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Habitat Associations of California Red-backed Voles in Young and Old-Growth Forests in Western Oregon

Abstract

Because of the reduction of old-growth forests in the Pacific Northwest, and the controversy over timber management practices, patterns of animal abundance in young and old forests have gained attention. Results from previous studies on California red-backed voles (*Clethrionomys californicus*), however, have been inconsistent; unmanaged young stands were reported to have similar abundance of California red-backed voles as old-growth stands, while other studies suggested that numbers are higher in older stands. We compared California red-backed vole abundance in 5 young (30-60 yr old) and 5 old-growth (>400 yr old) Douglas-fir (*Pseudotsuga menziesii*) stands in the central Oregon Cascade Range during spring 1988-1991. The average number of California red-backed voles captured was consistently higher in old-growth stands ($\bar{X}$ ± SE, 8.4 ± 1.9) than in young stands (2.0 ± 0.8) during the 4 years of the study; 80% of the voles captured in the 5 young stands were from one unmanaged, fire regenerated stand. Our results support hypotheses of lower abundance of California red-backed voles in managed young forests than in unmanaged older forests. Providing components of old-growth forests, such as deep organic-soil depths, residual large trees and snags, and coarse woody-debris in managed young stands will likely increase their potential as suitable habitat for California red-backed voles.

Introduction

California red-backed voles (*Clethrionomys californicus*) are endemic to forests in western Oregon and northwest California (Alexander and Verts 1992). Some investigators suggested that California red-backed voles occur more frequently in mature closed-canopy forests with little understory development, and select for habitat that has significant amounts of coarse woody debris (Tevis 1956, Gashwiler 1959, Maser 1981, Doyle 1987, Gomez 1992), or greater food resources (hypogeous fungi, Ure and Maser 1982). Other investigators did not detect a difference in abundance of California red-backed voles between young and older forests (Aubrey *et al.* 1991, Corn and Bury 1991, Gilbert and Allwine 1991). However, young stands examined in the latter studies were naturally regenerated after fire, and the authors suggested that California red-backed voles may respond differently to managed second-growth stands that originated from clear-cuttings.

The controversy over extensive harvesting of Pacific Northwest forests (e.g., Thomas *et al.* 1988, Booth 1991) has led to extensive investigations of wildlife associated with older forests (e.g., Ruggiero *et al.* 1991). In this paper, we report our findings on the abundance and habitat associations of California red-backed voles in young and old-growth forests in the Cascade Range in central Oregon and discuss our findings in relation to previous studies of this species in unmanaged (natural) young stands.

Methods

We selected 5 young (30 to 60 years old) and 5 old-growth (>400 years) forest stands in the Blue River and McKenzie Ranger districts, Willamette National Forest, located in the central Oregon Cascades. Stands were dominated by Douglas-fir (*Psuedotsuga menziesii*) and western hemlock (*Tsuga heterophylla*). Stands were between 375 and 900 m elevation; slopes ranged from 10 to 60%. Climate in this region is characterized by mild, wet winters and warm, dry summers (Franklin and Dyrness 1973).

Four of the 5 young stands resulted from planting after clear-cutting; the fifth stand was naturally regenerated after a wildfire in 1918 (Teensma 1987). Three of the 4 stands that were planted following harvest were broadcast burned. The records for the fourth stand were incomplete. Silvicultural treatments of the 4 planted stands varied from intensive clear-cuttings with no residual large trees to those with some large trees retained (1.2 trees >79 cm diameter at breast height (dbh)/ha). The 5 old-growth stands were not logged previously except for small areas where a few individual trees had been salvaged; <5% of the basal area was removed. Details of stand histories are given in Rosenberg and Anthony (1993).

We established 10 X 10 live-trapping grids (3.2 ha) in each of the 10 stands. Each grid consisted of 100 Sherman live-traps (7.6 X 7.6 X 25.4 cm) spaced at 20-m intervals. Traps were baited with oats and peanut butter and set for 8 consecutive nights on 2 grids (1 old and 1 young) simultaneously for 5 trapping sessions each year during April to June, 1988-91. Captured California red-backed voles were toe-clipped for individual recognition and released.

We used nested circular-plots modified from Spies *et al.* (1988) to sample vegetation at 80–120-m intervals centered at trap stations; a total of 329 plots was sampled (approximately 33 per stand). Samples were collected during July–September 1988 from a 13-ha grid that included the trapping grids; this larger grid was used in studies of northern flying squirrels (Rosenberg and Anthony 1992). In order to reduce the number of vegetation variables originally measured (Rosenberg 1991), we selected those that we believed to be most important biologically to California red-backed voles. Numbers of large (≥ 50 cm diameter) trees, snags (≥ 1.5 m tall), and fallen trees (coarse woody debris) were recorded in 0.12-ha (20-m-radius) plots centered at 40-m intervals. Smaller trees (5-49 cm dbh) and coarse woody debris (25-49 cm diameter) were measured in 0.05-ha (12.6 m-radius) plots. We recorded the species and diameter at breast height (dbh) of live trees and snags; with coarse woody debris, we recorded the diameter (mean of the 2 ends), % bark remaining, and the percent of the surface that was charred. Volume of coarse woody debris (m^3) was computed for fallen trees ≥ 25 cm in diameter (Rosenberg 1991). We computed the proportion of the coarse woody-debris volume that was considered in a late decay state (no bark remaining) and the proportion of the number of observations of coarse woody-debris that was not charred.

Percent cover of understory plants, ground cover of herbs, fine woody debris (< 25 cm diameter), and moss was estimated visually in 8 1-m^2 quadrats within the circular plots. These were placed 4 and 7 m from the trap station along each cardinal direction. We calculated the mean of the values from the 8 quadrats and used these data in our analyses. In the same quadrats, organic soil depth ≤ 10 cm (including litter) was measured to the nearest 1 cm; greater depths were recorded as > 10 cm. The median value of soil depth from the 8 samples was used in the analyses.

Statistical Analyses

We compared the number of voles captured between stand age-classes with a split-plot analysis of variance (Sokal and Rohlf 1981:394) with stand nested within stand age-class and year (where appropriate) as the error term. We used the number of individuals captured as a measure of relative abundance. This method was used rather than estimating actual abundance from mark-recapture data because numbers of captures and recaptures were low in young stands. The number of individual voles captured was log transformed.

Relationships of vole abundance to habitat characteristics were evaluated with regression and principal components analyses (PCA). Because of the correlated nature of the habitat variables, we derived a new set of uncorrelated variables from the habitat values from each stand using PCA. We examined the relationship of habitat (using the first principal component scores) and California red-backed vole abundance (total of the 4 years, log transformed) with linear regression analysis. We compared the proportion of the volume of coarse woody-debris without bark and the proportion of coarse woody-debris that was not charred between stand age-classes with Student's *t*-test after arc sine square-root transformation. The mean and standard error presented were those prior to transformations.

Results

We captured 209 individual California red-backed voles during the 4 years of the study. There were significantly more voles captured in old-growth (n = 168, 80.4%) than in young (n = 41, 19.6%) stands ($F_{1,8} = 7.8$, $P = 0.02$). There were no voles captured in 3 of 5 young stands in each year (Figure 1), and voles were never trapped in 1 young stand (Y-4, Figure 2). Most captures in young stands (33 of 41, 80%) occurred in 1 grid (Y-1, Figure 2). There was no consistent trend in abundance during the 4 years of the study; in a given year, the number of voles increased in some stands, but decreased in others (Figure 1). Therefore, year was not a statistically significant variable in explaining patterns of vole abundance ($F_{3,24} = 1.7$, $P = 0.18$).

Habitat characteristics differed between stand types; young and old- growth stands were separated primarily along the first principal component (Figure 3). The unmanaged young stand (Y-1), which had originated from wildfire, was more similar to the old-growth stands than the managed second-growth stands (Figure 3). The first principal

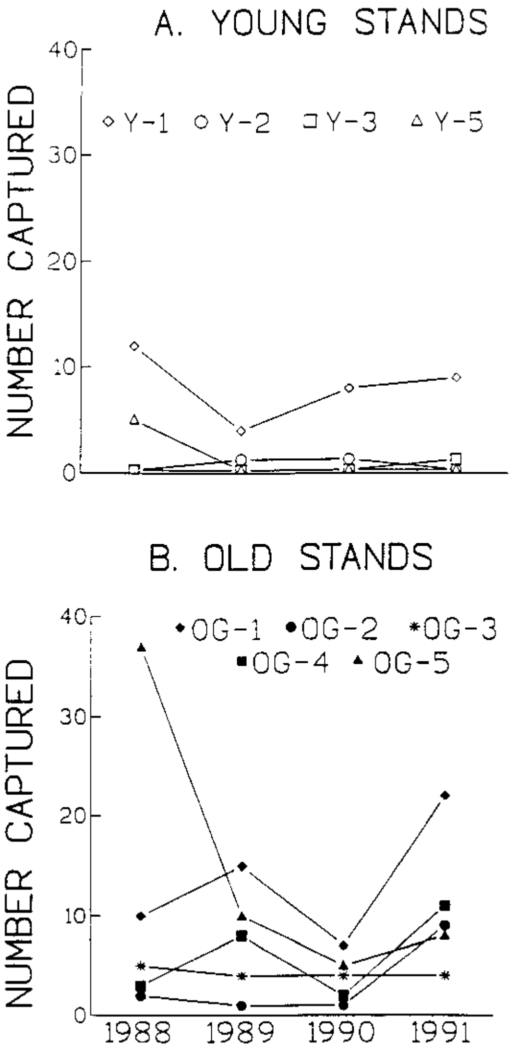

Figure 1. Fluctuation of number of individual western red-backed voles captured in (A) 4 young (Y) and in (B) 5 old-growth (OG) stands during spring 1988-1991, Willamette National Forest, Oregon. Not shown is the 1 young stand (Y-4) in which we did not capture any voles.

component explained 44% of the variation of the measured habitat variables among stands; the second added 21%, and each additional PC added ≤10%. The first principal component represents a gradient of increasing density of large trees and large snags, and increasing organic soil depth; the second PC was most related to increasing shrub cover (Table 1). California red-backed vole abundance (log transformed) was correlated positively with the first principal component scores ($r = 0.84$, $P = 0.003$, $n = 10$; Figure 4).

Although there were large volumes of coarse woody-debris in young and old-growth stands (Rosenberg and Anthony 1992), a higher proportion seemed further decayed (lacked bark) in young (0.71 ± 0.04) than in old-growth stands (0.37 ± 0.03; $t = 6.1$, df = 8, $P = 0.0003$). However, a higher proportion of the observations of coarse woody debris in old-growth stands (0.95 ± 0.02) did not have evidence of char compared to coarse woody-debris in young stands (0.36 ± 0.07; $t = -7.7$, df = 8, $P = 0.0001$).

Discussion

Although recent studies indicated that California red-backed voles were as abundant in unmanaged young stands as in old-growth stands (Aubrey *et al.* 1991, Corn and Bury 1991, Gilbert and Allwine 1991), this result was not found in managed young stands in our study. We found significantly higher numbers of voles in old-growth compared to managed young stands, with a paucity of voles in the latter type. We did, however, find similar California red-backed vole abundances in the 1 fire-regenerated young stand (Y-1) as in the old-growth stands. Although there are currently many sites where California red-backed voles reach high abundance (e.g., in old growth and unmanaged [natural] young stands), they will likely become less abundant as the forested landscape continues to change from old growth to managed young forests through intensive timber harvesting activities.

Two of the 3 habitat variables (density of large trees and snags) that characterized the first PC were those usually associated with old-growth Douglas-fir forests (e.g., Franklin and Spies 1991). These two variables also characterized older stands in Corn and Bury's (1991) study; however, they found no difference in vole abundance between young and older forests. Thus, California red-backed vole abundance may not be related directly to density of large trees and large snags. Forest floor conditions seem to be more predictive of high California red-baked vole abundance, which is not surprising considering their natural history: they nest in underground burrows or under debris (Stephens 1906:124), often forage in the organic layer of soil (Maser 1981), and use coarse woody-debris for cover, as travel corridors, and as a source of sporocarps of mycorrhizal fungi (Hayes and Cross 1987, Tallmon and Mills 1994).

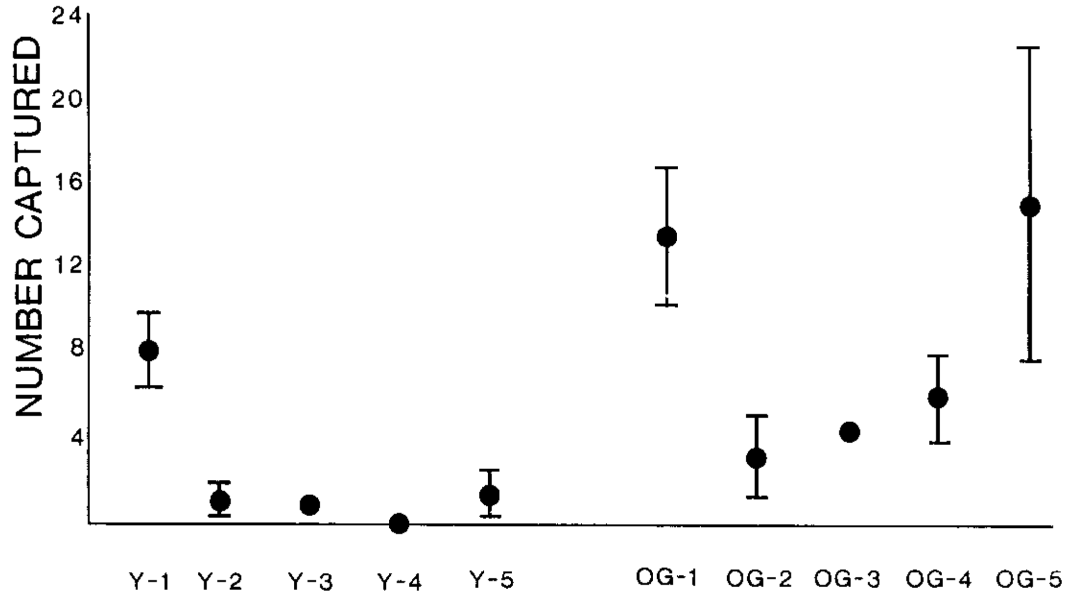

Figure 2. Number of individual western red-backed voles (X ± SE) captured in young (Y) and old-growth (OG) stands during spring 1988-1991. The SE represents the yearly variation in number of individual voles captured.

The presence of a deep organic soil layer may add significantly to forest-floor conditions for California red-backed voles. Our findings suggest that this is an important component in providing suitable habitat. Similarly, organic soil depth was correlated positively with California red-backed vole abundance in the Oregon Coast Ranges (Gomez 1992). Past fire histories of stands may be related to current organic soil depths. Prescribed broadcast-burning can reduce organic soil depth by consuming organic matter, volatizing nutrients, and increasing erosion (McNabb and Cromack 1990, McNabb and Swanson 1990). In our study, depth of the organic soil layer in the young stands that were broadcast burned averaged 2.4 cm, while depth in the old-growth stands averaged 7.9 cm (calculated from values in Rosenberg and Anthony 1992). California red-backed voles were captured infrequently in these young stands. The 1 young stand (Y-1) in which we consistently found voles had originated from a low intensity wildfire (Teensma 1987); the average organic soil depth in this stand was 7.8 cm. The old-growth stand (OG-2) that had low numbers of voles also had low organic soil depth (4.9 cm), probably due to erosion from the steep slope (60%) of the stand. Shallow organic soil depth may help explain why California red-backed voles are not common in recent clear-cuttings following prescribed burning (Tevis 1956, Gashwiler 1959, 1970; Hooven and Black 1976).

Although coarse woody-debris has been suggested to contribute significantly to California red-backed vole abundance (Tevis 1956, Maser 1981, Doyle 1987, Gomez 1992), our findings suggest that other attributes of the forest-floor may be more significant biologically. All of the young stands in our study had large volumes of woody debris (Rosenberg and Anthony 1992), yet red-backed voles were generally absent. Research on specific use of coarse woody debris by California red-backed voles demonstrated that large logs are used selectively over smaller logs (Hayes and Cross 1987), and that an increased decay state of coarse woody-debris was selected over less decayed woody debris (Tallmon and Mills 1994). These conditions seem to have been met in the young stands we examined, although the influence of char on quality of coarse woody-debris for California red-backed voles is unknown. Forest-floor conditions, including coarse woody debris (Tallmon and Mills 1994) as well as depth of organic soil, are likely to be critical components of the forest for providing high quality habitat for California red-backed voles.

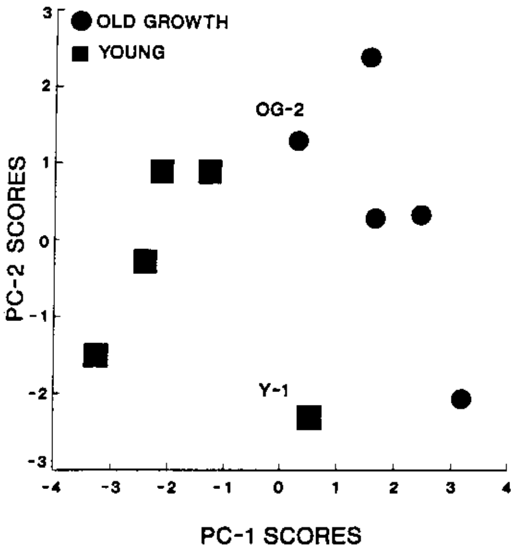

Figure 3. Young and old-growth stands plotted along the first 2 principal components. The first PC represents a gradient of increasing density of large trees and large snags, and increasing depth of the organic soil layer. The second PC was related most heavily to increasing shrub cover. Y-1 and OG-2 are the young and old-growth stands, respectively, that had mean number of voles captured most different from the other stands within their respective stand age-class.

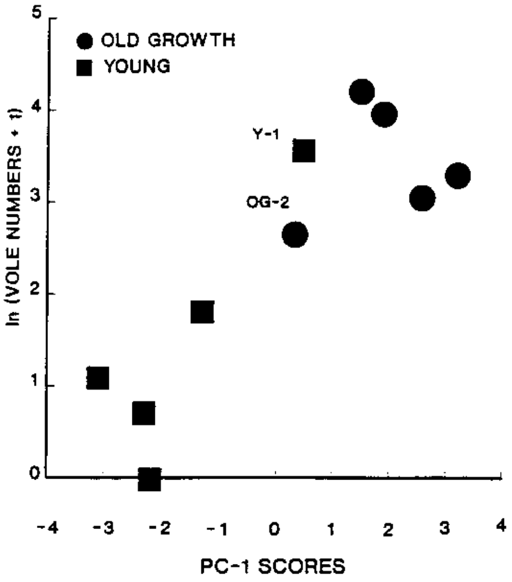

Figure 4. Relationship of the total number of individual voles captured (log transformed) during the 4 years (1988-1991) in each stand with the scores from the first principal component (PC-1). Y-1 and OG-2 are the young and old-growth stands, respectively, that had mean number of voles captured most different from the other stands within their respective stand age-class.

TABLE 1. Relationship (Pearson correlation coefficients, r) of habitat variables with the first 2 principal components.

Variable	Principal component 1 r	Principal component 1 P[1]	Principal component 2 r	Principal component 2 P
Herb cover	0.33	0.3	−0.13	0.7
Fine woody debris cover	0.71	0.02	−0.57	0.08
Moss cover	0.47	0.17	0.59	0.07
Shrub cover	−0.13	0.7	0.90	0.0003
Organic soil depth	0.89	0.0006	0.11	0.76
Tree diameter CV[2]	0.65	0.04	0.50	0.14
Large conifer trees	0.96	0.0001	0.06	0.86
Small conifer trees	−0.74	0.01	−0.51	0.13
Small deciduous trees	−0.65	0.04	0.42	0.23
Large snags	0.82	0.004	−0.37	0.29
Coarse woody debris	0.41	0.24	−0.004	0.99

[1] Significance level.

[2] Coefficient of variation of diameter at breast height (dbh).

California red-backed voles may contribute significantly to dispersal of mycorrhizal fungi (Maser *et al.* 1978, Ure and Maser 1982, Hayes *et al.* 1986), and are included in the diet of many avian and mammalian carnivores (reviewed in Alexander and Verts 1992). Because of these relationships, their absence in forests may affect ecological processes. Retaining or managing for components of old-growth forests, such as deep organic-soil depths, residual large trees and snags, and coarse woody-debris (McComb *et al.* 1993) may make managed young stands more suitable for California red-backed voles.

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