

**Habitat Utilization Patterns of Deer Mice (*Peromyscus maniculatus*) in Big Creek Reserve,
Big Creek, California**

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Abstract

Past studies on rodent population dynamics have narrowed down the mechanisms driving population fluctuations to single-factor theories such as the effects of resource pulses and top-down trophic cascades. The variation in rodent population dynamics across regional and climatic gradients, however, calls for a more holistic approach that takes into consideration multiple site-specific factors. To that end, the effects of shelter availability and diversity of food-producing plants on *Peromyscus* activity were tested across three habitat types along a watershed in Big Sur, California. Significant differences in rodent activity were found across all treatments, with more activity in areas with abundant shelter and greater diversity of food-producing plants. These findings support multi-factor theories of rodent population fluctuations, and provide a snapshot of late Spring habitat preferences of *Peromyscus* species in Big Sur, California.

Introduction

Rodent species in California of the genus *Peromyscus* (*P. boyleii*, *P. maniculatus*, *P. californicus*, and *P. trueii*) are habitat generalists found throughout North America, South America, and Europe. Because of their broad distribution across multiple habitat types, *Peromyscus* species have drawn the attention of many ecologists trying to support theories on population dynamics, community interactions over time, and the roles of resource availability in life history patterns (Dickman 1999; Clotfelter 2007; Valone 2007; Elmhagen 2007; Anderson 2008).

A common trend in this research is to adopt either a one-factor or multi-factor approach to explain the phenomena observed in a study. A one-factor approach has been supported by Clotfelter and Pederson (2007), Anderson and Wait (2008), Schmidt and Ostfeld (2008), and Dickman and Mahon (1999) by testing resource pulses and bottom-up trophic cascades on rodent population fluctuations. Resource pulses are large scale resource depositions such as seed release and rainfall that have the potential to influence population fluctuations throughout an ecosystem because of their uncommon magnitude and punctuated effect. Trophic cascades are the effects that fluctuations in a level of the food web have on the other levels. They can be bottom-up, as in the increase of rodent populations in response to an increase

in the growth of food-producing plants, or top-down, as in the increase of rodent populations due to a decrease in predators such as raptors and coyotes. Rainfall levels are an example of a bottom-up resource pulse that has been used to predict rodent populations (Dickman 1999). High precipitation levels lead to increased plant growth and a corresponding increase in herbivore populations, while low precipitation levels lead to low plant growth and declines in herbivores (Dickman 1999; Clotfelter 2007). Rodent populations can increase significantly between 2 and 10 months after a heavy rainfall, depending on the species (Schmidt 2008; Anderson 2008).

A problem with using resource pulses to predict population shifts, as pointed out by Hansson (1998), is that seasonal fluctuations in rodent populations can only be understood from the resource pulse perspective during years with significant pulse events. These events lead to marked differences in succeeding seasons, but are not conclusive in detailing the nature of rodent population fluctuations over time. A study conducted by Hansson (1987) showed that two different populations of the same species of vole (*Microtus agrestis*) were regulated by two different factors in different areas. One population showed a strong positive response to increased food supply while a similar population could not reach high densities even with an abundant food source because of heavy predation. This finding indicates that

population dynamics at one trophic level are influenced directly or indirectly by dynamics at all other levels (Hansson 1987; Hansson 1998). Research exploring population cycles must consider multi-factor theories because this approach is a more powerful tool for predicting the how populations respond to the various environmental and meteorological variables at a specific habitat over time (Hansson 1987; Hansson 1998; Elmhagen 1997).

The multi-factor approach suggested by Hansson (1998) has been redoubled in other studies on rodent populations and life history patterns. Several influential factors such as habitat composition, natal-site characteristics, movement patterns over time, and diet preference have been used to test the dynamics of rodent populations through time (Wecker 1963; Drickamer 1976; Barnum 1992; Stapp 1997; Roche 1999; Rehmeier 2004). Research from this perspective has not focused on determining a uni-causal factor for explaining rodent populations, but has instead focused on defining the multitude of factors that influence population dynamics. A common approach in these studies is to recognize site-specific temporal and spatial biotic and abiotic factors such as season (Dickman 1999;), climate, plant community characteristics (Barnum 1992; Stapp 1997), geography (Barnum 2002; Anderson 2008), presence of predators (Elmhagen 2007; Roche 1999), and the life history patterns of past generations of rodents (Wecker 1963). Findings interpreted through the lens of specifics such as these create a realistic view of rodent populations dependent on an understanding of regional-scale factors. While no study has been able to quantify the relationships between all of these variables and rodent communities, individual studies have paired several key factors and shown significant effects (Drickamer 1976; Barry 1980; Stapp 1997; Elmhagen 2007).

The goal of the present study was to test differences in *Peromyscus* populations across various habitats to see if the diversity of food producing plants and the abundance of shelter-forming structures had an effect on late Spring habitat preference. The design of this experiment supports the multi-factor approach suggested by Hansson (1998). We hypothesized that more rodent activity would be found in areas with more shelter and higher food diversity than in areas with little shelter and low food diversity. We also hypothesized

that rodents would prefer eating underneath some form of shelter as opposed to eating out in the open.

Materials and Methods

The study was conducted from May 20th to May 25th, 2008 in the Landels-Hill Big Creek Reserve in Big Sur, California. Differences in rodent populations were measured between several habitat types: a mixed hardwood riparian area, two grasslands at varying elevations, and Coastal Live Oak (*Quercus Agrifolia*) woodlands. Two of these habitats were grasslands so that we could measure differences in rodent communities between low and high elevations. Our sampling sites were spaced along the Interpretive Loop trail starting at an elevation of 75m in the riparian treatment and ending at 365m in the upper grassland treatment.

The riparian treatment had an abundance of fruit and seed producing plants including California Blackberry (*Rubus ursinus*), Wild Strawberry (*Fragaria Virginiana*), Tanbark Oak (*Lithocarpus densiflorus*), Thimbleberry (*Rubus parviflorus*), California Bay Tree (*Umbellularia californica*), Big Leaved Maple (*Acer macrophyllum*), Fat Solomon's Seal (*Smilacina racemosa*), Star Lily (*Zigadenus fremontii*), and Coast Live Oak (*Quercus agrifolia*). Our sampling area was no more than 30m from Big Creek on any given day. The site was characterized by numerous fallen Redwoods (*Sequoia sempervirens*), a dense under story of Big Leaved Maple, Tanbark Oak, and California Bay Tree, and an abundance of ground-covering species such as Redwood Sorel (*Oxalis oregana*) and Western Sword Fern (*Polystichum munitum*). The abundance of trees with densely developed top stories such as Redwood, Doug Fir (*Pseudotsuga menziesii*), and Madrone (*Arbutus menziesii*) made for a cooler, shadier treatment than the grassland or Oak woodland treatments. Large boulders and Slate scree fields were common in the study site.

The lower and upper grassland treatments were dominated by mixed compositions of Wild Oats (*Avena fatua*), Ripgut Brome (*Bromus diandrus*), Barnyard Foxtail (*Hordeum leporinum*), California Brome (*Bromus carinatus*), Italian ryegrass (*Lolium multiflorum*), Purple and Yellow Bush Lupine (*Lupinus*

arboreus, *Lupinus albus*), and Chamise (*Adenostoma fasciculatum*). Most of the grasses were past their annual seeding period at the time of the study. The lower grassland treatment was at an elevation 110m on a gently sloped Southwest facing hill. The upper grassland treatment was at an elevation of 365m on a Southeast facing hill. Sparse Coyote Brush and slate scree fields were found throughout our grassland sites. Exposure to direct sunlight and strong coastal winds were defining characteristics of the floral compositions in these treatments.

The Oak woodland we sampled in was dominated by Coastal Live Oaks (*Quercus agrifolia*), and maintained smaller proportions of California Bay Trees, Spring Vetch (*Vicia sativa*), Red Huckleberry (*Vaccinium parvifolium*), Coyote Brush, Sticky Monkey Flower (*Mimulus aurantiacus*), and California Bunchgrass. Shade forming tree species such as Coastal Live Oak and California Bay were not densely clustered in this treatment, allowing more light to reach the under story. This made for a dense, clustered under story in areas where light could reach the forest floor. Fallen Oak leaves and acorn mast covered large portions of the study site.

In each treatment we used footprint tracking pads baited with dry cat food, paraffin wax chew blocks flavored with maple extract, and Sherman live-traps (H.B. Sherman Traps, Inc., Tallahassee, Florida, 8 by 10 by 25cm) baited with mixed nuts and seeds for five trapping nights. We randomly assigned these metrics between sheltered and unsheltered sites within each treatment. Each metric was moved after a trapping night to a new sampling area at least 15m from a previously used site to avoid sampling the same individuals multiple times (Wecker, 1963). Each treatment had fifteen track pads, fifteen chew blocks, and ten Sherman traps per night. Shelter was defined as any structure less than 0.5m from the ground that could shield a rodent from terrestrial and avian predators. This included fallen trees, low-lying shrubs, ground holes and burrows, bunches of grass, and rocky outcroppings. We sampled shelter forming structures in each treatment using four 5 x 1 m belt transects in North, South, East, and West bearings around each track pad for two days.

We counted the diversity of food-producing plants along the same transects used to sample shelter. We used a point intercept method to count the total diversity around each track pad in every treatment for two days.

We compared the proportion of sampling metrics with evidence of rodent activity to the proportion without evidence across all treatments and included the effects of shelter availability and diversity of food-producing plants with a series of one-way and two-way ANOVAs (JMP v. 7, SYSTAT v. 12, $\alpha=0.05$). Because the data were collected as proportions we used arcsine transformations before calculating differences.

Results

FOOTPRINT TRACKING PADS. We found significant differences in the proportion of sheltered track pads with evidence of rodent activity between almost every treatment ($F_{(3, 19)}=50.083, P < 0.0001$) (See Fig. 1). A post-hoc pair-wise comparison of means revealed that the only treatments not significantly different from each other were the upper grassland and the Oak woodland (post-hoc Tukey, $P = 0.27$). A two-way ANOVA revealed that the Oak woodland treatment was the only treatment to show a significant difference between the proportions of covered and uncovered track pads visited by rodents ($F_{(1,8)} = 9.52, P = 0.01$). We ran a one way ANOVA between the total number of sheltered and unsheltered track pads with signs of rodent activity across all treatments and found that there was no significant difference overall ($F_{(1, 38)} = 1.33, P = 0.26$).

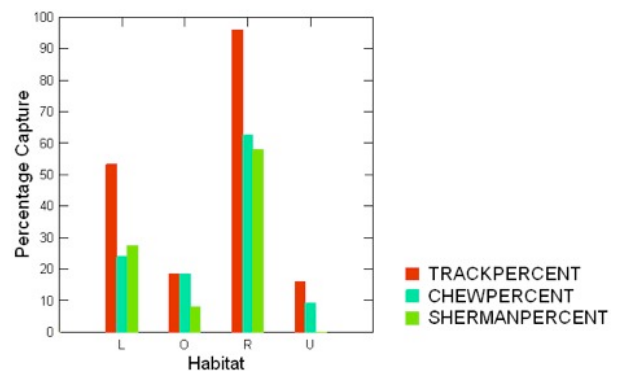


Figure 1. Overall success rates of each sampling metric across all treatments. L= Lower grassland, O=Oak woodland, R=Riparian, U=Upper grassland.

WAX CHEW BLOCKS. The riparian habitat was the only treatment to show a significant difference from all other treatments in the proportion of sheltered chew blocks with evidence of rodent activity ($F_{(3,13)} = 10.57$, $P < 0.0001$)(See Fig. 1). A two-way ANOVA revealed that the riparian area was the only treatment with a significant difference between the proportions of covered and uncovered chew blocks chewed by rodents ($F_{(1,8)} = 9.92$, $P = 0.01$). A one-way ANOVA between the total number of sheltered and unsheltered chew blocks with evidence of rodent activity across all treatments revealed that there was an overall significant difference between sheltered and unsheltered chew blocks ($F_{(1,38)} = 4.74$, $P = 0.03$).

SHERMAN LIVE TRAPS. There were significant differences in the proportions of sheltered Sherman traps that caught rodents between the riparian and Oak woodland treatments ($F_{(3,15)} = 7.85$, $P = 0.002$), and between the riparian and upper grassland treatments ($F_{(3,15)} = 7.85$, $P = 0.002$)(See Fig. 1). A two-way ANOVA revealed that the Oak woodland was the only habitat to show a significant difference between the proportions of covered and uncovered Sherman traps that caught rodents ($F_{(1,8)} = 16$, $P = 0.003$). A one-way ANOVA between the total number of sheltered and unsheltered Sherman traps that caught rodents across all treatments revealed that there was a significant difference between sheltered and unsheltered traps overall ($F_{(1,36)} = 3.91$, $P = 0.05$).

FOOD PRODUCING PLANTS. The diversity of food producing plants varied from a low of 4.7 ± 0.2 (mean, standard error) in the lower grassland to a high of 8 ± 0.2 (mean, standard error) in the riparian area (See Fig. 2). We found significant differences in the arithmetic mean of the diversity of food producing plants between almost every treatment ($F_{(3,116)} = 47.4$, $P < 0.0001$). A post-hoc pair-wise comparison revealed that the only treatments not significantly different were the upper and lower grasslands (post-hoc Tukey, $P = 0.93$).

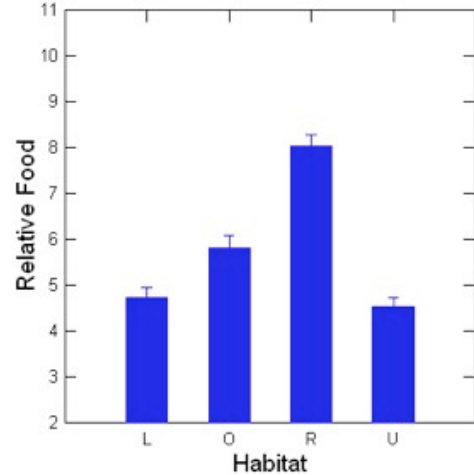


Figure 2. Mean diversity of food producing plants across all treatments.

COVER FORMING STRUCTURES. The number of cover forming structures ranged from a low of 5.7 ± 0.7 (mean, standard error) in the lower grassland to a high of 13.1 ± 0.7 (mean, standard error) in the riparian area (See Fig. 3). The only treatments without a significant difference in the arithmetic means of cover forming structures were the lower grassland and Oak woodland (post-hoc Tukey, $P = 0.71$), and the riparian and upper grassland (post-hoc Tukey, $P = 0.38$).

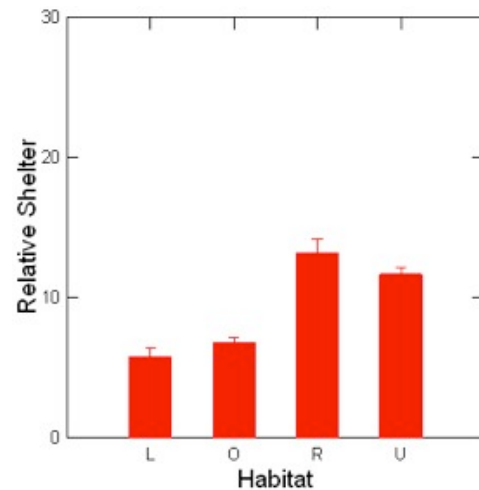


Figure 3. Mean abundance of shelter-forming structures across all treatments.

Discussion and Conclusion

Our findings indicate that the availability of shelter and the diversity of food may have an effect on rodent habitat selection. The riparian treatment yielded the most consistent rodent activity throughout the course of our

experiment, likely due to the abundance of cover (mean=13.1 +/- 0.7) and the relatively high diversity of food producing plants (mean=8 +/- 0.2). These results support the findings of Drickamer (1976), who found that *Peromyscus* food preferences are closely linked to home-site selection. The results also support the findings reported in several past studies. Barnum and Manville (1992) found that *Peromyscus* restrict their movements to paths that offer protection from predators searching by sight or sound, often using logs larger than 5cm for navigational aids and coniferous substrates over hardwood substrates to minimize rustling noise. Barry and Francq (1980) found that *Peromyscus* use trees, fallen branches and trunks, rocks, and rock piles for short-range orientation to their surroundings. Stapp (1997) found that densities and small scale movements of *Peromyscus* increased with increasing shrub cover. In sum, these studies indicate that the variables considered in the present study help explain why *Peromyscus* are more likely to be found in certain habitats, but also help point out that habitat use is a function of a myriad of factors.

Our riparian treatment had a diverse landscape of large fallen Redwoods, rock piles, dense under story vegetation, and consistent ground cover by Redwood Sorel. These characteristics in the midst of a relatively diverse food supply make it clear why there was a strong association between cover, food availability, and rodent activity.

These associations may not necessarily lead to the conclusion that increased cover and food diversity are definitive predictors of rodent habitat preference. There was no significant difference in the amount of cover between the riparian treatment and the upper grassland treatment, yet we found almost no sign of rodent activity in the upper grassland. There was no significant difference in the diversity of food producing plants between the lower and upper grassland, yet there was a marked difference in the amount of rodent activity in favor of the lower grassland treatment. These findings may indicate that some other factor—proximity to water, predation risk, or inter-specific competition—is driving habitat selection.

The lower and upper grasslands were characterized by thick accumulations of seed-rich grasses and abundant ground holes and

burrows within the grass. Rocky outcroppings and scree fields were also common in the grassland treatments. Possible explanations for the differences in rodent activity between the high and low grassland are that the holes and burrows we counted as cover were used by a different species (most likely Pocket Gophers (*Thomomys bottae*) and Ground Squirrels (*Spermophilus beecheyi*)), and that rodent activity we sampled at the lower grassland was from individuals active in the transitional zone between the riparian area and the grassland, making the sampling there non-representative.

Our results might have more explanatory power if we were able to replicate our treatments at different sites within the Big Creek Reserve. Due to time and resource limits we could only test differences between one set of treatments. Our experimental design involved moving every sampling metric at least 15m into a new sampling region after each trapping day, but this step alone was not enough to generate strong predictive data. This step was taken to ensure that we weren't sampling the same individuals within treatments, but without replicates of each treatment across other regions of the reserve it is difficult to generalize our findings for other habitats.

Our findings seem to contradict the results of several past studies. Clotfelter and Pederson (2007) found that acorn mast can be a strong predictor of rodent populations as soon as a year after a mast load. Although there was an abundance of acorn-producing Oaks in our Oak woodland treatment, we found little evidence of rodent activity. This inconsistency may be explained by Rehmeir and Kaufman (2004), who found that *Peromyscus* will travel up to 1,320m within three days in search of food or breeding opportunities. The Oak woodland treatment may have provided an abundance of easy to reach food, but the overall amount of cover was low, making exposure to predators an obvious risk. This site would best suit *Peromyscus* who could harvest a food load and transport it safely back to their home-site. It is possible that the abundance of acorns on the ground deterred rodents from our sampling metrics. Drickamer (1976) found that *Peromyscus* food searching and consumption patterns change from season to season, and that *Peromyscus* species with flexible food habits could shift their home site and travel through diverse habitats with ease. He also

found that young mice inherit predispositions to respond to certain foods, so rodents accustomed to seasonal gluts of acorns may not be attracted to other food sources (chew blocks and cat food, for example) during the time of year they are predisposed to hunt for acorns. This means it is possible we found very little activity in the Oak woodland because of seasonal fluctuations in the behavior of *Peromyscus* species.

Because our results are somewhat inconsistent with our overall hypothesis it is reasonable to conclude that our attempt to validate multi-factor approaches was at least partly successful, but did not include the range of factors necessary to fully explain rodent population dynamics. We narrowed down a few key variables—food diversity and shelter availability—as probable indicators of *Peromyscus* habitat preference in late Spring, but there are undoubtedly more to consider for future efforts.

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