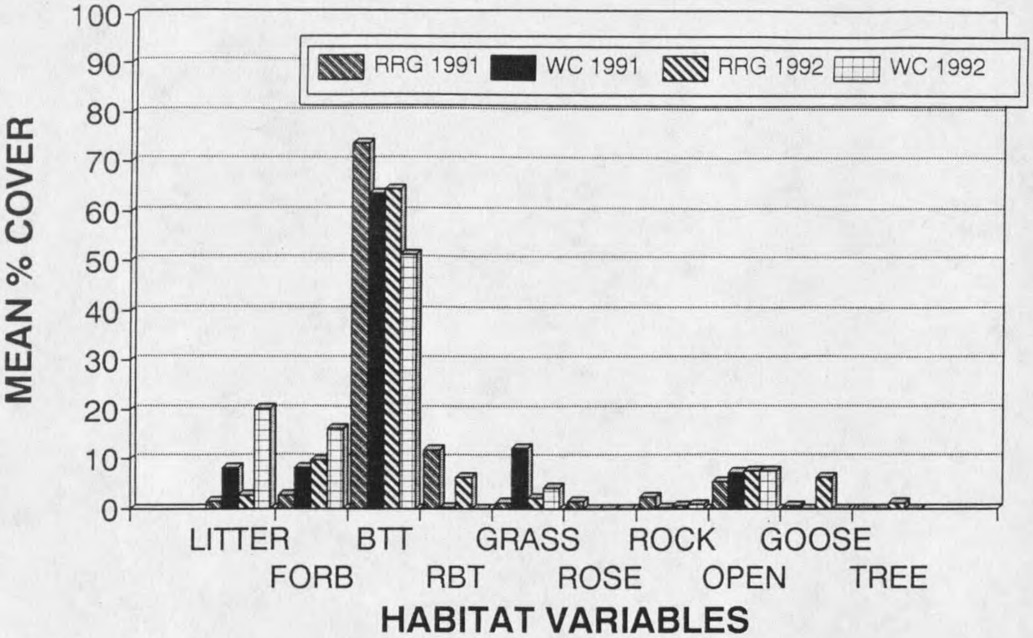

Figure 21. 20 cm level habitat variable location comparisons between deermice on Willow Creek and Railroad Gulch for 1991 and 1992.

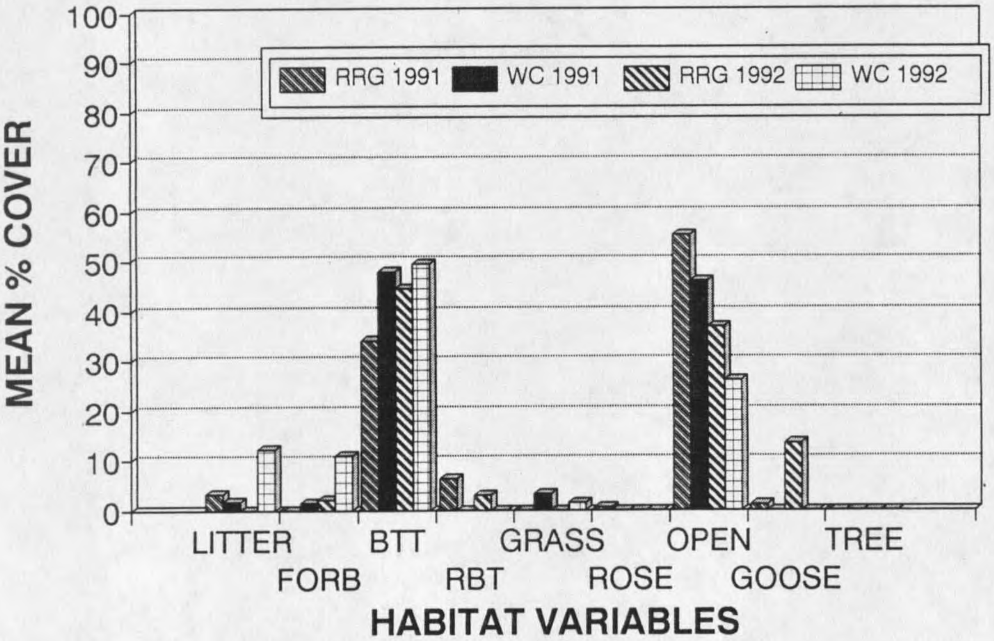

Figure 22. 50 cm level habitat variable location comparisons between deermice on Willow Creek and Railroad Gulch in 1991 and 1992.

grazing activity altering variables at WC.

Deermice Habitat Use before and after Cattle Grazing Treatment

For the cattle-grazing experiment, a total of 3 mice in 1991 and 4 in 1992 were tracked at WC, and 3 in 1991 and 1 in 1992 at RRG. Prior to cattle grazing, 63 locations in 1991 and 113 in 1992 were made at WC, and 85 in 1991 and 52 in 1992 were made at RRG. After grazing, 43 locations in 1991 and 96 in 1992 were made at WC, and 34 in 1991 and 41 in 1992 at RRG.

Significant mean differences of mice habitat variable selection between and within sites, before and after grazing, are given in Table 2 (means and standard deviations in Table 10 in Appendix). Bitterbrush and rabbitbrush at the surface level, and rock at the 20 cm above ground level, were the only habitat variables that mice used significantly differently ($P<0.05$) between pre- and post-grazing for RRG in 1991. There were no significant differences between pre- and post-grazing habitat use at RRG in 1992.

Because RRG was considered to be the control site, and had no treatment of grazing, it was expected that habitat selection by deermice would not change during the period of the grazing experiment at WC. When mice were tracked at RRG during the grazing experiment at WC, little to no change in habitat selection was apparent. Differences at RRG, in mice selection of bitterbrush and rabbitbrush at the surface, and rock at the 20 cm level, are small (Figures 23 and 24).

Table 2. t-test significance levels for mean differences between RRG and WC deermice habitat use pre/post-cattle grazing.

Habitat Variable	RRG Pre vs. Post Grazing 91	RRG Pre vs. Post Grazing 92	WC Pre vs. Post Grazing 91	WC Pre vs. Post Grazing 92
Surface				
Litter			***	
Forb			***	
Btt	**			
Rbt	**			
Grass			***	***
Moss				
Ground			***	
Rock				
20 cm above ground				
Litter				
Forb			***	
Btt			***	
Rbt				
Grass			***	
Rose				
Rock	**		***	
Open			***	
Goose				
Tree				
50 cm above ground				
Litter			***	
Forb				
Btt			***	**
Rbt			***	
Grass			***	
Open			**	
Goose				
Tree				

*** = $P \leq 0.01$
** = $P = 0.01$ to 0.05
Blank = $P > 0.05$

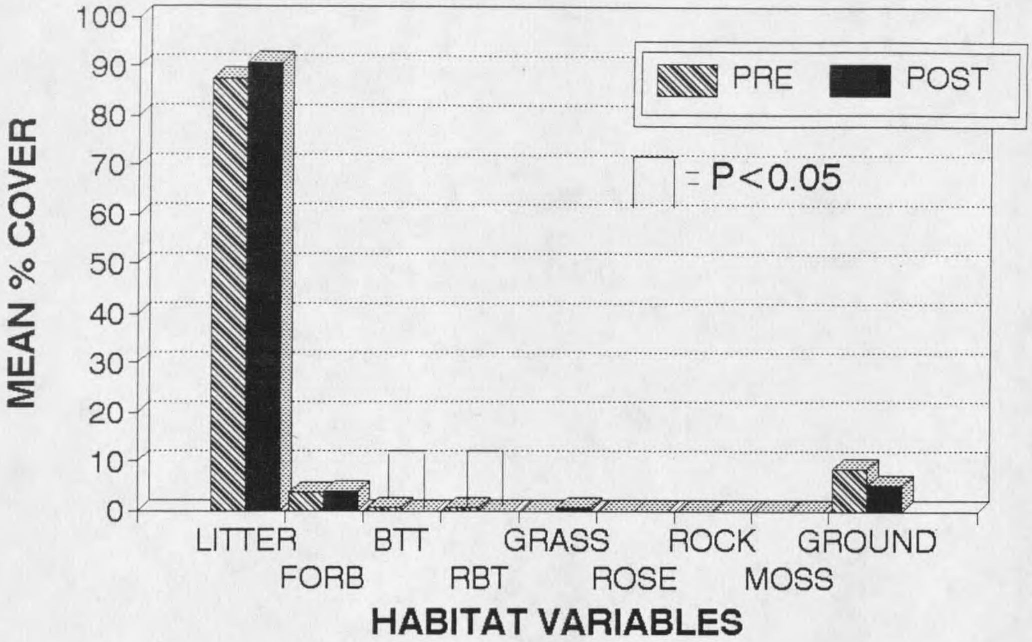

Figure 23. Comparison of mean % cover of surface habitat variables at pre- and post-grazing deermouse locations on Railroad Gulch in 1991.

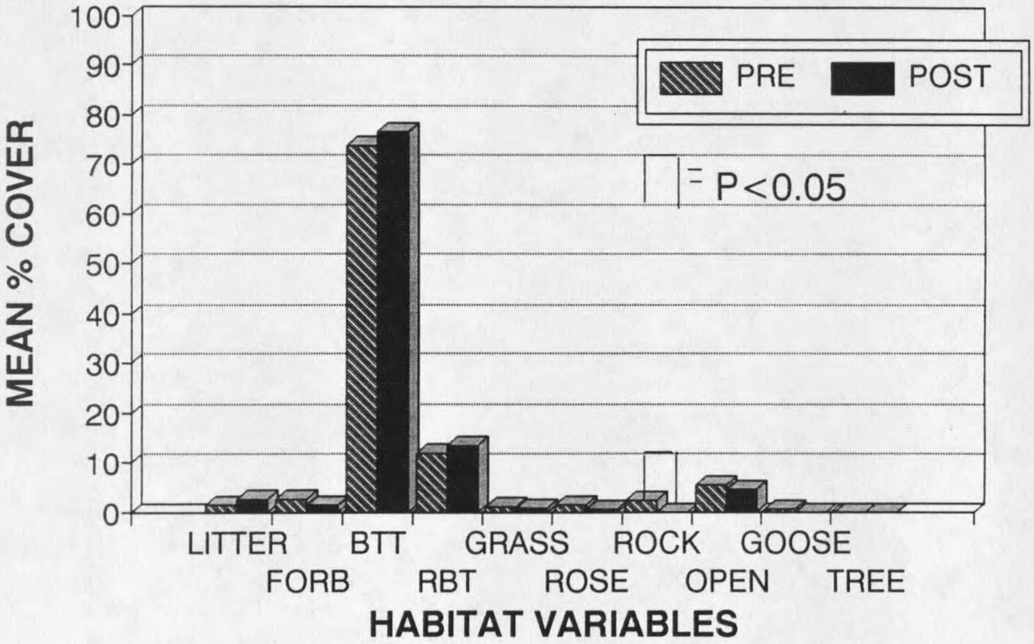

Figure 24. Comparison of mean % cover of the 20 cm level habitat variables at pre- and post-grazing deermouse locations on Railroad Gulch in 1991.

At the WC surface level in 1991, there were significant differences (P<0.001) between mean habitat variable selection by mice, pre/post grazing, for litter, forbs, grass, and bare ground (Table 2 and Figure 25). For the 20 cm level at WC in 1991, significant differences (P<0.0001) were found between forbs, bitterbrush, rabbitbrush, grass, rock, and open space (Figure 26). At the 50 cm level, at WC in 1991, significant differences (P<0.001) in habitat selection were found between litter, forbs, bitterbrush, grass, and open space (Figure 27).

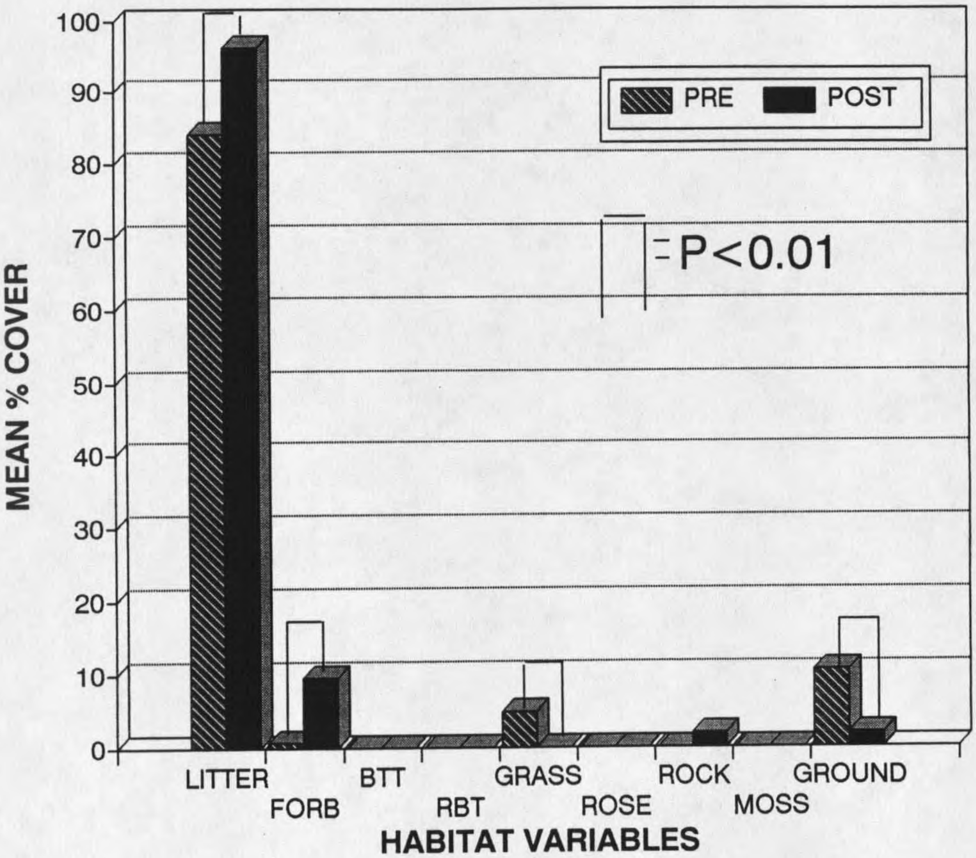

Figure 25. Comparison of mean % cover of surface habitat variables at pre- and post-grazing deermouse locations on Willow Creek in 1991.

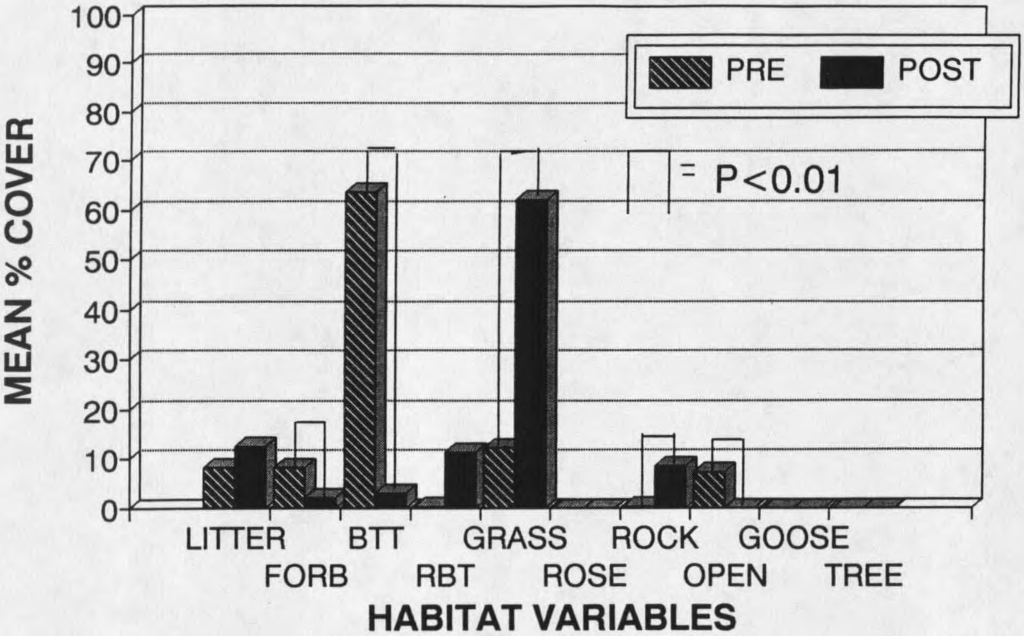

Figure 26. Comparison of mean % cover of the 20 cm level habitat variables at pre- and post-grazing deermouse locations on Willow Creek in 1991.

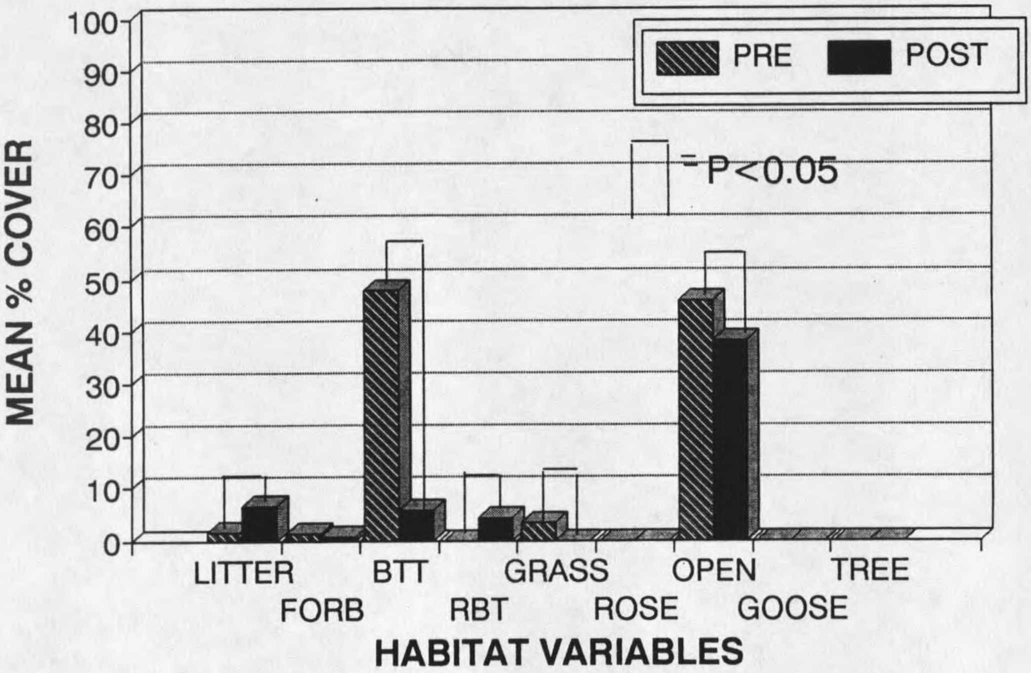

Figure 27. Comparison of mean % cover of 50 cm level habitat variables at pre- and post-grazing deermouse locations on Willow Creek in 1991.

Because this site was treated with cattle grazing, it was hypothesized that deermice habitat use would change after cattle were removed. Statistical tests indicate a significant difference for selection of most habitat variables by the mice after cattle were allowed to graze.

No previous data are available for deermouse habitat use immediately after grazing. However, Phillips (1936) found that moderately overgrazed grasslands in Oklahoma had a maximum abundance of deermice. He indicates the mice preferred this type of "sub-climax" community for the food sources they supply (Phillips 1936). Grant et al. (1982) found an increase in deermice biomass in grazed montane grasslands of Montana. Other studies also found a higher abundance of deermice in a variety of grazed habitats (Black and Frischknecht 1971; Hanley and Page 1982; Samson et al. 1989).

The overall indication is that deermice prefer grazed areas. Black and Frischknecht (1971) suggest this preference may be due to an increase in insects in areas where grazing has occurred, and Phillips (1936) suggests it is due to an increase in "sub-climax" type plants that deermice eat.

Few studies have addressed the specific microhabitat use of deermice before and after grazing has occurred. Based on trapping data only, Samson et al. (1989) noted that deermice were often found in areas where shrubs were present and litter and grass cover was lower. They indicate that habitat use by deermice was similar between control and grazed pastures prior to grazing treatment, and differed by the end of the summer grazing program (Samson et al. 1989).

Grass selection (% cover at locations), at the 20 cm level at WC, increased dramatically in 1991 after grazing (Figure 26). Mice used grass-covered areas very little prior to grazing, since the grass was thick and probably restricted movement (Hansen and Warnock 1978). Other research has indicated an avoidance of grass by deermice (Getz 1961; Barnum et al. 1992). In 1991, the cattle grazed these grassy areas so thoroughly it appeared as though a lawn mower had been used (Figure 28) (P=0.0027 mean height before=16.1 cm and mean

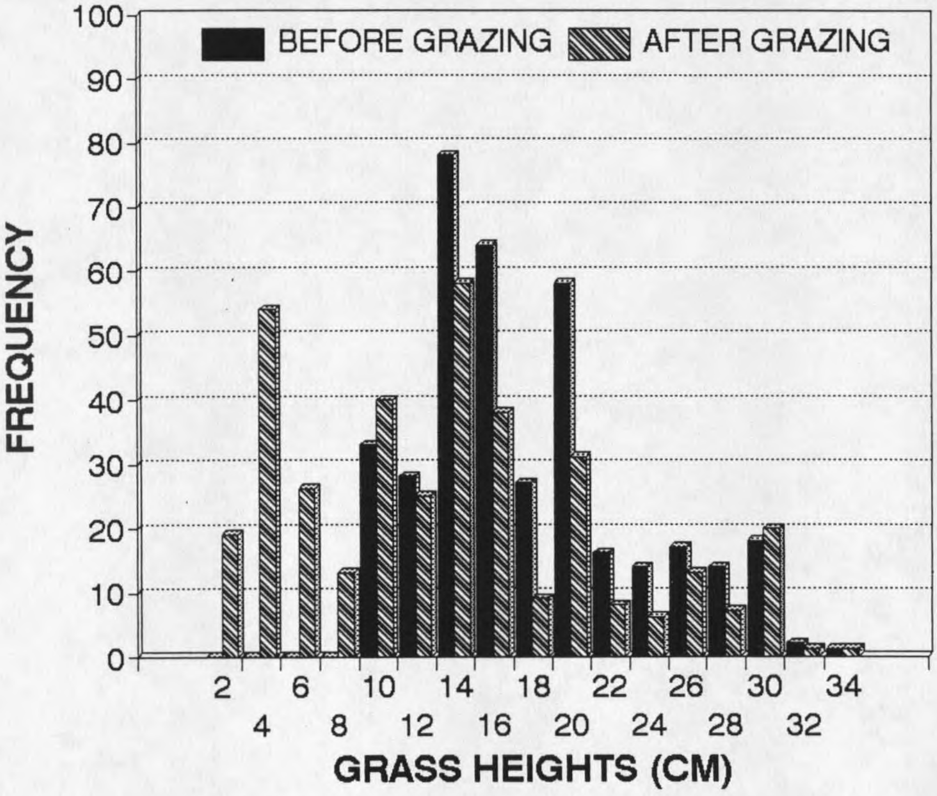

Figure 28. Grazing effects on grass heights at Willow Creek in 1991.

height after=12.1 cm). After cattle were removed and the mice were followed that night, mice used those newly grazed areas to a much greater extent. After several days, mice were observed traveling in the grazed, grass-covered areas frequently, and digging in dried manure where they encountered and ate undigested seeds and domestic grains.

Litter use by mice increased after grazing for all 3 levels at WC in 1991, but was only significantly different at the surface and 50 cm levels ($P<0.001$). Litter at WC consisted of dead grass, manure, dead forbs, and dead bitterbrush twigs. The increased use of litter may be a result of cattle increasing litter availability through manure piles and killing vegetation. Other suggestions for an increase in litter use may be due to an increase in insects found in the litter layer from the resulting cattle disturbance (Black and Frischknecht 1971), or use of manure piles for extraction of undigested grains.

Bitterbrush selection decreased significantly ($P<0.0001$) after grazing for the 20 and 50 cm levels, at WC in 1991, and conversely rabbitbrush use increased significantly ($P<0.0001$) for the 20 cm level. Rabbitbrush is sparse at WC and mostly scattered throughout the grassy area. This increased selection after grazing may be due to the mice choosing these small shrubs for a protective retreat after foraging in the grassy areas, because they would be highly visible in the grazed grass. Selection of bitterbrush decreased from 64% use prior to grazing, to 3% after grazing for the 20 cm level, and decreased from 48% prior to grazing, to 6% after grazing for the 50 cm level (Figure 26 and 27). It is possible that this decrease in bitterbrush selection is due to the increased use of grass for foraging, or the increased selection of areas adjacent to the grass, like rabbitbrush. In the nights following the grazing, mice were observed in the grassy areas more than prior to cattle grazing. In addition to the manure deposition by the cattle, trampled grass and forbs, undigested material from the cattles' mouths, and insects stirred up from hooves could all be increasing potential forage for the mice.

Deermice at WC in 1991 significantly increased selection of open space, at the 20 and 50 cm levels ($P<0.05$) after cattle grazing. Again this increase may be due to an increase in selection of grazed grassy areas with less cover.

In 1992, the cattle used to graze WC were very different behaviorally, physically, and numerically compared to those used in 1991. In 1991, the 130 cattle used were all cows and calves which grazed the grass the entire day, but the 40 cattle used in 1992 were all yearling bulls more interested in humans and each other than grazing. The most prominent effect of the 1992 cattle on the habitat was the destruction of a few bitterbrush bushes. The deermice selected grass at the WC surface level in 1992 significantly more ($P<0.01$) prior to grazing, which may support the idea that some grazing did occur, or that open areas may have been created by cattle trampling (Table 2 and Figures 29 and 30). The only other variable used significantly differently at WC after grazing was bitterbrush (P<0.05) at the 50 cm level. Mice selected this habitat variable less after grazing (Figure 30). This again could support the hypothesis of increased use of open areas after cattle-grazing activity, and decreased use of bitterbrush as the major form of cover.

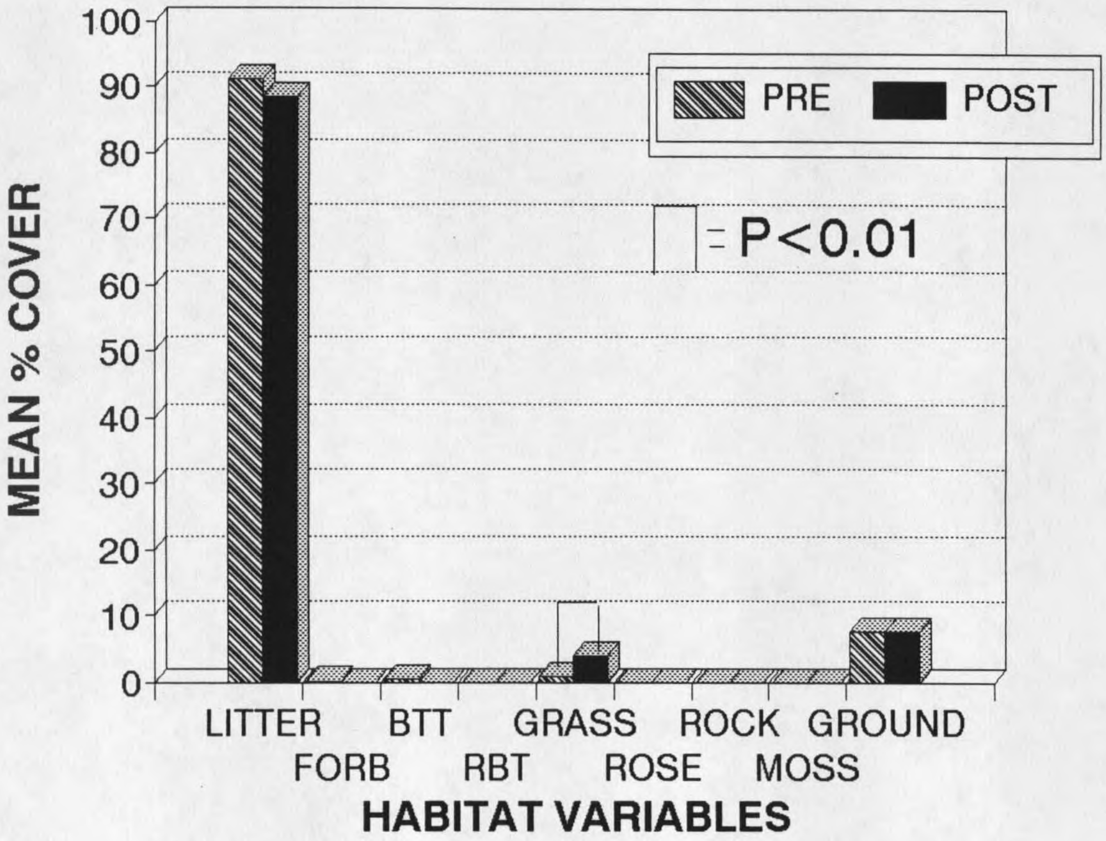

Figure 29. Comparisons of mean % cover at surface habitat variables at pre- and post-grazing deermouse locations on Willow Creek in 1992.

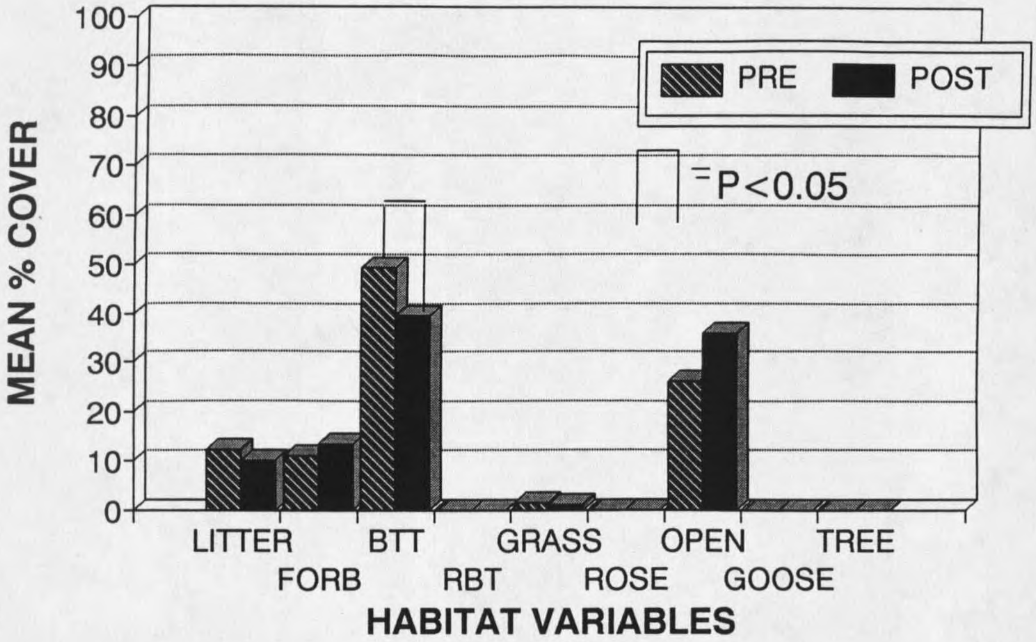

Figure 30. Comparisons of mean % cover at the 50 cm level habitat variables at pre- and post-grazing deermouse locations on Willow Creek in 1992.

<u>Monthly Habitat Use at RRG and WC</u>

Mice locations at both sites, for June 1991, were used from the post-cattle grazing period to compare with the post-cattle-grazing periods in July and August 1991. A total of 3 mice at RRG, and 3 at WC, were tracked during the June period; 2 at RRG and 6 at WC during the July period; and 2 at RRG and 2 at WC during the August period (Table 7 in the Appendix). A total of 34 mice locations at RRG were compared to 43 mice locations at WC for June, 51 at RRG to 162 at WC for July, and 60 at RRG to 51 at WC for August.

Habitat variable selection at the surface exhibited the same pattern as previously discussed. Mice were located in litter at both sites and for all 3 months, ranging from 76% to 98% cover (Figure 31). Although there were significant differences by month in variable use at the two sites, many of these were due to varying availability of those habitat variables at the two sites (Figure 3). It may be more pertinent to discuss the selection of habitat variables that were not significantly different (e.g., litter and bare ground) because of the consistency in preference by mice at both sites. This is consistent with observations and the literature (see deermice vs. representative vegetation section above).

At the 20 cm stratum, there were significant selections by the mice at sites in August for nearly every habitat variable (Table 3), and for a few in June and July (Table 11 in the Appendix contains means and standard deviations). The June selections were mainly due to the cattle-grazing experiment occurring so soon prior to tracking. There was a dramatic change at WC from bitterbrush selection to grass selection immediately after grazing (Figure 32). The reasons for different selections between the sites for August are difficult to determine, but may be due to a change in use of variables as they increased or decreased in availability as the growing season progressed.

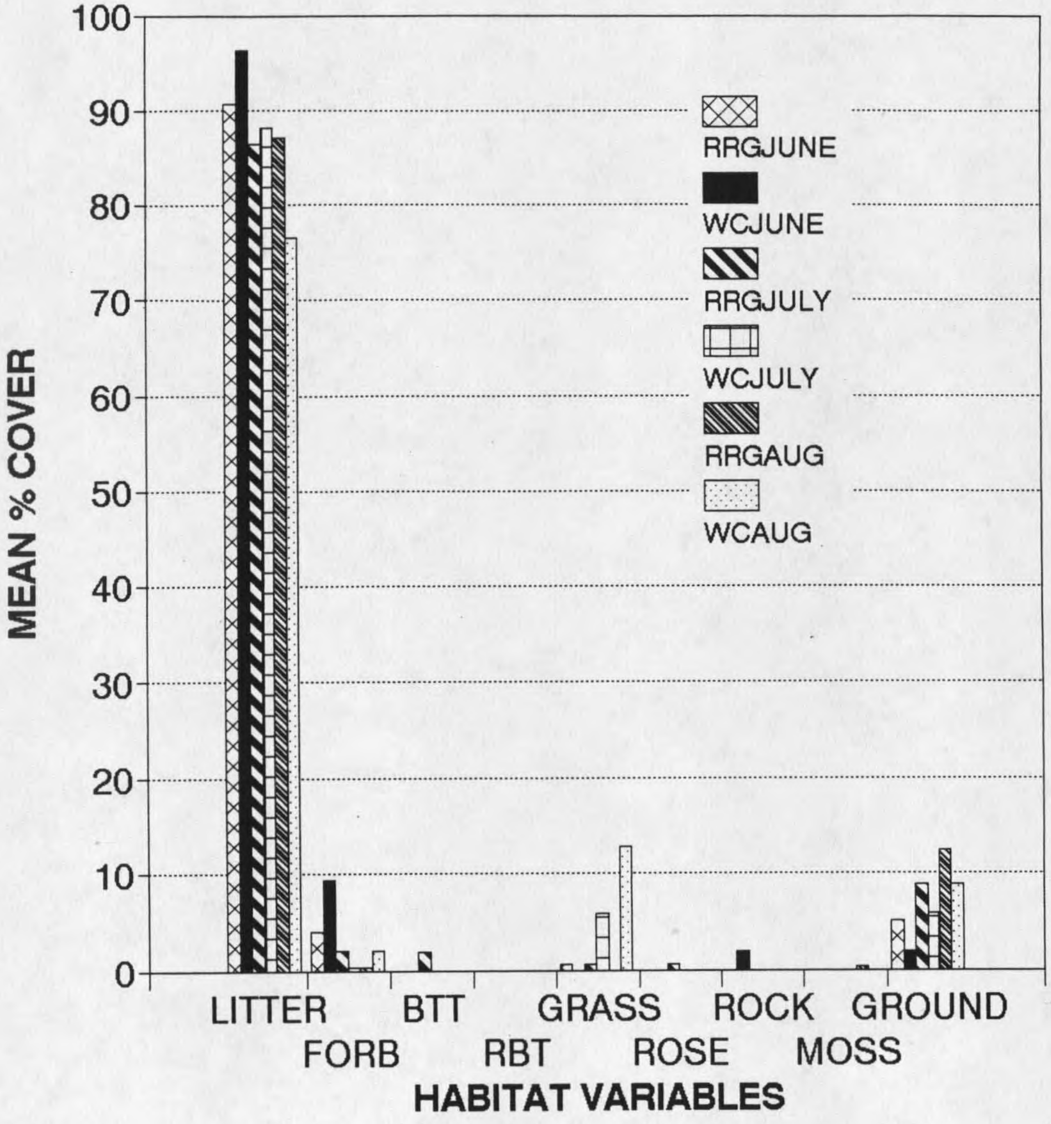

Figure 31. Mean % of cover of surface habitat variables at deermouse locations grouped by month on Willow Creek and Railroad Gulch in 1991.

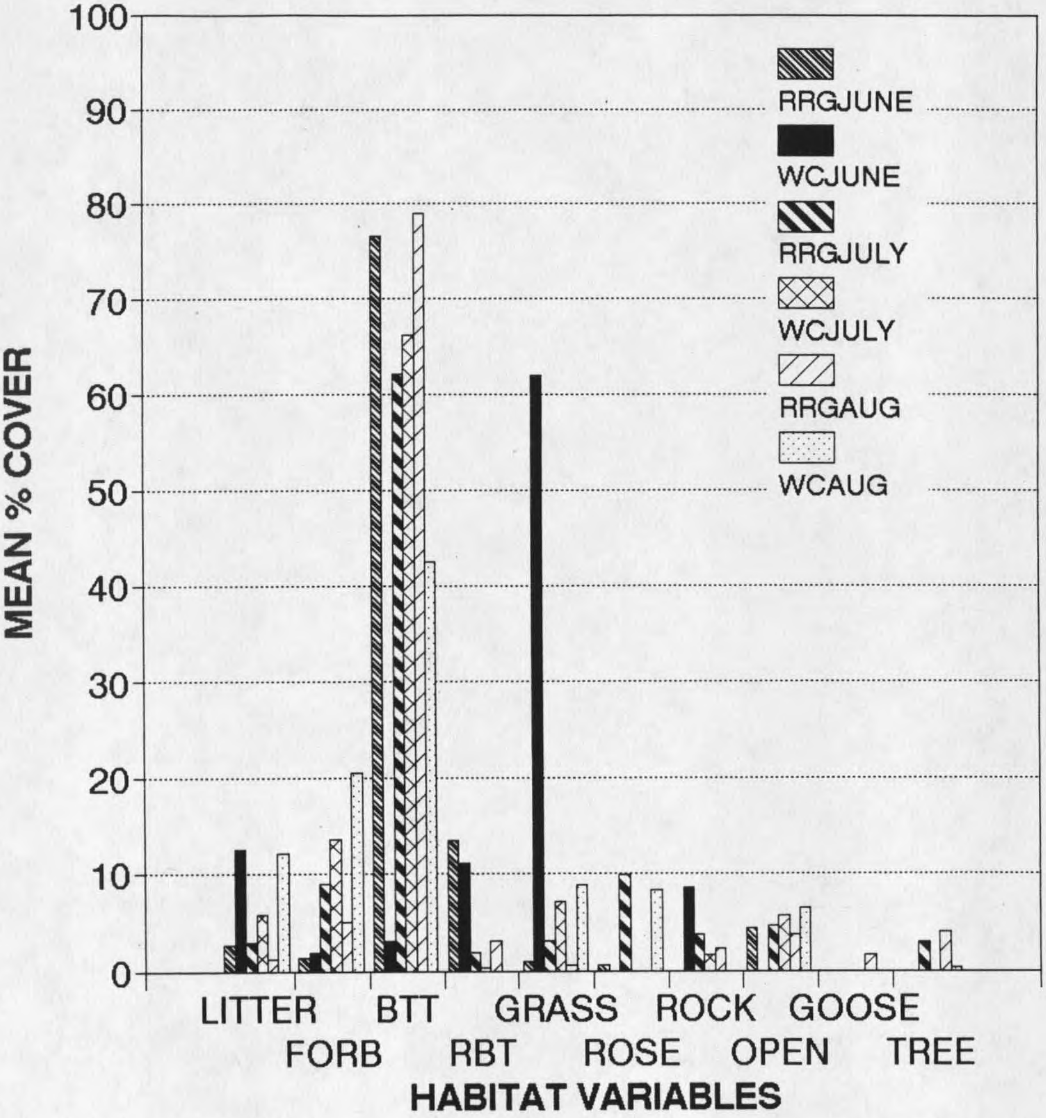

Figure 32. Mean % cover of 20 cm level habitat variables at deermouse locations grouped by month on Willow Creek and Railroad Gulch in 1991.

For the 50 cm stratum, forb selection was significant for every month ($P<0.0001$). Forb use was higher at WC for all months, but this may be due to the large amount of leafy spurge available to the mice at this site. Forbs at RRG were widely dispersed and low. At RRG the use of bitterbrush was much higher than at WC, again this may be due to the increased availability of forbs at WC, and the lack of this habitat component at RRG. The overall selection of bitterbrush and open space was similar for both sites during the 3 months, and followed the trends described above (Figure 33). Although the structure of vegetation changed as the summer progressed, the mice apparently preferred the same habitat variables. This preference was similar for all months, regardless of the individual or site. Litter was important to mice at the surface, and bitterbrush was important at the 20 and 50 cm levels. Monthly changes in growth and availability of vegetation did not appear to affect deermice preferences.

Seed Removal

Comparisons of seeds available for consumption by deermice were made between exclosures and marked exterior bushes. Seeds available are defined as ripe and easily removed from the parent bush or that fallen to the ground. The number of seeds in the enclosures were used as a standard, in order to determine the percentage of bitterbrush seed removed. The removal of exterior seed was calculated as a percentage of the expected removed, as estimated by the enclosure seeds falling

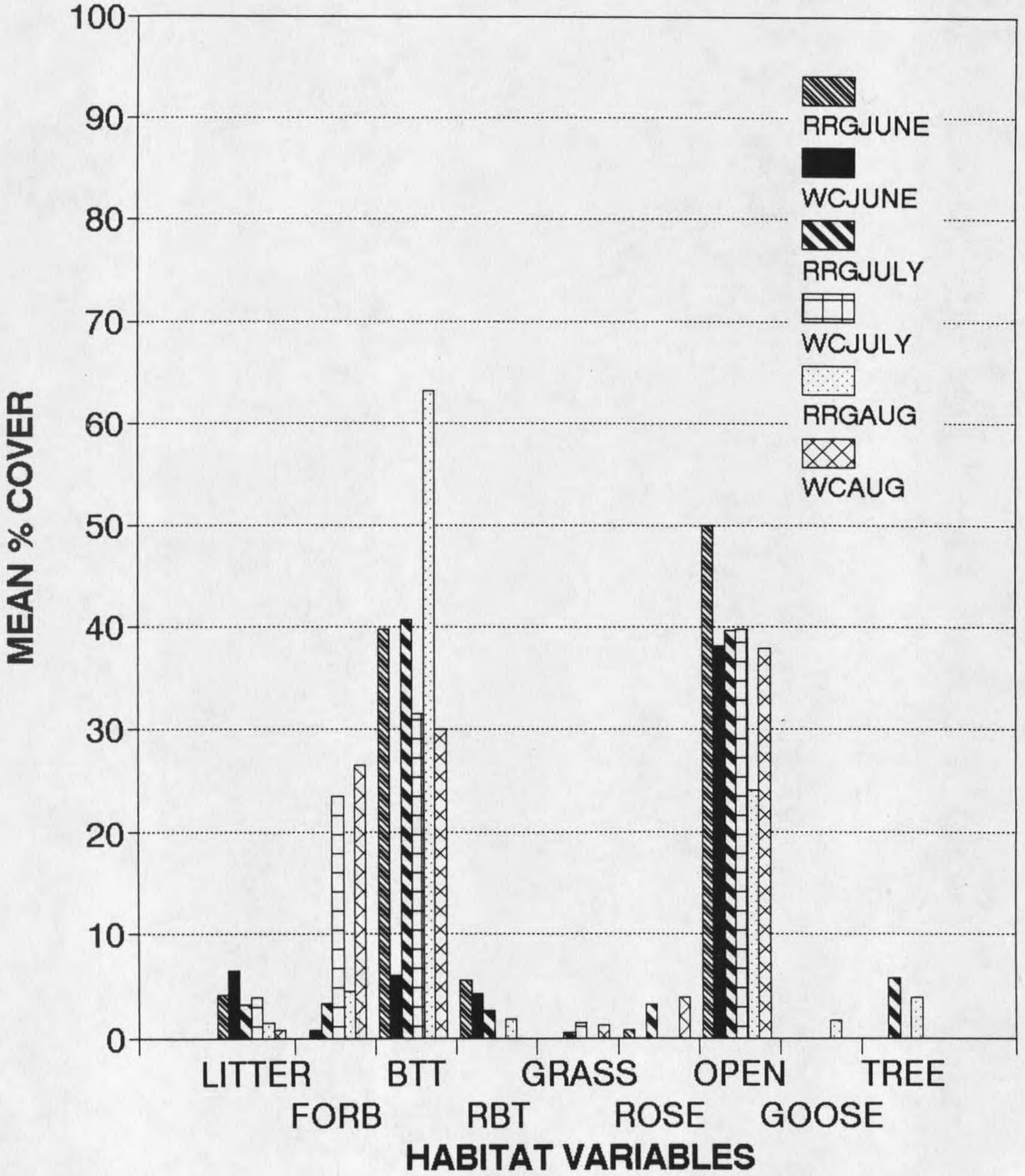

Figure 33. Mean % cover of 50 cm level habitat variables at deermouse locations grouped by month on Willow Creek and Railroad Gulch in 1991.

on the plates. The number of seeds on the plates were divided by the number of seeds on the bush, and differences between the percent left on the plate inside and outside the

Table 3. t-test significance levels for mean differences between RRG and WC deermice variable selection in June, July and August.

Habitat Variable	RRG vs WC June	RRG vs WC July	RRG vs. WC August
Surface			
Litter			
Forb	***	**	
Btt			
Rbt			
Grass		***	***
Moss			
Ground			
Rock	**		
20 cm Above Ground			
Litter	***		***
Forb		**	***
Btt	***		***
Rbt			**
Grass	***	***	***
Rose		***	***
Rock	***		***
Open			
Goose			
Tree			
50 cm Above Ground			
Litter			
Forb		***	***
Btt	***		***
Rbt			**
Grass		**	***
Rose			**
Open	***		**
Goose			
Tree		**	

*** = $P<0.01$
** = $P=0.01$ to 0.05

Blank = $P>0.05$

enclosures, was divided by the total percent left on the plates. For WC, average percent seeds removed was 70%, and for RRG, average percent seed removed was 87% (Table 4).

Seed-eating vertebrates were excluded from the enclosed bushes, but Western thatching ants (Formica sp.) were not, and may have removed seed. Removal of seed from the exterior bushes was achieved by deermice, yellow-pine chipmunks, seed-eating birds such as chipping sparrows, or ants. Although chipmunks were trapped on both grids the first year, their numbers were very low (<1% trap success at both grids) compared to deermice numbers (45% trap success at WC and 70% at RRG).

Seeds appeared plentiful on the ground underneath the enclosed bushes and around the paper plates but were scarce underneath the exterior bushes. By headlamp, deermice under bitterbrush bushes were observed picking up and eating seeds, or storing seeds in their mouths. Because of the high numbers of deermice compared to other vertebrate granivores, it is possible that deermice were the main vertebrates removing bitterbrush seeds from the exterior bushes. In addition, the higher percent removal of bitterbrush seed at RRG may be due to the higher density of deermice at that site.

Competition for seeds can be fierce between deermice and ants, and even lead to attacks on mice by biting and stinging ants (Brown et al. 1979). Although this was never observed at this site, the potential for this competitive interaction over bitterbrush seed cannot be discounted. These two organisms are probably responsible for the majority of seed removal in this area.

Simulated Caches

A total of 30 artificial caches were created inside the enclosures at WC with 30 seeds per cache and 30 at exterior bushes with 30 seeds per cache. Caches were difficult to make at WC due to the dense grass and ground level litter. At RRG, 36 artificial caches were created inside the enclosures with 30 seeds per cache, and 36 at the exterior bushes with 30 seeds per cache.

Table 4. Bitterbrush seed counted in a ratio of seeds on the bush to seeds on the ground, and percentage of seed removed. Percent removed calculated by dividing percent difference by percent found in enclosure.

Site	Location	Plates/Bush	%On Plates	%Seeds Remvd	Site Av
WC	Encl 66	94/425	22	80	
WC	Ext	45/993	4.5		
WC	Encl 49	76/692	11	54	
WC	Ext	33/617	5		70
WC	Encl 72	54/436	12	66	
WC	Ext	38/939	4		
WC	Encl 33	43/270	16	81	
WC	Ext	24/723	3		
RRG	Encl 47	0/37	0	0	
RRG	Ext	23/560	4		
RRG	Encl 38	71/297	24	88	
RRG	Ext	34/1325	3		87
RRG	Encl 41	54/285	19	79	
RRG	Ext	6/158	4		
RRG	Encl 29	145/379	38	95	
RRG	Ext	23/1330	2		

At WC on September 14, 1991, 19 exterior caches out of 30 had been completely or partially disturbed. This was apparent from the fresh digging activity and discarded hulls next to the excavated cache locations. The discarded fleshy remnants of 288 of the original 300 bitterbrush seeds were collected. All disturbed caches had been planted with either purchased seed or native seed. It appeared that deermice were the perpetrators because excavations at cache locations were less than 10-15 cm in diameter (Abbott and Quink 1970). The deermice appeared to have eaten the seed in situ and discarded the fleshy remains. This behavior has been noted by other researchers in the field (Abbott and Quink 1970). Inspection of caches at RRG did not indicate any of the caches had been disturbed, or at least not in exterior appearance. Abbott and Quink (1970) indicated that the deermice in their study not only discarded pine seed coats, but also covered disturbed areas with litter. It is possible that the mice at RRG might have covered disturbed caches, however I did not excavate the caches to determine disturbances.

Surviving bitterbrush seedlings were counted on three separate occasions (Table 5). Germination at WC in the spring of 1992 was 28 percent for the enclosure caches and 10 percent for the exterior caches. By June 3, 1992, survival of the seedlings had dropped to less than one half of the original germination with 13% surviving in the enclosures and 3% surviving in the exterior caches. The following year, on June 21, 1993, a count of surviving seedlings yielded 1% survival

Table 5. Counts of bitterbrush seedlings germinating May 16, 1992 and surviving in 1992 and 1993. (Exterior = P1 and P2 exterior bushes combined; Surv. 1 = 6\3\92 Surv 2 = 6\21\93). Seedling numbers are out of 300 possible for WC and 360 for RRG for each location.

Site	Location	# Seedlgs Germintng	# Seedlgs Surv 1	# Seedlgs Surv 2	%Germ	%Surv 1	%Surv 2
WC	Encl. #66	73	30	1	24	10	.03
	Exterior	7	4	1	2	1	.03
	Encl. #72	96	49	6	32	16	2
	Exterior	18	8	2	6	3	.06
	Encl. #33	86	35	2	29	12	.06
	Exterior	61	12	2	20	4	.06
Total Encl.		255	114	9	28	13	1
Total Ext.		86	24	5	10	3	.03
RRG	Encl. #38	16	0	0	4	0	0
	Exterior	0	0	0	0	0	0
	Encl. #29	29	10	2	8	3	.05
	Exterior	3	2	0	.08	.05	0
	Encl. #41	95	66	8	26	18	2
	Exterior	0	0	0	0	0	0
Total Encl.		140	76	10	13	7	.09
Total Ext.		3	2	0	.03	.02	0

for the enclosure caches and .03% for the exterior caches (Figure 34).

At RRG, germination was 13% for the interior, and .03% for the exterior caches. By June 3, 1992, survival rate dropped to 7% for the enclosure caches and .02% for the exterior caches. At the final count on June 21, 1993, these numbers decreased to .09% survival in the enclosures and 0% for the exterior bushes.

Bitterbrush seed purchased for this study was tested using tetrazolium and found to be 88%-90% viable. The native

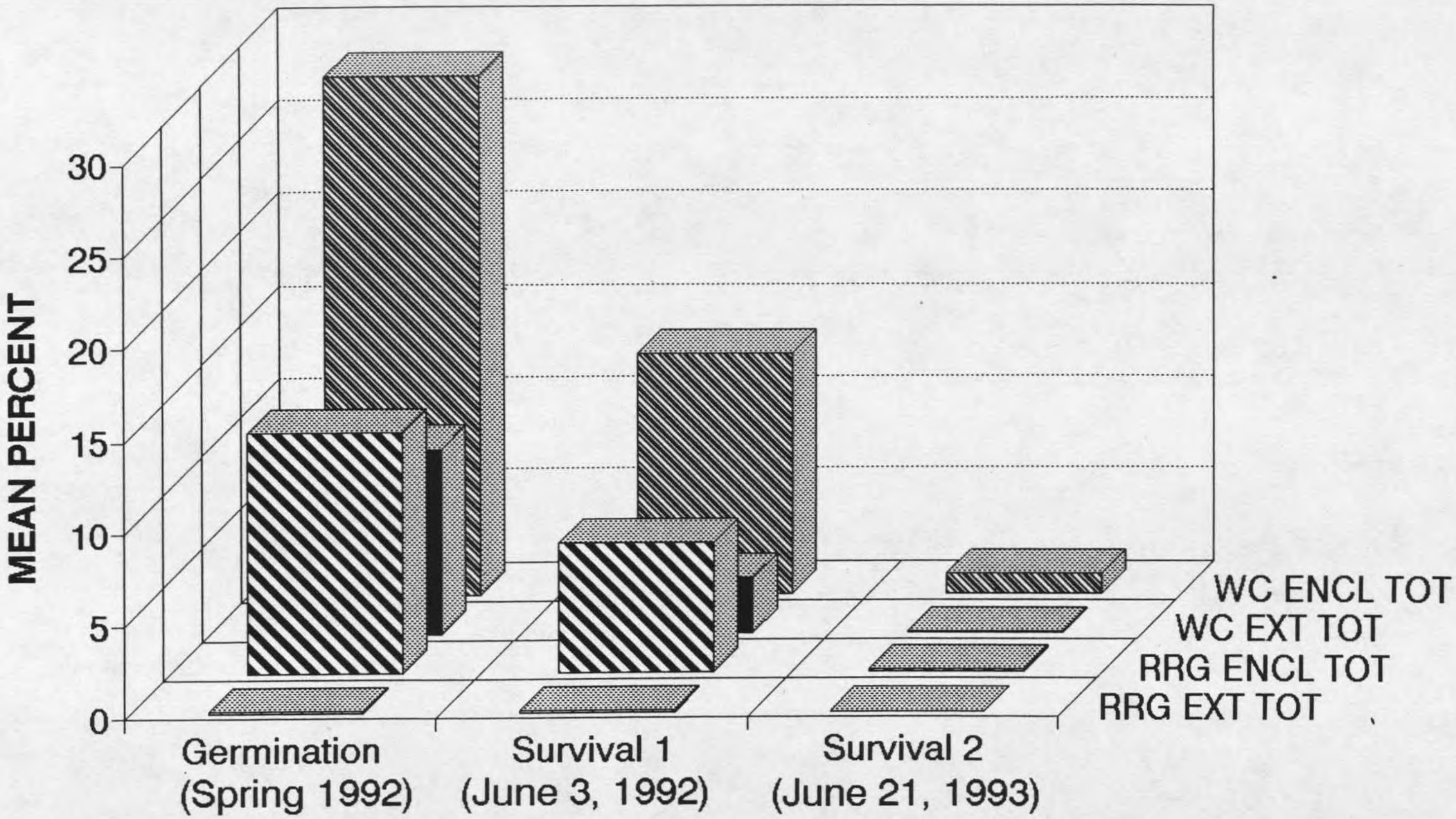

Figure 34. Mean % germination and survival of bitterbrush seedlings from artificial caches on Willow Creek and Railroad Gulch. Encl= Enclosure Caches and Ext=Exterior caches. Germination was measured in early spring 1992, and survival was measured on June 3, 1992 and June 21, 1993.

seed was tested by using both tetrazolium and cold stratification methods (Fraas 1992), viability was 69%-80% for the WC seed, and 68%-79% for the RRG seed (Fraas, pers. com). Both the viability tests, and the fact that the seeds did germinate, indicate that seedling survival is possible for both sites. Several factors were involved in the decreased survival rate for both sites.

At WC the exterior caches that had been disturbed, i.e., seeds consumed, did not have many germinating seedlings. The seedlings that did germinate were examined closely, and some were found to have all new leaves nipped off by rodents. Evans et al. (1983) and LaTourrette et al. (1971) noted rodents grazing in their studies reduced seedling survival. Destruction of caches by cattle, deer, and vehicles was noted by West (1968) and one cache of 8 seedlings in my study had been completely mashed by a cow's hoof following the cattle-grazing experiment. As I tracked mice at night, I discovered the following morning that I had mashed several seedlings.

Several seedlings had chewed stem bases and were dying. Chewed stem bases are often the result of insect damage. Other researchers have found insect damage to both bitterbrush seedlings and mature plants to be a factor in reducing overall survival rate (Hubbard 1956; Nord 1965; Evans et al. 1983).

Another factor partially affecting bitterbrush seedling survival at this site is the high density of grass and litter.

Many of the seedlings found under bushes or in deep litter were dead or nearly dead when seedlings were counted in June. Seedlings found in more open areas appeared to be healthy and vigorous. This competition with the adult plant and lack of sunshine were major factors in decreased survival of seedlings inside the enclosures. Guenther (1989) noted a possible autoallelopathic interaction between mature bitterbrush plants and new seedlings. Stanton (1959) indicated that survival of seedlings was rare beneath large shrubs. Since the seedlings in the enclosures were planted near or under the mature bushes this may also affect seedling survival past the initial germination phase.

Weather was also a possible contributing factor to the mortality of the bitterbrush seedlings. The later part of the spring and early part of the summer (77 mm precipitation in May 1991 versus 19 mm in May in 1992) were dry and many seedlings were completely dried and dead in the open and exposed areas of RRG.

At RRG, besides the previously mentioned factors, there are others to consider. The density of mice at this site was almost double that of WC (70% trap success at RRG vs 42% at WC). This high density may decrease the chances for seeds to germinate initially. At RRG, mice were more likely to eat seed rather than cache it, since the chances of their caches being found and consumed by others was very high. All exterior caches at RRG that had been planted with the healthy and plump purchased seed failed to produce any seedlings, yet the caches planted with the native seed did produce 3 seedlings. Because purchased seed caches did germinate at WC, complete inviability is unlikely. Although I did not find any apparent disturbances to caches, it is probable that the caches were consumed in their entirety.

A short experiment was conducted on the final night of tracking in 1991. Two paper plates were placed at RRG, one with purchased seed and the other with native seed. The plates were monitored with a headlamp, and several mice were observed visiting the plates. Mice would place 19-20 seeds in their mouths per visit and then leave the feeding area, return, and repeat the process. This was observed until all the purchased seed placed on the plate had been removed by the mice. Mice then smelled the remaining native seeds on the other plate, and ignored the seed. This short experiment led me to believe that the mice preferred the purchased seed over the native seed, and supports the idea that the mice at RRG probably ate all the seeds planted in the caches. Abbott and Quink (1970) noted that most natural caches planted in the summer (June-Sept.) had a very short tenure and most had been completely destroyed by deermice. I think caches at RRG remained intact for only a short time.

Deermice cache bitterbrush seed in the states south of Montana, yet in the MHWMA this activity is not apparent, and seedlings are not found. Researchers for the past five years have directed extensive efforts to find seedlings or cached seedlings germinating (Guenther 1989; Fraas 1992). My experiment caching bitterbrush seed has shown that initial germination of seedlings is possible and seedlings can survive up to 2 years in this area.

Radio collared deermice were never observed caching at either site, but did deposit seeds in burrows. Two burrows were excavated at WC over the course of the study to retrieve collars from deceased individuals. Bitterbrush seed was abundant in both burrows. One of the burrows was located in dense forbs 20 m from the nearest bitterbrush plant, and yet bitterbrush seed covered the burrow floor.

One of the possible inhibiting factors for caching at WC is the dense grass cover and litter found between the bushes. Sherman and Chilcote (1972) noted that rodents habitually cached seeds in areas with little or no litter. They felt that litter was one of the most important factors in determining caching behavior and locations of caches (Sherman and Chilcote 1972). In my opinion, constructing caches at WC required more energy than most deermice would expend. I had to remove grass and litter initially before digging a hole in hard soil to plant the seeds. The presence of litter and grass probably prevents deermice from caching at WC.

Alternately, deermice may be less dependent on bitterbrush seeds at WC. Mice at this site were observed eating seed heads of leafy spurge, spotted knapweed, and grasses, and were found in areas where beetles were abundant. It is possible that the deermice at this site used other food sources and relied on bitterbrush more for protective cover. Regional differences and yearly fluctuations of seed production may also be a factor in the lack of caching behavior, since caching would not be necessary if food supply was sufficient.

It is possible that the mice at RRG are caching bitterbrush seed; however, due to the high concentration of mice at that site, survival of these caches is rather ephemeral.

CONCLUSIONS

Rodent community structure is based on the availability of resources necessary for survival. These resources are associated with vegetation compositions. One of the objectives of this research project was to determine if there was a close association between deermice and bitterbrush. Bitterbrush was found to be an important resource for deermice at two unique sites. Bitterbrush, from 1 to 50 cm in height, was used extensively by all collared deermice. Even when mice had other forms of vegetation to choose from, bitterbrush was generally preferred at both sites. This use of bitterbrush was similar at each site even though the RRG site appeared to be in poor vegetative condition compared to WC. Deermice used the bitterbrush shrubs for protection from predators, nesting, resting, social interacting, and food procuring (presumably both primary and secondary food sources) during all summer months of the research. Therefore, it is clear that a close and important association between deermice and bitterbrush exists.

The second objective of this project was to determine if there were differences in habitat use by deermice following cattle-grazing activity. Rodent habitat preference changes when cattle graze in their home use areas. Deermice at WC, where grazing occurred, did exhibit changes in habitat use following cattle grazing, especially after cow/calf pairs had grazed in 1991. These changes in selection of habitat variables were exhibited during the following and subsequent evenings immediately after cattle had grazed the site during the day. Mice at WC shifted their use from largely bitterbrush at the 1 to 20 cm height, to grass at that same level. At 20 to 50 cm in height, the mice shifted from bitterbrush to open space such as were found in the low vegetation of open grassy areas. Cattle, by removing grass at this site, changed the appearance and composition of the habitat.

Deermice are generalists and easily adapt to changing situations. Grazing and the activities associated with grazing gave the deermice an advantage in the creation of new areas with potential food sources and passageways. Immediately after grazing, deermice at WC left the bitterbrush bushes and began using grazed grassy areas more than they had previously. This activity had the potential risk of increasing predation, but the benefits of increased resource availability apparently outweighed those risks. Therefore short-term cattle grazing at WC did affect deermice habitat use in a positive manner.

Comparisons with the control site at RRG where grazing did not take place strengthened the conclusions that grazing did alter selection of habitat variables at WC, because little to no alteration in habitat variable use occurred at RRG. The selection of variables at the two sites was different due to the different availability of habitat variables at the two sites; however, this use only changed markedly at WC when cattle were introduced into the area.

The final objective of the study was to determine if bitterbrush seed removal by deermice was excessive and thereby inhibited germination of cached seed. Caching behavior of deermice can enable bitterbrush seeds to germinate. This behavior is found in many areas of the western U.S., but not at MHWMA. Why was this supposed ubiquitous behavior not observed in this study?

Since 1987, my fellow researchers and I have been unable to locate bitterbrush seedlings in the Mt. Haggin Area. Guenther (1989) suggested the lack of seedlings found was due to unfavorable climatic conditions. Anderson (1989) suggested the period of time for adequate seedling establishment was intermittent for long-lived perennials. Fraas (1992) noted small bitterbrush seeds, common in this area, may be a factor in the plant's inability to reproduce by seed, and he also agreed with Anderson's theory of intermittent seedling establishment in mature stands (Anderson 1989). All of these previous suggestions indicate why seedling establishment might be rare at MHWMA.

What is apparent after my research is that artificial caches do produce viable seedlings at both sites, but that caching behavior was not observed, and no natural caches were found. Deermice did consume bitterbrush seeds at both sites and were observed filling cheek pouches with bitterbrush seed. Because seedling establishment was possible at both sites, two possibilities exist for the lack of observed natural seedling germination. One is that deermice do cache at RRG, but that the high population of mice consume cached seed entirely. The second possibility is that scatter hoard caching by deermice does not exist at either location.

All excavated burrows contained a large amount of bitterbrush seed. It is possible that deermice at these sites do not make many scattered caches as found in other western states, but hoard seed only in their burrows. Burrows tended to be either underground or encased by extremely dense vegetation. In these circumstances, seeds would never germinate since bitterbrush seeds need a great deal of sunshine to germinate and survive. Therefore it is my opinion that caching does not take place at these sites, and that bitterbrush will not be regenerated in this manner. Furthermore, short-term cattle grazing may hamper the caching situation, because grazing induces deermice to leave bitterbrush areas and utilize grassy areas for forage, and some seedlings that did germinate from artificial caches were destroyed by cattles' hooves. However, long-term grazing treatments may be beneficial to this situation because it would reduce the thick grass cover in the WC area. Periodic seasonal grazing would allow the mice to cache seed in areas denuded of vegetation and the seedlings would have a better chance of germinating without the competition from other vegetation.

Bitterbrush is an integral part of the community at both

RRG and WC and is used by many vertebrates and invertebrates, its continued existence will enhance the diversity of life in this area.

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APPENDIX

Table 6. Plant species found at Willow Creek (WC) and Railroad Gulch (RRG).

Scientific Name	Common Name	Site	Location
Shrubs, Half-Shrubs, and Trees			
Acer glabrum	Rocky Mountain maple		RRG
Amelanchier alnifolia	serviceberry		WC
Chrysothamnus nauseosus	rubber rabbitbrush		RRG,WC
Chrysothamnus viscidiflorus	green rabbitbrush		RRG,WC
Gutierrezia sarothrae	broom snakeweed		RRG,WC
Juniperus scopulorum	Rocky Mt. juniper		RRG,WC
Purshia tridentata	antelope bitterbrush		RRG,WC
Pseudotsuga menziesii	Douglas fir		RRG,WC
Ribes setosum	gooseberry		RRG
Ribes cereum	wild currant		RRG,WC
Rosa woodsii	Wood's rose		RRG,WC
Tetradymia canescens	gray horsebrush		WC
Graminoids			
Agropyron spicatum	bluebunch wheatgrass		RRG,WC
Bromus tectorum	cheatgrass		RRG
Elymus cinereus	basin wildrye		RRG,WC
Poa pratensis	Kentucky bluegrass		RRG,WC
Poa cusikii	Cusik's bluegrass		RRG,WC
Stipa comata	needleandthread		RRG,WC
Forbs			
Achillea millefolium	yarrow		RRG,WC
Allium cernuum	nodding onion		RRG,WC
Artemisia ludoviciana	prairie sage		WC
Aster integrifolius	thickstem aster		RRG,WC
Astragalus spp.	milk vetch		WC
Centaurea maculosa	spotted knapweed		RRG,WC
Cirsium vulgare	bull thistle		WC
Erigeron spp.	daisy fleabane		RRG
Erigonum umbellatum	sulphur flower		RRG,WC
Euphorbia esula	leafy spurge		RRG,WC
Gaura coccinea	scarlet gaura		RRG
Helianthus annuus	sunflower		RRG,WC
Iris missouriensis	mountain iris		RRG,WC
Lepidium densiflorum	pepper grass		WC
Lupinus wyethii	bluebonnet		RRG,WC
Madia glomerata	sticky tarweed		RRG,WC
Phacelia hastata	scorpion weed		RRG
Phlox spp.	phlox		RRG,WC
Rumex spp.	dock		WC
Sisymbrium altissimum	tumble mustard		RRG,WC
Soldago missouriensis	goldenrod		RRG,WC
Tragopogon dubius	meadow salsify		RRG
Valerian dioica	valerian		RRG,WC

Table 7. Deermice trapping and tracking details.

YEAR	TAG#	FREQ	SEX	1ST TRAP	TRACK PERIOD	OUTCOME
1991						
Willow Creek						
	827	714	M	5.19.91	6.03.91/6.06.91	P: 6.06
	690	760	F	5.19.91	6.03.91/6.07.91	D: 6.05
	238	245	M	5.18.91	6.03.91/6.10.91	S
	237	737	F	5.18.91	6.03.91/6.10.91	S
	551	685	M	6.03.91	7.07.91/7.09.91	CK
	237	715	F	5.18.91	7.07.91/7.15.91	S
	840	220	F	5.18.91	7.07.91/7.15.91	S
	431	246	F	7.08.91	7.26.91/8.03.91	S
	554	966	F	6.03.91	7.26.91/7.27.91	CK
	689	220	F	5.19.91	7.26.91/8.03.91	S
	244	246	F	5.19.91	8.07.91/8.12.91	S
	423	220	M	5.20.91	8.07.91/8.12.91	S
Railroad Gulch						
	733	274	M	5.20.91	6.03.91/6.10.91	S
	819	845	F	5.19.91	6.03.91/6.10.91	S
	727	641	M	5.20.91	6.03.91	D: 6.03
	805	520	F	5.19.91	6.03.91/6.10.91	S
	717	735	M	5.20.91	7.09.91	D: 7.09
	725	845	M	5.19.91	7.09.91/7.10.91	RC
	709	245	M	5.20.91	7.09.91/7.16.91	S
	720	520	M	5.20.91	7.26.91	D: 7.26
	710	272	F	5.20.91	7.26.91/8.03.91	RC
	737	786	F	5.20.91	7.26.91	P: 7.26
	518	686	M	6.03.91	8.07.91/8.12.91	S
	705	715	M	5.20.91	8.07.91/8.12.91	S
1992						
Willow Creek						
	5066	784	M	5.16.92	5.29.92/6.04.92	S
	5065	617	F	5.16.92	5.29.92/6.04.92	S
	5064	736	F	5.16.92	5.29.92/6.04.92	S
	5190	535	F	5.16.92	5.29.92/6.04.92	S
Railroad Gulch						
	805	220	F	5.19.91	5.29.92/6.04.92	D: 6.05
	5172	245	M	5.16.92	5.29.92/6.04.92	RC
	5187	515	F	5.16.92	5.29.92/6.04.92	D: 5.29

RC=Recaptured with inoperable collar; CK=Killed by collar; D=Disappeared; P=Possible predation; S=Successful tracking

Table 8. Type of bitterbrush seed planted in artificial caches.

Site	Cache Location	Seed Type
WC	Encl. 72	Purchased
WC	Exterior	1991 Native
WC	Encl. 33	1991 Native
WC	Exterior	Purchased
WC	Encl. 66	1990 Native
WC	Exterior	Purchased
WC	Encl. 49	Control
RRG	Encl. 38	1990 Native
RRG	Exterior	Purchased
RRG	Encl. 41	Purchased
RRG	Exterior	Purchased
RRG	Encl. 29	1991 Native
RRG	Exterior	1991 Native
RRG	Encl. 47	Control

Table 9. Means (M) and standard deviations (SD) for t-test comparisons at 3 levels on Railroad Gulch (RRG) and Willow Creek (WC) sites between deermice (MC) habitat use and representative sample vegetation (RP) (LIT=litter, BTT=bitterbrush, RBT=rabbitbrush, GRS=grass, RSE=rose, RCK=rock, MOSS=club-moss, OPEN= open space, GSE= gooseberry).

Site/Year — Habitat Variables

A. Deermice means vs. representative vegetation sample means

Surface Level

Site/Year		LIT	FORB	BTT	RBT	GRS	RSE	RCK	MOSS	GROUND
RRG91MC	M	87.1	3.4	0.47	0.47	0	0	0	0	8.35
	SD	2.38	0.96	0.21	0.21	0	0	0	0	2.09
RRG91RP	M	50.3	5.5	2.75	0.5	7.5	0	0	2.83	0.8
	SD	2.7	1.08	0.78	0.22	1.06	0	0	0.78	2.63
RRG92MC	M	86.9	0	0	0	0.19	0	0	0.58	12.31
	SD	1.59	0	0	0	0.14	0	0	0.24	1.58
RRG92RP	M	41	4.5	3	8.25	1.5	0	0	11.7	42
	SD	2.02	0.64	0.76	1.06	0.43	0	0	1.03	2.41
WC91MC	M	84.1	0.65	0	0	4.76	0	0	0	10.48
	SD	2.3	0.3	0	0	1.05	0	0	0	1.97
WC91RP	M	66.6	0.73	1.22	0.49	11.22	0	0	1.46	8.29
	SD	3.12	0.26	0.51	0.31	2.06	0	0	0.48	2.59
WC92MC	M	91.2	0.09	0.53	0	0.62	0	0	0	7.52
	SD	1.89	9.41	0.48	0	0.43	0	0	0	1.68
WC92RP	M	72.7	3.9	6.34	1.71	8.78	0	0	0.49	5.85
	SD	2.09	0.8	1.18	0.54	1.23	0	0	0.22	0.92

20 cm level

Site/Year		LIT	FORB	BTT	RBT	GRS	RSE	RCK	OPEN	GSE	TREE
RRG91MC	M	1.41	2.6	73.6	11.8	0.94	1.4	2.35	5.29	0.59	0
	SD	0.69	0.6	3.64	2.4	0.45	1.1	1.1	1.21	3.22	0
RRG91RP	M	21.8	0	13.8	3	7	0	0.25	53.8	0	0
	SD	1.95	0	2.16	0.91	1.14	0	0.16	2.24	0	0
RRG92MC	M	2.5	9.81	64.6	6.15	1.93	0	0.38	7.5	6.15	0.96
	SD	0.59	1.24	2.92	1.92	0.53	0	0.19	0.76	1.6	0.7
RRG92RP	M	11.8	6	5.85	1.75	5.5	0	0.5	71.8	0	0
	SD	1.12	1.1	0.46	0.45	0.85	0	0.22	1.77	0	0
WC91MC	M	8.25	8.25	63.6	0.16	12.2	0	0.16	7.3	0	0
	SD	1.33	1.1	2.42	0.13	1.5	0	0.13	1.05	0	0
WC91RP	M	9.76	10.5	15.6	0.24	14.4	0	0.73	50.7	0	0
	SD	1.15	1.5	2.72	0.16	1.87	0	0.35	2.1	0	0
WC92MC	M	20.3	16	51.2	0	4.16	0	0.88	7.43	0	0
	SD	2.77	2.17	3.83	0	1.2	0	0.45	1.36	0	0
WC92RP	M	15.4	11.2	15.8	0.49	11.2	0.98	1.22	43.7	0	0
	SD	1.26	1.21	2.48	0.22	1	0.44	0.4	1.68	0	0

50 cm level

Site/Year		LIT	FORB	BTT	RBT	GRS	RSE	OPEN	GSE	TREE
RRG91MC	M	3.29	0	34.1	6.35	0	0.59	55.3	0.94	0
	SD	0.78	0	3.53	1.9	0	0	3.5	0.7	0
RRG91RP	M	4.75	0	3.25	1	0	0	89.8	1.25	0
	SD	0.99	0	0.89	0.44	0	0	1.79	0.79	0

Table 9. Continued

Site/Year		Habitat Variables								
		50 cm level								
		LIT	FORB	BTT	RBT	GRS	RSE	OPEN	GSE	TREE
RRG92MC	M	0	2.12	44.6	2.88	0	0	36.92	13.46	0
	SD	0	0.7	3.06	1.18	0	0	2.62	3.3	0
RRG92RP	M	0.3	0.75	5	2	0	0	86.5	1.5	1.25
	SD	0.56	0.35	1.4	0.72	0	0	1.98	0.95	0.79
WC91MC	M	1.59	1.27	47.9	0	3.33	0	45.87	0	0
	SD	0.37	0.46	2.94	0	6.96	0	2.96	0	0
WC91RP	M	4.15	0.24	3.17	0	0.49	0	91.95	0	0
	SD	0.87	0.16	0.91	0	0.22	0	1.45	0	0
WC92MC	M	12.2	10.8	49.5	0	1.42	0	26.12	0	0
	SD	1.61	1.3	3.39	0	0.94	0	3.01	0	0
WC92RP	M	10.2	0.24	4.15	0	1.22	0	84.15	0	0
	SD	1.37	0.16	0.77	0	0.33	0	1.53	0	0

Table 10. Means (M) and Standard Deviations (SD) for t-test comparisons at 3 levels on Railroad Gulch (RRG) and Willow Creek (WC) sites between deermice habitat use before (PRE) and after grazing (PST) treatment (LIT=litter, BTT=bitterbrush, RBT=rabbitbrush, GRS=grass, RSE=rose, RCK=rock, MOSS=club-moss, OPEN= open space, GSE= gooseberry).

Site/Year		Habitat Variables								
Surface Level										
		LIT	FORB	BTT	RBT	GRS	RSE	RCK	MOSS	GROUND
RRG91PRE	M	87.29	3.41	0.47	0.47	0	0	0	0	8.35
	SD	2.38	0.96	0.21	0.21	0	0	0	0	2.09
RRG91PST	M	90.59	3.82	0	0	0.59	0	0	0	5
	SD	1.95	0.78	0	0	0.34	0	0	0	1.8
RRG92PRE	M	86.92	0	0	0	0.19	0	0	0.58	12.31
	SD	1.59	0	0	0	0.14	0	0	0.24	1.58
RRG92PST	M	85.85	1.46	0	0	0	0	0	0.98	11.71
	SD	1.73	0.48	0	0	0	0	0	0.3	1.56
WC91PRE	M	84.13	0.63	0	0	4.76	0	0	0	10.48
	SD	2.3	0.3	0	0	1.05	0	0	0	1.97
WC91PST	M	96.28	9.53	0	0	0	0	1.86	0	1.86
	SD	1	1.19	0	0	0	0	0.59	0	0.63
WC92PRE	M	91.24	0.09	0.53	0	0.62	0	0	0	7.52
	SD	1.89	9.41	0.48	0	0.43	0	0	0	1.68
WC92PST	M	88.54	0	0	0	3.96	0	0	0	7.5
	SD	1.88	0	0	0	1.18	0	0	0	1.58
20 cm level										
		LIT	FORB	BTT	RBT	GRS	RSE	RCK	OPEN	GSE	TREE
RRG91PRE	M	1.4	2.59	73.6	11.8	0.94	1.41	2.35	5.29	0.59	0
	SD	0.7	0.6	3.64	2.4	0.45	1.1	1.1	1.21	3.22	0
RRG91PST	M	2.7	1.47	76.5	13.5	0.88	0.59	0	4.41	0	0
	SD	0.8	0.36	3.75	3.25	0.51	0.34	0	1.46	0	0
RRG92PRE	M	2.5	9.8	64.6	6.15	1.93	0	0.38	7.5	6.15	0.96
	SD	0.6	1.24	2.92	1.92	0.53	0	0.19	0.76	1.61	0.69
RRG92PST	M	7.8	12.2	61.2	2.44	0.98	0	0.24	8.54	2.93	3.66
	SD	1.7	1.29	2.79	0.97	0.37	0	0.16	1.04	1.1	1.32
WC91PRE	M	8.2	8.25	63.7	0.16	12.2	0	0.16	7.3	0	0
	SD	1.3	1.1	2.42	0.13	1.5	0	0.13	1.05	0	0
WC91PST	M	12.6	1.86	3.02	11.2	61.9	0	8.6	0	0	0
	SD	1.5	0.55	0.74	1.18	2.5	0	0.97	0	0	0
WC92PRE	M	20.3	6.02	51.2	0	4.16	0	0.88	7.43	0	0
	SD	2.8	2.17	3.83	0	1.2	0	0.45	1.36	0	0
WC92PST	M	17.9	20.4	48.4	0.10	6.35	0	0.52	6.25	0	0
	SD	2.6	2.29	3.41	0.10	1.22	0	0.34	1.1	0	0
50 cm level										
		LIT	FORB	BTT	RBT	GRS	RSE	OPEN	GSE	TREE
RRG91PRE	M	0.33	0	3.41	0.64	0	0	5.53	0.09	0
	SD	0.78	0	3.53	1.9	0	0	3.5	0.7	0
RRG91PST	M	0.41	0	3.97	0.56	0	0.06	5	0	0
	SD	1.05	0	3.9	1.62	0	0.34	3.41	0	0

Table 10. Continued

Site/Year		Habitat Variables								
		50 cm level								
		LIT	FORB	BTT	RBT	GRS	RSE	OPEN	GSE	TREE
RRG92PRE	M	0	0.21	4.46	0.29	0	0	3.69	1.35	0
	SD	0	0.7	3.06	1.18	0	0	2.62	3.3	0
RRG92PST	M	0	0.2	4.61	0	0.05	0	3.98	1.02	0.15
	SD	0	0.64	2.63	0	0.31	0	2.82	2.55	0.94
WC91PRE	M	1.59	1.27	47.9	0	3.33	0	45.9	0	0
	SD	0.37	0.46	2.94	0	6.96	0	2.96	0	0
WC91PST	M	6.51	0.7	5.81	4.21	0	0	38.2	0	0
	SD	0.87	0.34	1.26	3.19	0	0	2.64	0	0
WC92PRE	M	12.2	10.8	49.5	0	1.42	0	26.1	0	0
	SD	1.61	1.3	3.39	0	0.94	0	3.01	0	0
WC92PST	M	10.1	13.3	39.7	0	0.94	0	35.9	0	0
	SD	1.47	1.7	3.48	0	0.36	0	3.54	0	0

Table 11. Means (M) and standard deviations (SD) for t-test comparisons of monthly habitat use by deermice on Railroad Gulch (RRG) and Willow Creek (WC) sites (LIT=litter, BTT=bitterbrush, RBT=rabbitbrush, GRS=grass, RSE=rose, RCK=rock, MOSS=club-moss, OPEN= open space, GSE= gooseberry).

Site/Year — Habitat variables

Surface Level

Site/Year		LIT	FORB	BTT	RBT	GRS	RSE	RCK	MOSS	GROUND
RRGJUNE	M	90.6	3.82	0	0	0.59	0	0	0	5
	SD	1.95	0.78	0	0	0.34	0	0	0	1.8
WCJUNE	M	96.3	9.53	0	0	0	0	1.86	0	1.86
	SD	1	1.19	0	0	0	0	0.59	0	0.63
RRGJULY	M	86.3	1.96	1.76	0	0.59	0.59	0	0	8.82
	SD	2.23	0.53	0.79	0	0.24	0.24	0	0	1.89
WCJULY	M	88	0.37	0	0	5.86	0	0	0	5.8
	SD	2.38	0.33	0	0	1.48	0	0	0	1.69
RRGAUG	M	87	0.33	0	0	0	0	0	0.33	12.33
	SD	2.48	0.26	0	0	0	0	0	0.26	2.32
WCAUG	M	76.5	1.96	0	0	12.8	0	0	0	8.82
	SD	3.53	0.98	0	0	2.7	0	0	0	1.86

20 cm level

Site/Year		LIT	FORB	BTT	RBT	GRS	RSE	RCK	OPEN	GSE	TREE
RRGJUNE	M	2.65	1.47	76.5	13.5	0.88	0.59	0	4.41	0	0
	SD	0.79	0.36	3.75	1.35	0.51	0.34	0	1.46	0	0
WCJUNE	M	12.6	1.86	3.02	11.2	61.9	0	8.6	0	0	0
	SD	1.54	0.55	0.3	1.12	2.51	0	0.97	0	0	0
RRGJULY	M	2.94	9.02	62.2	1.76	3.14	9.8	3.73	4.51	0	2.94
	SD	0.7	1.28	3.6	0.62	0.76	2.41	1.87	0.92	0	1.47
WCJULY	M	5.74	13.8	66.2	0.25	7.1	0	1.54	5.68	0	0
	SD	1.44	2.11	3.2	0.22	1.2	0	0.99	1.55	0	0
RRGAUG	M	1.17	5	78.8	3	0.5	0	2.33	3.67	1.67	3.83
	SD	0.56	0.91	3.31	1.05	0.22	0	0.67	1.31	0.94	1.5
WCAUG	M	12.2	20.6	42.5	0	8.82	8.43	0	6.47	0	0.39
	SD	1.75	2.63	4.29	0	1.46	1.86	0	1.09	0	0.28

50 cm level

Site/Year		LIT	FORB	BTT	RBT	GRS	RSE	NO	GSE	TREE
RRGJUNE	M	4.12	0	39.7	5.59	0	0.59	50	0	0
	SD	1.05	0	3.9	1.62	0	0.34	3.41	0	0
WCJUNE	M	6.51	38.1	5.81	4.21	0	0	0.7	0	0
	SD	0.87	2.64	1.26	3.19	0	0	0.34	0	0
RRGJULY	M	3.14	3.33	40.8	2.55	0.39	3.14	39.6	0	5.69
	SD	0.81	0.65	3.74	0.25	0.2	1.33	3.4	0	0.57
WCJULY	M	3.77	23.5	31.5	0	1.42	0	39.8	0	0
	SD	1.13	2.41	2.9	0	0.51	0	3.43	0	0
RRGAUG	M	1.33	4.33	63.2	1.83	0	0	24	1.5	3.83
	SD	0.43	0.67	3.66	0.65	0	0	3.26	0.94	1.74
WCAUG	M	0.59	26.5	30	0	1.18	3.92	37.8	0	0
	SD	0.24	2.23	3.26	0	0.33	1.36	3.75	0	0