

Small Mammal Populations and Ecology in the Kings River Sustainable Forest Ecosystems Project Area¹

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Abstract

Small mammals are important components of woodlands and forests. Since 1992, we have been studying several aspects of small mammal ecology in oak woodlands in western foothills of the southern Sierra Nevada. Assemblages of small, nocturnal mammal species are dominated by the brush mouse (*Peromyscus boylii*), California mouse (*P. californicus*), and dusky-footed woodrat (*Neotoma fuscipes*). Brush mice and California mice were found in highest numbers on sites with the densest vegetative cover. Populations of both species generally appeared to decline over the 4 years of study. Dusky-footed woodrats in our study sites were arboreal and often used specific travel paths to move about their home ranges. These behaviors made them difficult to capture with standard trapping grids, and we found that capture success was increased markedly by placing traps near their houses, either on the ground or in trees. Woodrats on our sites constructed several kinds of houses—some of which were difficult to detect—and house use was difficult to detect. We did not find a close correspondence between the numbers of woodrats and the numbers of their houses.

Small mammals, principally rodents, are important residents of a variety of habitats in the Kings River Sustainable Forest Ecosystems Project Area. They affect the composition and structure of their environment through consumption and distribution of foliage, plant seeds, and fungal spores. They also serve as food for larger predators, including species of concern, such as the northern goshawk (*Accipiter gentilis*), California spotted owl (*Strix occidentalis occidentalis*), marten (*Martes americana*), and fisher (*Martes pennanti*). Although existing literature includes some reports of small mammal assemblages in California's oak woodlands, information on species composition is lacking, even in relation to gross vegetation structure and particularly in relation to predator activity.

The initial objective of this study was to learn more about small mammal-spotted owl relations where the owls breed in riparian hardwood forests of the oak woodland zone of the western Sierra Nevada foothills. Critical methodical questions surfaced during the course of the work, however, some of which required answers before we could move forward effectively with studies of the mammal-owl relations.

Repeat live trapping on grids is commonly used to detect the presence and estimate the abundance of small mammals. If traps or trapping locations are biased, however, comparisons between sampling locations and species are probably unreliable. Different types of traps may bias trap success toward some species and against others (Laudenslayer and Fargo 1997, O'Farrell and others 1994, Willy 1985). The placement of traps within or outside of particular

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microhabitats, and their proximity to travel paths, may also bias trap success for some species. Reliable data on arboreal and fossorial species can be especially difficult to obtain because of uncertainties associated with identifying appropriate microhabitats and travel paths for setting traps.

Typically, dusky-footed woodrats (*Neotoma fuscipes*) (hereafter, woodrats) build stick houses in which to nest. These houses are conspicuous and often are used as an index of woodrat presence and abundance (Hamm 1995, Sakai and Noon 1993, Vogl 1967). Some studies have suggested, however, that woodrat numbers are poorly correlated with numbers of houses (Fargo and Laudenslayer 1999, Hamm 1995, Humphrey 1988).

Woodrats are often arboreal, but little is known about their activity patterns on the ground and in the trees. Studies of the ecology of nocturnal small mammals, such as the woodrat, have used various methods, such as mark-recapture, radio telemetry, and laboratory simulations. Although these approaches provide important ecological information, data on behavior and home-range use are often incomplete. For example, mark-recapture and telemetry data usually provide two-dimensional spatial information on animals. This is often incomplete, however, because many small mammals, including woodrats, are at least partially arboreal and thus use a third dimension.

Since 1993, we have been studying small mammal assemblages in three 2.25-ha oak woodland sites in eastern Fresno County, California. Efforts to date have examined rodent responses to five general questions: Are standard trapping grids for small mammals effective for estimating presence and abundance of nocturnal small mammals in these oak woodland habitats? Do the abundances of small mammal species vary in relation to habitat structure and through time? Do woodrats construct their visually obvious stick houses under all habitat structures examined? Can surveys of stick houses suffice to estimate relative abundance of woodrats? How do woodrats use their three-dimensional environment?

Study Sites

Our study sites are adjacent to Pine Flat Reservoir on the Kings River, Fresno County, California. All sites are within 2 km of the Kings River, and elevations range from 300-450 m. We chose three 2.25-ha study sites—Pine Flat, Camp 4-1/2, and Secata. Although all sites were classified as oak woodland, they differed markedly in the structure and composition of their vegetation (*table 1*).

Table 1—Percent of plant species 1-4 m and >4 m high at Pine Flat, Secata, and Camp 4-1/2 study sites (frequency is based on the species of tree or shrub providing the highest percentage of canopy cover over each survey point)

Species	Pine Flat		Secata		Camp 4-1/2	
	1-4 m	>4 m	1-4 m	>4 m	1-4 m	>4 m
Blue oak	4.0	16.7	50.0	68.4	4.3	21.7
California ash	4.0	4.2	—	—	13.0	4.3
California buckeye	—	—	5.6	5.3	17.4	13.0
California redbud	—	—	—	—	4.3	—
Foothill pine	—	20.8	—	—	—	—
Interior live oak	40.0	54.2	11.1	21.1	39.1	60.9
Manzanita	16.0	4.2	22.2	5.3	—	—
Poison oak	8.0	—	—	—	—	—
Redberry	8.0	—	—	—	4.3	—
Wedgeleaf ceanothus	20.0	—	11.1	—	17.4	—

The Pine Flat site, with 80 percent canopy cover, is characterized by a dense, shrubby cover dominated by interior live oak (*Quercus wislizenii*), wedgeleaf ceanothus (*Ceanothus cuneatus*), and poison oak (*Toxicodendron diversiloba*), with some manzanita (*Arctostaphylos* sp.), blue oak (*Q. douglasii*), and foothill pine (*Pinus sabiniana*). The Camp 4-1/2 study site, with 65 percent canopy cover, is dominated by interior live oak, blue oak, and California buckeye (*Aesculus californica*) and has a moderately open understory of poison oak and ceanothus. The Secata study site is relatively open—45 percent canopy cover—with patches of large trees dominated by blue oak and lesser amounts of interior live oak, California buckeye, and manzanita.

The largest oaks in bole and canopy diameter are at Secata, followed by Camp 4-1/2, and then Pine Flat. The tallest blue oaks are at Secata and the tallest interior live oaks are at Camp 4-1/2. Shrubs also vary in size across the sites with the largest poison oaks at Camp 4-1/2 and largest manzanitas at Secata (tables 2, 3, and 4).

Table 2—Mean bole diameters (cm) of trees and shrubs at Pine Flat, Secata, and Camp 4-1/2 study sites

Species	Pine Flat	Secata	Camp 4-1/2
Blue oak	13.4	34.0	18.8
California ash	2.7	1.2	10.2
Foothill pine	28.0	—	—
Interior live oak	8.3	20.6	15.0
Manzanita	5.5	11.7	—
Poison oak	1.1	1.0	3.5
Wedgeleaf ceanothus	3.6	5.5	5.4

Table 3—Mean crown diameters (m) of trees and shrubs at Pine Flat, Secata, and Camp 4-1/2 study sites

Species	Pine Flat	Secata	Camp 4-1/2
Blue oak	2.9	5.0	3.5
California ash	1.2	1.0	3.2
Foothill pine	4.5	—	—
Interior live oak	3.4	4.3	3.3
Manzanita	2.4	2.9	—
Poison oak	1.1	1.0	1.6
Wedgeleaf ceanothus	2.0	1.7	1.7

Table 4—Mean heights (m) of trees and shrubs at Pine Flat, Secata, and Camp 4-1/2 study sites

Species	Pine Flat	Secata	Camp 4-1/2
Blue oak	5.1	9.9	7.8
California ash	1.8	1.0	4.3
Foothill pine	10.0	—	—
Interior live oak	4.8	5.6	6.3
Manzanita	2.7	3.0	—
Poison oak	1.4	1.0	2.6
Wedgeleaf ceanothus	2.0	2.0	2.0

Methods

Effectiveness of Standard Trapping Grids

Initially, we randomly placed a 7 x 7 trap-station grid with 15-m spacing in each study site. We positioned one Sherman XLK (7.7 x 9.5 x 30.5 cm) and one Tomahawk 201 (12.7 x 12.7 x 40.6 cm)⁴ at each station in 1993. Because attempts to capture woodrats on the grid were essentially unsuccessful, we also set Tomahawk traps at woodrat houses, both on the ground and in trees. Traps set at houses on the ground were positioned along woodrat travel paths, if evident. Because this approach was successful, in 1994 and 1995 we set only one Sherman XLK at each grid station, in addition to Tomahawks at the houses. In 1995, we also used Shermans at houses on the ground and in trees for a short period to confirm that the woodrats were not avoiding this type of trap. In 1996, we concentrated the trapping adjacent to woodrat houses, based on questions that had arisen during the previous years of trapping. Nocturnal trapping was done in the spring (April-June) and in the late summer/early fall (September-November), and traps were checked in the early morning to reduce incidental mortality from long exposures to the weather.

Woodrat Stick Houses

Each study site was thoroughly surveyed for woodrat houses. In addition to houses found during initial establishment of study sites, newly built houses found over the course of the study were added to the inventory. Occupancy of individual houses was determined by observations at the houses and by the presence or absence of woodrat "sign." Direct observations of woodrats often indicated which houses were being used. For other houses, the presence of fresh vegetative cuttings, recently deposited fecal matter, and travel paths and house entrances clear of debris and spider webs demonstrated their current use. All houses found were classified as typical, intermediate, or atypical, based on stick content and nest location.

We did vegetation surveys in the spring of 1998 to compare house types with vegetation structure and composition on the sites. House information collected included house type, size, substrate, and cover. Site information included tree and shrub characteristics such as species, bole diameter, height, and percent cover; and ground cover attributes such as rock outcrops, logs, vegetation, and woody material.

Woodrat Behavior and Movements

To study the behavior and track the movements of woodrats, we set 10 Tomahawk traps at randomly selected, active woodrat houses each night of tracking. The first two adult or subadult woodrats captured were generally selected as the subject animals for the night. Each was equipped with a light-emitting diode (LED) package and dusted with fluorescent powder before release. Different colors of LEDs and fluorescent powder permitted discrimination of activity patterns between the two woodrats being observed (Fargo and Laudenslayer 1997).

Using audio cassettes, two observers (one per woodrat) verbally recorded the movements of the tagged woodrats throughout each night of observation, noting the time and duration of each detection of an animal, microhabitat at the animal's location (for example, tree canopy), characterization of the animal's location as a "travel route" or "destination," position of the animal (height above the ground and the azimuth and distance from its house), and the animal's activity (for example, walking, tail and foot tapping).

The evening following observations, woodrats were recaptured to remove the LED units, and their fluorescent powder trails were tracked. Information

⁴ Mention of trade names or products is for information only and does not imply endorsement by the U.S. Department of Agriculture.

collected included length of the powder trail within each microhabitat, characterization of sections of the powder trail as “travel route” or “destination,” position of the powder trail (height above the ground and the azimuth and distance from the woodrat’s house), and canopy cover over each powder trail.

Vegetation surveys will be done to compare each woodrat’s use of the microhabitat in its range with what is available. For each woodrat observed, vegetation information within a specified area around each house will be collected as described above for woodrat houses.

Results

Small Mammal Fauna

Nine species of small mammals were captured at the study sites, with most being active mainly at night (*table 5*). The brush mouse, California mouse, and dusky-footed woodrat were the most abundant mammal species captured. Six other species were captured but in low numbers. Despite their occurrence in similar habitats elsewhere in California, we have yet to capture any piñon mice (*Peromyscus truei*).

Effectiveness of Standard Trapping Grids

Both Sherman and Tomahawk traps successfully captured woodrats, but few were captured on trapping grids. Instead, most were captured at woodrat houses, either on the ground or in nearby trees (*table 6*). Both species of mice were captured more successfully in Sherman than in Tomahawk traps. This was especially true for brush mice, regardless of trap placement (*table 6*), because nearly all of them could escape through the Tomahawk trap’s mesh and the space around the door. Although results are inconclusive because of changes in trapping methods, capture rates for both mice may be better at traps associated with trees and woodrat houses (*table 6*).

Abundance of Small Mammals

Woodrat numbers varied markedly over the 4 years of the study, but the annual variability was not consistent among the study sites (*table 7*). Woodrats were most abundant at Pine Flat, which generally had the most immatures and the highest female to male ratio. This site also had the greatest canopy cover and

Table 5—Small mammal species captured in oak woodland study sites between 1993 and 1996

Common name	Scientific name	Activity period
Brush mouse	<i>Peromyscus boylii</i>	Nocturnal
California ground squirrel	<i>Spermophilus beecheyi</i>	Diurnal
California mouse	<i>Peromyscus californicus</i>	Diurnal
California pocket mouse	<i>Chaetodipus californicus</i>	Nocturnal
California vole	<i>Microtus californicus</i>	Nocturnal
Deer mouse	<i>Peromyscus maniculatus</i>	Nocturnal
Dusky-footed woodrat	<i>Neotoma fuscipes</i>	Nocturnal
Merriam’s chipmunk	<i>Tamias merriami</i>	Diurnal
Shrew	<i>Sorex</i> sp.	Nocturnal
Western harvest mouse	<i>Reithrodontomys megalotis</i>	Nocturnal

Table 6—Small mammal capture success [$\text{pct success} = 100 \times (\text{number captured}/\text{number of trap nights})$] compared by trap type and trapping location (numbers of trap nights: on grid—Shermans = 4,525, Tomahawks = 2,183; at houses on ground—Shermans = 52, Tomahawks = 2,106; at houses in trees—Shermans = 10, Tomahawks = 1,877)

Animal	On grid ¹		At houses on ground ²		At houses in trees ³	
	Sherman ⁴	Tomahawk ⁵	Sherman	Tomahawk	Sherman	Tomahawk
Brush mouse	17.46	1.05	26.92	0.09	70.00	0.11
California mouse	2.34	0.78	9.62	0.57	10.00	0.59
Dusky-footed woodrat	0.49	1.65	23.08	8.74	10.00	12.63

¹ Traps set in grid on the ground and in trees.

² Traps set at woodrat houses on the ground.

³ Traps set at woodrat houses in adjacent trees.

⁴ Sherman XLK trap.

⁵ Tomahawk 201 trap.

Table 7—Numbers of individuals captured on trapping grids from 1993 to 1996

Animal	Pine Flat				Secata				Camp 4-1/2			
	1993	1994	1995	1996	1993	1994	1995	1996	1993	1994	1995	1996
Brush mouse	55	59	54	15	47	8	15	6	104	37	50	24
California mouse	21	14	13	5	2	0	0	0	19	6	4	2
Dusky-footed woodrat	24	34	19	25	10	13	12	18	9	25	16	20

densest understory vegetation. Captures at Secata, which had the least canopy cover and sparsest understory vegetation, were approximately half the number at Pine Flat in 1993 and 1994, but increases at Secata and decreases at Pine Flat narrowed the difference in 1995 and 1996 (table 7).

Both brush mice and California mice appeared to be generally more abundant at Camp 4-1/2 and Pine Flat than at Secata, and our capture rate tended to show a general decline from 1993 to 1996, although a decline in brush mice at Pine Flat was evident only in 1996 (table 7).

Woodrat Stick Houses

Typical and intermediate woodrat houses were found in high numbers at Pine Flat, where they were primarily found on rock outcrops or at the bases of shrubs or trees (fig. 1). Atypical houses were prevalent at Secata, where most were associated with tree cavities or rock outcrops. Camp 4-1/2 had nearly equal numbers of the three house types, with many in tree cavities.

Individual woodrats used one to four houses at any given time, and this number often changed over time.

Woodrat Behavior and Movements

Results to date indicate that woodrats spent slightly more time in trees (45.27 percent) than on the ground (40.01 percent) (table 8). While on the ground,

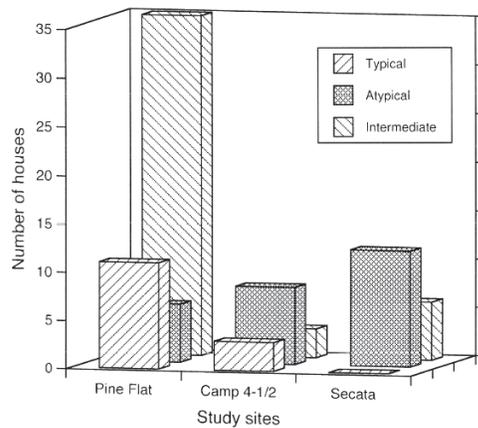


Figure 1—Numbers of typical, atypical, and intermediate woodrat houses at Pine Flat, Camp 4-1/2, and Secata study sites.

Table 8—Amount of time woodrats spent in various microhabitats in the three study sites combined

Microhabitat	Time (seconds)	Percent of time
Downed log	11	0.08
Downed woody material	336	2.44
Ground (unknown substrate)	3,222	23.43
Grass/forb	184	1.34
Rock outcrop	2,360	17.16
Shrub canopy	314	2.28
Shrub limb	999	7.27
Tree Bole	1,142	8.31
Tree canopy	1,227	8.92
Tree limb	3,955	28.76

however, they spent much of their time on rock outcrops. Whether remaining stationary or moving about, they usually stayed under dense canopy cover. They tended to use established travel paths along limbs, on rocks, or on the ground. Travel paths on the ground were characteristically clear of debris and vegetation.

Discussion

Effectiveness of Standard Trapping Grids

Our results indicate that capture success for different species of small mammals varies by trap type and trapping location. Effects of trap type on capture success were based, at least in part, on the ability of small mammals to escape from the traps and probably to some extent on selection of particular trap types by certain species and/or individuals. Similarly, Willy (1985) found that Tomahawk traps captured only woodrats, and at a higher rate than Shermans, whereas Shermans captured woodrats as well as other species. O'Farrell and others (1994) also found variation in capture success based on trap type, with wire mesh traps generally capturing more species and individuals of small mammals than Shermans in a variety of western habitats and geographic locations.

Variation in our trapping success in relation to trap location appeared to be associated with microhabitat affinities and travel corridors. Similarly, Murray (1957) reported varying trap success between parallel trap lines depending on

the structure and composition of vegetation, such that small differences in trap placement could seriously alter results. Differences in capture success could bias estimates of small mammal populations, thereby affecting decisions based on the assessments. It is important, therefore, to carefully evaluate methods to ensure that they are unbiased, or at least biased equally among the habitats and species being compared.

Kirkland and Griffin (1974), Price (1978), Sakai and Noon (1993), and Tietje (1995) all found that patchiness of the animals' habitat and their use of it influenced capture success. We captured woodrats more successfully in traps placed at their houses than on the trap grid, indicating that these animals, too, are not randomly distributed in their habitat.

Several species of *Peromyscus*, including the piñon mouse and the California mouse, often construct their nests within woodrat houses (Cranford 1982; Merritt 1974, 1978). Our findings, based on only a few trap nights, show that both brush and California mice are more successfully captured near woodrat houses. We did not, however, confirm cohabitation by searching woodrat houses for *Peromyscus* nests.

Abundance of Small Mammals

Although preliminary and without replication, our data suggest that these three study sites support different numbers of the three commonly captured rodent species. Secata, the most open site, supported the lowest numbers of all three species. Both Pine Flat and Camp 4-1/2, with denser vegetation, support higher numbers of all three species.

Only a few California mice were captured at Secata, and in only 1 year, suggesting that California mice are not typically resident there, that they are present only in low numbers, or that our trapping methods are ineffective for capturing California mice at this site.

Additional work is needed over a longer period to more clearly understand the relations between populations of these small mammals and the vegetation.

Woodrat Stick Houses

Woodrat houses have been described as conspicuous, conical piles of sticks with many passageways and compartments (Ashley and Bohnsack 1974, Cameron 1971, English 1923, Gander 1929, Linsdale and Tevis 1951). Some observers have described "atypical" houses built in hollow limbs and rock crevices (Davis 1934, Gander 1929), but these are usually mentioned only briefly and apparently are considered to be uncommon.

The presence of numerous atypical and cryptic woodrat houses in our study sites, however, suggests potentially large biases in estimates of woodrat populations if based on house counts. The Key Largo woodrat (*Neotoma floridana smalli*), for example, is generally known for its large stick houses, but it is also known to reside within rock crevices in some habitats, thereby escaping detection during house-count surveys (Barbour and Humphrey 1982). In spite of this problem, some observers have based population estimates on counts of houses (Hammer and Maser 1973, Sakai and Noon 1993, Vogl 1967), either assuming that each active house contained one woodrat (Vestal 1938, Vogl 1967) or applying some standard number of houses per woodrat across the entire study area. Not all locations may include cryptic houses, however, so investigators need to become familiar with all house types characteristic of their study site and to search accordingly for all houses before using house counts to estimate population size.

Woodrats in our study sites also differed in the number of houses they used, and that number changed over time. English (1923) reported that dusky-footed

woodrats near Corvallis, Oregon, were familiar with several houses in their home range, and Cranford (1977), in a study of radio-tagged woodrats, found that they resided within a house for an average of 34 days. When a home range contained only one house, it tended to be larger than average, and the woodrat resided in it for a longer period. Such variation in house use may also bias population estimates when based on one woodrat per house. In some seasons, more than one woodrat may reside in a house, especially during spring and summer when males reside with females for breeding (Donat 1933, English 1923) and when females are nursing young (Linsdale and Tevis 1956). Without further study, we consider it risky to use counts of woodrat houses for much more than determining woodrat presence (but not absence!).

Woodrat Behavior and Movements

Woodrats in our study sites appear to restrict their travel routes to limbs, rocks, and cleared paths that likely expedite their movements and reduce the noise produced. These travel paths are also generally beneath dense canopies. This behavior probably aids in reducing predation. As our research progresses and questions are answered about woodrat ecology (for example, habitat requirements), management decisions can be better informed regarding this species and others that depend upon it for their sustenance.

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