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USE OF LOGS WITHIN HOME RANGES OF CALIFORNIA RED-BACKED VOLES ON A REMNANT OF FOREST

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We used radiotelemetry to investigate patterns of space use of the California red-backed vole (*Clethrionomys californicus*) on a remnant of forest in southwestern Oregon. We radiotracked four voles and mapped the locations of logs of varying decay classes within the home range of each vole. Of the collective locations of voles, 98% coincided with downed logs even though logs covered only 7% of the areas of estimated home ranges. Furthermore, voles used logs in later stages of decay significantly more often than logs in earlier stages of decay. This high use of decayed logs suggests that decayed logs are a critical component of suitable habitat for voles.

Key words: *Clethrionomys californicus*, vole, home range, decayed logs, remnant of forest, coarse and woody debris, radiotelemetry, forest remnant

California red-backed voles (*Clethrionomys californicus*) have received special attention for their role as dispersers of mycorrhizal fungi, which are critical symbionts for growth of forests (Harris, 1984; Maser et al., 1978a, 1978b). Trapping studies have shown California red-backed voles to be rare in clearcuts and common in old-growth forest (e.g., Gashweiler, 1970; Maser et al., 1978a; Tevis, 1956), where they are strongly associated with logs (Doyle, 1987; Hayes and Cross, 1987). No published estimates of home range are available for this species.

In terms of spatial distribution and patterns of habitat use, there are limitations to what trapping alone can discern (Desy et al., 1989). For example, an animal in a trap indicates only that it has visited the area, but does not reveal the intensity of use during the trapping period (Kikkawa, 1964). Also, baited traps potentially can draw animals away from areas of normal use, and high mortality rates in traps can make it difficult to study animals for sufficient periods of time to gain long-term information about patterns of space use.

In southwestern Oregon, California red-

backed voles disappear from clearcuts surrounding remnants of forest and are significantly less likely to be trapped near the edge of the remnants than in the interior (Mills, 1993). Given the ecological importance of this species, and the presumed importance of coarse, woody debris, we used radiotelemetry to follow red-backed voles on one of these remnants of forest; by conducting the study on a remnant completely surrounded by clearcuts, we incorporated into our assay of microhabitat and space use the conditions of fragmented habitat rapidly becoming the norm for many vertebrates of the forests of the Pacific Northwest. In addition to obtaining the first radiotelemetric estimates of home-range size for this species, our objectives were to provide a test of two null hypotheses: voles do not preferentially use downed logs; use of logs by voles is random with respect to the state of decay of logs.

MATERIALS AND METHODS

All voles were captured and radiotracked on a 2.5-ha remnant of forest that was surrounded by clearcutting conducted between 1964 and

1987; a minimum of 100 m separates the study site from other forest. The site was located in the northern region of the Klamath Mountains of the Siskiyou National Forest ca. 5 km W Oregon Caves National Monument, at an elevation of 1,342 m, and with a west-facing slope of 32°. Overstory was dominated by old-growth Douglas fir (*Pseudotsuga menziesii*).

We captured voles in Sherman live traps baited with oat groats, sunflower seeds, and apple (Mills, 1993). Because the transmitters (AVM Electronics, Livermore, CA) weighed 2.4 g, we radiocollared only voles weighing >24 g. After observing the collared voles for 1 h to check for adverse effects, we released the voles at the sites of capture and waited at least 1 day before radiotracking. We do not believe the radiocollars negatively affected foraging activities of voles because the three voles recaptured alive during the study period (16, 36, and 39 days after radiocollaring) were heavier than when initially captured.

Radiotracking was conducted 13 August–15 September 1991, using a hand-held, three-element, yagi antenna. From preliminary sessions of radiotracking, we determined the periods of greatest activity of voles to be 2000–0300 h. Subsequent tracking effort was concentrated during this period, and observations were recorded for each vole at ca. 50-min intervals, with an average of four observations recorded for each animal during each session of radiotracking.

Voies were located by first obtaining an initial signal at 30–50 m away. We then approached from one direction to within 5 m, stepped back 5–10 m, and then approached from another direction to obtain a roughly triangulated location. Final locations were determined by removing the antenna and using the end of the coaxial cable to make the final reading. In test trials, we found error with this method to be <1 m. Observations for each vole were analyzed by both minimum-convex-polygon and harmonic-mean estimators of home range; harmonic-mean estimates are given as the 95%-utilization distribution (Ackerman et al., 1990).

To minimize disturbance by the observer during nighttime sessions of radiotelemetry, each location of an observation was flagged, but not otherwise disturbed; the next day we mapped the locations onto a 1-m graduated grid. At the same time, we assigned each location to either an “under logs” or “not under logs” group based on the

exact telemetric position. “Logs” were defined as any coarse, woody debris >10 cm in diameter, including branches, sloughed-off bark, and stumps.

A test of preferential use of logs requires not only a measure of the number of observations of voles under logs, but also availability of logs. To determine availability of coarse, woody debris to voles, we mapped the exact placement and length of all logs within each vole’s home range. Based on six line transects of 20-m length randomly placed across the site (Mills, 1993), we calculated mean widths of logs and a 95% confidence interval. Total area covered by logs on a home range was calculated by summing, for logs mapped on each home range, the measured length times the upper value from the 95% confidence interval for width. By using an upper estimate for the area of logs, we made our test conservative by making it more difficult to reject the null hypothesis that the proportion of observations of voles under logs is not greater than the proportion of the home range covered by logs.

In addition to measuring the area covered by logs in the home ranges, we assigned each log to a decay class (Sollins, 1982). Decay classes ranged from I through V; class I included undecayed logs with intact bark and branches, whereas class V logs were barely discernable mounds of rotten, moss-covered heartwood.

The two hypotheses regarding space use were tested with chi-square goodness-of-fit tests. Specifically, the proportion of observations of voles under logs was compared to the expected proportion based on the area of the home range covered by logs, and the frequencies of observations of voles under logs of various classes of decay were tested against expected frequencies based on decay classes of all logs present on the home ranges of voles.

RESULTS AND DISCUSSION

Although eight voles were radiocollared, loss and malfunction of collars resulted in adequate observations (>17) for analysis of home ranges of four voles: two males and two females (Table 1). Sixteen sessions of radiotelemetry yielded 134 locations for these four voles. All locations were confined to the remnant of forest, corroborating trapping data from this and nearby remnants,

TABLE 1.—Estimates of home-range size and use of logs for four California red-backed voles in southwestern Oregon. The relative number of observations of voles corresponding to logs ("under logs") and in open areas ("not under logs") can be compared to the relative area of the home ranges covered by logs.

Animal number	Sex	Number of observations	Size of home range		Number of observations		Coverage by logs ^b	
			MCP ^a	HM ^a	Under logs	Not under logs	Logs present	Logs absent
1	Male	33	3,418	3,440	33	0	205	3,213
2	Female	18	927	1,374	16	2	46	881
3	Female	37	606	1,123	37	0	48	558
4	Male	46	1,437	2,573	45	1	155	1,282

^a MCP = minimum-convex polygon (m²); HM = 95% utilization distribution of harmonic-mean estimator (m²).

^b Square meters of minimum-convex-polygon home range covered or not covered by logs.

which found that California red-backed voles rarely used clearcuts surrounding remnants (Mills, 1993).

Sizes of home ranges estimated by minimum-convex polygons ranged from 606 to 3,418 m², and sizes of home ranges based on harmonic means ranged from 1,123 to 3,440 m² (Table 1). Minimum-convex-polygon estimates of size reached asymptotes at ca. 21 locations/animal. Both home-range estimators yielded larger home ranges for male voles. This sex-specific difference in sizes of home ranges agrees with other studies which found home ranges of males of other species of *Clethrionomys* to be larger than those of females (reviewed by Bondrup-Nielsen and Karlsson, 1985; Kikkawa, 1964). The home ranges of one female and one male overlapped slightly throughout the period of study. Tests for autocorrelation using the method of Swihart and Slade (1985) proved positive only for vole 3 ($T^2/R^2 = 0.9479$, $P < 0.05$). In addition, movement of voles between extremes of their home ranges between successive observations indicates that recorded points were largely independent.

The relationship of these four voles to logs, particularly more decayed logs, was striking. Within the home ranges, voles used logs significantly more than expected by chance ($\chi^2 = 1,664$, $d.f. = 1$, $P < 0.001$). Of

the 134 observations recorded, 131 (98%) coincided with downed logs even though logs covered only 7% of the collective minimum-convex-polygon area (Table 1). Observations of voles coincided with downed logs in both central and peripheral regions of the home ranges (Fig. 1). There were no observable differences in use of logs during periods of activity and inactivity.

We assumed that our presence did not cause the voles to run beneath logs, resulting in an exaggerated relationship between voles and logs. Although we did not test for such a confounding factor, we did not observe any movements of voles during the triangulation process that would indicate this was a problem. Furthermore, the procedure we employed for locating voles was similar to that used by Ostfeld (1986) in which he demonstrated that movement of California voles (*Microtus californicus*) in coastal-prairie habitat was random with respect to his location. Finally, previous trapping studies corroborate the relationship of voles to logs found in the present study (Doyle, 1987; Hayes and Cross, 1987).

Although it has been suggested that voles particularly prefer late-stage rotting logs (e.g., Doyle, 1987), actual evidence is scanty. Our results give strong support for such a relationship. Although logs of all decay classes were present on home ranges of voles in a

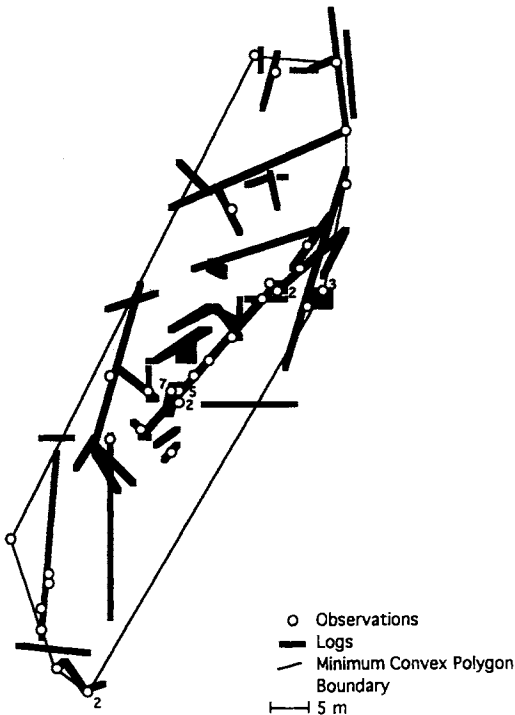


FIG. 1.—Logs and telemetry observations in the home range of vole 4 (numbers indicate multiple observations at one location).

roughly normal distribution, voles were found significantly more often than expected under logs in later stages of decay ($\chi^2 = 47.5$, $d.f. = 4$, $P < 0.001$; Fig. 2). Particularly striking is the fact that on average, less than one-half of the logs in decay classes I and II were associated with observations of voles (11 observations/27 logs), whereas logs in classes IV and V had associations of almost two observations of voles for each log (79 observations/45 logs).

It is possible that the strong relationship between voles and more decayed logs in this study was accentuated by the time of year. During the dry summer months in the Coast Ranges, California red-backed voles probably subsist on cached sporocarp supplies, as the abundance of hypogeous sporocarps of mycorrhizal fungi is at a yearly low, while sporocarp consumption by voles is at a yearly high (Ure and Maser, 1982). Increased moisture tends to increase abundance of

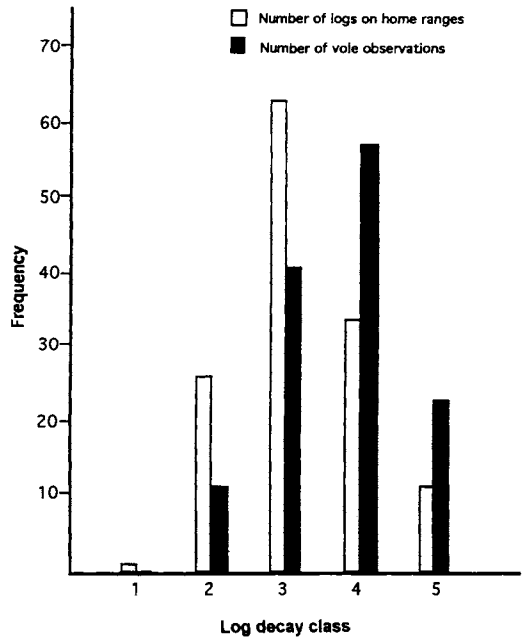


FIG. 2.—Availability and use of logs according to decay class on the home ranges of four California red-backed voles in southwestern Oregon.

mycorrhizal fungi (Slankis, 1974), and decaying logs are well-known reservoirs of moisture (Franklin et al., 1981). The caches of sporocarps important to voles in the summer are associated with decaying logs at our study site (D. A. Clarkson and L. S. Mills, pers. obser.), which would likely contribute to activity of voles around these logs during dry periods.

The critical role of the California red-backed vole in the ecology of forests in the Northwest has been intimated from its role as a consumer of hypogeous sporocarps of mycorrhizal fungi (Hayes et al., 1986; Ure and Maser, 1982). Because these sporocarps are not wind-dispersed, small-mammal mycophagy is critical for dispersal. Trees, in turn, require mycorrhizal networks for exchanging nutrients and water in soil for photosynthates (Maser et al., 1978a). The interdependence of these components of the forest ecosystem in the Northwest implies that loss of one component could jeopardize others (Wilcox and Murphy, 1985). The

presence of downed logs, which generally are removed from fire-treated clearcuts, may aid in the re-establishment of California red-backed voles in regenerating forest. In any case, it seems likely that retention of logs in later stages of decay is essential to the continued persistence of California red-backed voles.

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