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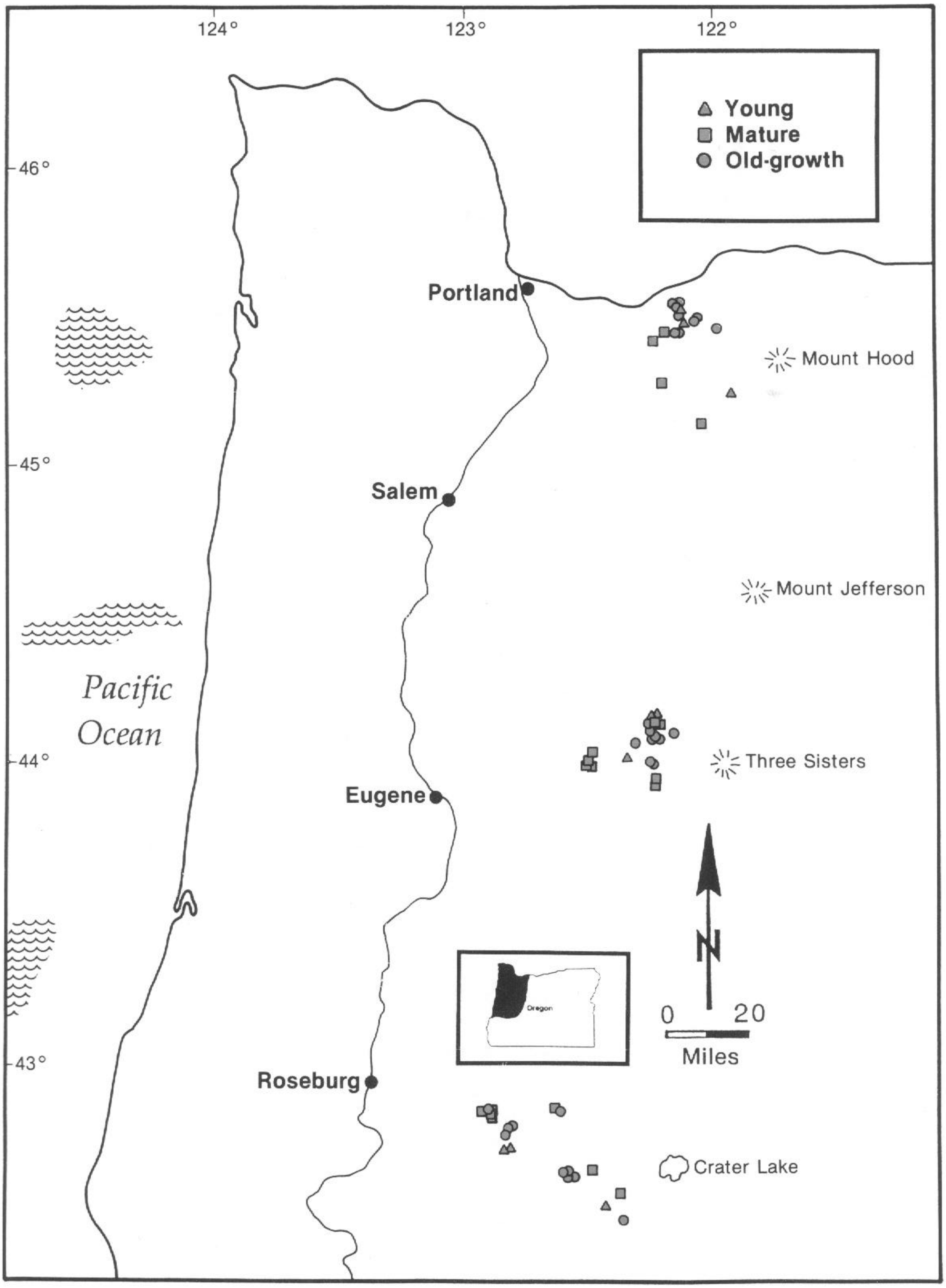

Location of study sites.

Small Mammal Communities in the Oregon Cascade Range

Frederick F. Gilbert and Rochelle Allwine

Authors

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Abstract

Pitfall and snap-trapping of small mammals in the western Oregon Cascade Range in 1984-85 revealed no significant differences in species richness among young, mature, and old-growth Douglas-fir stands. Trowbridge's shrew was the most abundant small mammal captured, accounting for about half of all captures. Species showing some association with older stands included Trowbridge's shrew, the shrew-mole, the deer mouse, and the red tree vole. The coast mole was found only in mature and old-growth stands in 1985. These species' associations with vegetational and physical characteristics indicated temporal and spatial differences in habitat use. The tree squirrels (Douglas' squirrel and northern flying squirrel) showed strong positive correlations with snags. The Soricidae segregated themselves on latitudinal, elevational, and moisture gradients.

Results from this study need to be treated with some caution: the young and mature stands contained many characteristics of old-growth stands because they had been naturally regenerated (usually after fire) and thus did not represent conditions that might be expected in stands managed for timber production.

Introduction

The effects of forest fragmentation or general loss of habitat are seldom immediately visible in small mammal communities. Studies in the western National Parks, though, support the contention that declines in species richness are likely over time with insularization of habitat (Weisbrod 1976). Harris and others (1982), Raphael (1988c), and Rosenberg and Raphael (1986) suggest that the long-term reduction of old-growth forests will negatively affect small mammal populations. Comparisons of species occurrence and abundance in different-aged stands may provide insight into the effects of truncation of seral development on existing faunal communities. The objectives of the current study were to assess the small mammal communities of young, mature, and old-growth Douglas-fir stands in the Oregon Cascade Range and and determine which environmental factors might be responsible for any differences observed.

Materials and Methods

Three locations on the western slopes of the Oregon Cascades were studied in 1984. Twenty stands were selected in the Rogue River and Umpqua National Forests (Rogue-Umpqua), 20 near the H.J. Andrews Experimental Forest (Andrews) and 16 in the Mount Hood region (Mt. Hood). These stands were selected to represent young, mature, and old-growth Douglas-fir forests and a moisture gradient (wet, mesic and dry) in the old-growth stands (Gilbert and Allwine, this volume b: see appendix table 15). In addition, a few stands were selected to represent either a mature-age moisture gradient or managed stands. Final analyses were done for fewer than 56 stands to assure comparison between mesic, unmanaged stands of the three age-classes (22 old-growth, 17 mature, and 9 young); 28 old-growth stands were in the moisture-gradient analysis (7 dry, 9 mesic, 12 wet).

Trapping Methods

Pitfall grids (6 x 6) were established in each stand and checked during September and October 1984. One pitfall trap consisting of 2 number 10 cans taped together and lined with plastic margarine tubs was buried within 2 m of each grid station. A cedar shake was placed above the opening to minimize rain and snow accumulation in the cans. Water was removed at each check. The traps were opened in early September and checked every 5 to 7 days for at least 50 days. In 1985, 15 stands at the Andrews were studied; the old pitfall grids were used in all stands, and new grids were established in 8 of them (Gilbert and Allwine, this volume b: see appendix table 15). Results from the old and new pitfall grids were compared to determine whether the previous year's trapping had affected the resident populations. Chi-square testing was used to examine species captured and number of individuals of each species in the eight stands. Because the new grids showed no difference in species composition and abundance, the old grids were used for analysis.

In 1984, snap trap grids (12 x 12) with 15-m spacing between grid locations also were used to sample the small-mammal fauna. Trapping took place in July and August, and each stand was trapped for 4 consecutive nights. Two Museum Special traps (Woodstream Corp., Lititz, PA) baited with a mixture of peanut butter and rolled oats were placed within a 1.5-m radius of each grid location.

Mammals caught in the pitfall traps usually had drowned or otherwise died by the time of collection. All animals were identified to species, sexed, measured, and preserved in the Conner Museum at Washington State University as skulls, skeletons, or skins and skulls. Identifications were verified by museum staff. Even with the examination by museum personnel, many Soricidae could not be identified to species.

Vegetative Measurements

The physical and vegetative characteristics of the trapping grids were sampled at 9 points within the pitfall grid and 16 points within the snap trap grids, with the center of each sampling point equidistant from four stations. Measurements were made using a nested-plot design, with 5.6-m and 15-m radius circles (appendix table 12). Percentage cover was visually estimated. The species capture rates (corrected for actual trap nights of operation) were compared to these environmental variables.

Statistical Analysis

Data analysis was based on two major statistical goals: testing the hypotheses that animal abundance did not differ among age-classes, moisture-classes, and locations, and number of species (species richness) did not differ among these classes; and using exploratory statistics to associate individual species with individual habitat components and with either age-classes or moisture-classes.

We used nonparametric analysis of variance (ANOVA) to test the hypothesis that abundance (number of captures per 1000 trap-nights) of animals and species richness did not differ among the age- and moisture-classes or locations. We used detrended correspondence analysis (DCA) (Hill 1979a) to explore the relations between animal abundances and habitat-classes or environmental variables. Detrended correspondence analysis is an ordination technique that arranges a matrix of species' abundances (communities) by samples (stands) in low-dimensional space so that the communities occurring in each stand are represented in space along several axes. Thus, many components are reduced to a few important ones and variability is reduced. Communities with similar species composition and relative abundances occupy positions near each other within the space described by the first and second DCA axes. In this way, it functions as a principal components analysis. To determine whether stands grouped themselves according to a physiographic gradient, a plot of the detrended correspondence analysis axes scores was examined to detect clustering.

To classify sites into community phases, two-way indicator species analysis (TWINSPAN) (Hill 1979b) was used. This method, based on a multi-level two-way partitioning of the correspondence analysis scores, was used to classify species into categories related to location or to age- or moisture-classes. Species found to be associated with old-growth forests, from TWINSPAN analysis or from Spearman rank correlations of animal abundances with stand age, were then correlated (Spearman rank correlations) with individual environmental and vegetative variables to examine the relation between animal species and individual habitat features.

Statistical significance was determined as $P \leq 0.05$. Means are given $\pm$ SE.

Results

Pitfall Trap Results

A total of 18 species of small mammals were caught in the pitfall traps in 1984. Species richness was greatest at Mt. Hood (16) and lower at Andrews (11) and Rogue-Umpqua

(13). Species' abundances (number of captures per 1000 trap-nights) varied by subprovince, with five species having significantly more captures at Mt. Hood and two more at Rogue-Umpqua (table 1). Trowbridge's shrew, by far the most common species at all three locations, accounted for 62.6 percent of all captures and ranged from 53.0 percent at Mt. Hood to 59.2 percent at Rogue-Umpqua and 75.8 percent at Andrews (table 2). The Soricidae represented 76.9 percent of the total captures. The western red-backed vole was the only nonshrew species to represent more than 10 percent of the captures (14.6 percent) mainly because of a relative abundance of 26.5 percent at Rogue-Umpqua.

Old-growth stands had 17 species, mature 15, and young 12. The average number of individuals captured by age-class was old-growth (49.5 $\pm$ 5.0), mature (46.5 $\pm$ 5.7), and young (49.1 $\pm$ 12.9). The deer mouse ($R = 0.35$, $P = 0.01$) and the red tree vole ($R = 0.37$, $P = 0.005$) were significantly positively associated with stand age. No species were significantly associated with any age category in the chronosequence (ANOVA, $P < 0.05$) (table 3). The average number of captures per stand was not different along the moisture gradient (wet 47.3 $\pm$ 5.7, mesic 50.8 $\pm$ 7.5, dry 53.0 $\pm$ 12.1), and no species were significantly associated with the moisture gradient (ANOVA, $P < 0.05$) (table 3). DECORANA analysis confirmed that age and moisture conditions did not influence the mammal distribution (figs. 1,2). A location effect was related to the pitfall captures (fig. 3), however. TWINSPAN analysis showed no indicator species for age or moisture conditions, but the Pacific jumping mouse, the montane shrew, the heather vole, Townsend's chipmunk, the northern flying squirrel, and the ermine separated out as Mt. Hood indicators; Townsend's vole and the northern pocket gopher were indicator species for Rogue-Umpqua.

No significant differences were found between the old and new grids in species abundances or richness ($P < 0.05$). Significantly more small mammals were caught in young stands (average 59.0 $\pm$ 4.6) than in old-growth stands (29.8 $\pm$ 4.2) in 1985. The mature-stand average (46.7 $\pm$ 6.8) was not different from the other two age-categories. Fourteen species were captured in 1985 compared to 10 in the same stands in 1984. The four additional species (red tree vole, Pacific shrew, Townsend's chipmunk, and the montane vole) were represented only by 1 to 3 specimens each.

None of the small mammals captured in 1985 were significantly related to old growth in the chronosequence, although five species showed an association with mature or young stands (table 4). The coast mole and red tree vole were only captured in mature and old-growth stands. The only significant difference in age- or moisture-classes for any species between 1984 and 1985 was the increased proportion of Trowbridge's shrew caught in young stands in 1985 ($x^2 = 56.6$, $P < 0.0001$).

Table 1-Significant ANQVA values for small mammal abundance based on pitfall captures corrected for effort (number of captures per 1000 trap-nights) related to subprovince location, Oregon Cascades 1984

Species	Location[a]	F-Value	*P*
Western red-backed vole	RRU > HJA,MTH	25.59	<0.0001
Pacific shrew	RRU > HJA, MTH	11.33	<0.0001
Deer mouse	RRU > HJA	4.81	0.01
sorex spp.	HJA > MTH, RRU		<0.05
Pacific jumping mouse	MTH > HJA, RRU	45.37	<0.0001
Northern flying squirrel	MTH > HJA, RRU	35.64	<0.0001
Montane shrew	MTH > HJA, RRU	16.40	<0.0001
Ermine	MTH > HJA, RRU	8.10	<0.0009
Townsend's chipmunk	MTH > HJA, RRU	3.91	<0.03
Heather vole	captured only at MTH	2.91	0.06

[a] RRU = Rogue River-Umpqua; HJA = H.J. Andrews; MTH = Mt. Hood.

Table 2-Small mammal relative abundance (captures per 1000 trap-nights) from pitfall trapping by location, Oregon Cascades, 1984 (values in brackets are percentage of capture at that location)

Species	Rogue-Umpqua	Andrews	Mt. Hood
Trowbridge's shrew	331.1 (59.2)	316.9 (75.8)	244.2 (53.0)
Western red-backed vole	148.3 (26.5)	21.2 (5.1)	39.9 (8.7)
sorex spp.	8.3 (1.5)	42.2 (10.1)	2.7 (<1.0)
Montane shrew	0.6 (<1.0)	1.7 (<1.0)	76.0 (16.5)
Pacific shrew	39.0 (7.0)	12.8 (3.1)	0.0 (0.0)
Vagrant shrew	2.8 (<1.0)	2.2 (<1.0)	12.3 (<1.0)
Marsh shrew	2.7 (<1.0)	4.4 (1.1)	5.1 (1.1)
Water shrew	0.0 (0.0)	0.0 (0.0)	0.5 (0.0)
Pacific jumping mouse	1.2 (<1.0)	1.7 (<1.0)	35.1 (7.6)
Shrew-mole	6.1 (1.1)	8.8 (2.1)	11.2 (2.4)
Deer mouse	12.9 (2.3)	1.1 (<1.0)	7.3 (1.6)
Northern flying squirrel	0.0 (1.0)	0.0 (0.0)	11.9 (2.6)
Coast mole	3.8 (<1.0)	4.5 (1.1)	6.2 (1.3)
Townsend's chipmunk	0.0 (0.0)	0.0 (0.0)	3.4 (<0.0)
Creeping vole	1.7 (<1.0)	0.6 (<1.0)	0.5 (<1.0)
Townsend's vole	0.5 (<1.0)	0.0 (0.0)	0.0 (0.0)
Heather vole	0.0 (0.0)	0.0 (0.0)	0.6 (<1.0)
Northern pocket gopher	0.6 (<1.0)	0.0 (0.0)	0.0 (0.0)
Douglas' squirrel	0.0 (0.0)	0.0 (0.0)	1.1 (0.0)
Ermine	0.0 (0.0)	0.0 (0.0)	2.9 (<1.0)

Snap Trap Results

Eighteen species and 1493 individuals were captured in the snap traps (table 5). Trowbridge's shrew was the dominant species at all locations (44.8-55.4 percent of all captures). The Pacific shrew was the second most captured species (24.1 percent) at Andrews, the montane shrew (14.2 percent) at Mt. Hood, and the western red-backed vole (29.4 percent) at Rogue-Umpqua. Species richness was not significantly different between locations. The western red-backed vole, the deer mouse, and the marsh, montane, and Pacific shrews were significantly associated with location (table 6). This

Table 3—Captures of individual mammals in pitfall traps (mean number captured per stand, corrected for effort in parentheses) for age- and moisture-classes, Oregon Cascades 1984

	Age			Moisture		
	Young	Mature	Old	Dry	Mesic	Wet
Red tree vole	—	2 (0.1)	6 (0.3)	—	6 (0.7)	3 (0.3)
Western red-backed vole	58 (7.3)	100 (6.1)	189 (8.6)	95 (10.7)	86 (9.6)	55 (4.4)
Townsend's chipmunk	3 (0.3)	—	—	—	—	—
Northern flying squirrel	6 (0.7)	2 (0.1)	6 (0.3)	—	6 (0.7)	7 (0.6)
Creeping vole	—	4 (0.2)	2 (0.1)	—	1 (0.1)	1 (0.1)
Townsend's vole	—	—	2 (0.1)	—	1 (0.1)	2 (0.2)
Ermine	1 (0.1)	2 (0.2)	—	—	—	2 (0.2)
Shrew-mole	3 (0.3)	10 (0.7)	22 (1.1)	7 (1.0)	7 (0.8)	19 (1.7)
Deer mouse	7 (0.8)	6 (0.4)	19 (1.0)	4 (0.6)	12 (1.4)	8 (0.8)
Coast mole	3 (0.3)	10 (0.7)	9 (0.4)	2 (0.3)	4 (0.4)	7 (0.6)
Marsh shrew	1 (0.2)	8 (0.8)	9 (0.4)	1 (0.1)	4 (0.4)	7 (0.6)
Montane shrew	46 (5.1)	37 (2.4)	8 (0.4)	1 (0.1)	6 (0.8)	47 (3.8)
Sorex spp.	5 (0.6)	19 (1.1)	15 (0.7)	10 (1.6)	13 (1.4)	19 (1.7)
Heather vole	—	1 (0.1)	—	—	—	1 (0.1)
Pacific shrew	7 (0.8)	29 (1.7)	58 (2.8)	17 (2.9)	24 (2.8)	17 (1.4)
Trowbridge's shrew	241 (28.9)	482 (28.4)	695 (31.0)	254 (34.4)	264 (29.6)	334 (27.7)
Vagrant shrew	8 (1.0)	4 (0.5)	6 (0.5)	4 (1.3)	2 (0.2)	12 (1.1)
Douglas' squirrel	—	—	2 (0.1)	—	2 (0.1)	—
Northern pocket gopher	—	1 (0.1)	—	—	—	—
Pacific jumping mouse	12 (1.3)	19 (1.1)	15 (0.7)	—	13 (1.4)	24 (2.2)

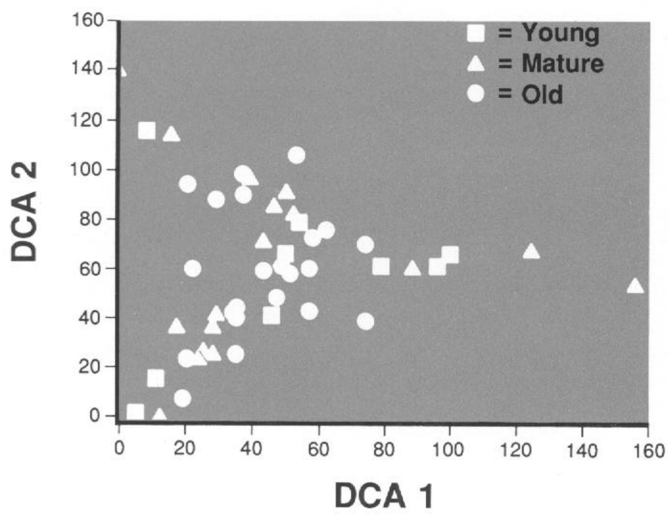

Figure 1—Detrended correspondence analysis of 1984 pitfall capture data for small mammals compared to age of stands, Oregon Cascade Range.

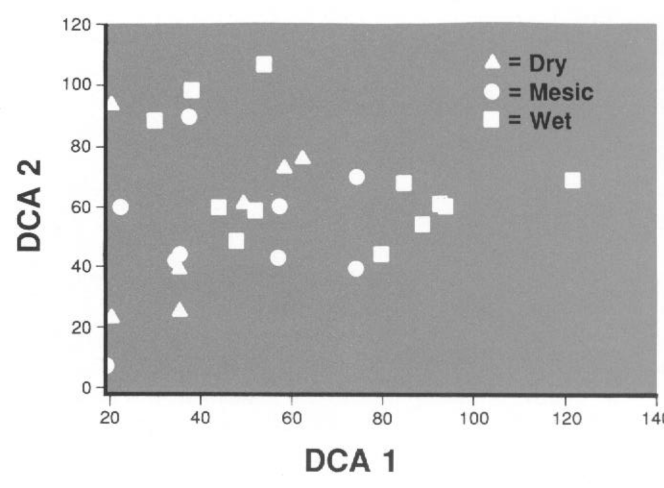

Figure 2—Detrended correspondence analysis of 1984 small mammal pitfall capture data compared to the moisture gradient, Oregon Cascade Range.

location effect was verified by the DCA scores, which showed definite clustering (fig. 4). No similar moisture or age effects were found (table 7; figs. 5, 6).

The mean captures per stand were highest in mature (29.2 ± 3.6) and lower in old-growth (26.3 ± 2.5) and young stands (15.5 ± 3.5) (ANOVA, $F = 3.24$, $P < 0.05$). The mature and young values were significantly different, but the values for old-growth did not differ significantly from the other two age-classes. Captures of the Pacific shrew were significantly associated with mature stands (ANOVA, $F = 3.62$, $P < 0.04$). Spearman rank correlations showed the shrew-mole and Trowbridge's shrew to have a positive association with stand age that neared significance ($P = 0.06$). The mean capture rates of all species did not differ along the moisture gradient (wet 26.4 ± 3.7, mesic 30.3 ± 3.9, dry 21.0 ± 3.5). Only the

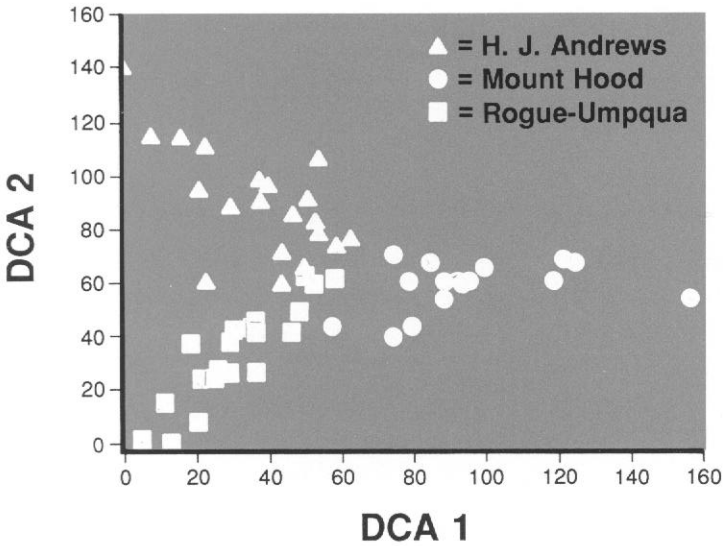

Figure 3—Detrended correspondence analysis of 1984 small mammal pitfall capture data by location within the Oregon Cascade Range.

Table 4—Small mammals significantly associated (ANOVA) with age of stand for pitfall captures, Oregon Cascades 1985

Species	Stand age association
Western red-backed vole	Mature > old-growth
Coast mole	Mature
Montane shrew	Young > old-growth
Trowbridge's shrew	Young > old-growth
Vagrant shrew	Mature > old-growth

western red-backed vole showed a relation to moisture conditions that was near significance, with average captures in mesic conditions (6.4) greater than dry (4.0) or wet (2.8) (ANOVA, $F = 3.14$, $P = 0.06$).

No differences were found in the average number of small mammals caught per stand by location (Rogue-Umpqua, 27.7 ± 2.8; Andrews, 24.9 ± 3.1; Mt. Hood, 24.0 ± 3.6). The western red-backed vole and the deer mouse were captured more frequently ($P < 0.05$) at Rogue-Umpqua, the marsh and the montane shrew at Mt. Hood, and the Pacific shrew at Andrews (table 5). The marsh, montane, vagrant, and Pacific shrews all had significant ($P < 0.05$) Spearman rank correlations for latitude.

Habitat Relations

Pitfall results—In 1984, the shrew-mole had a significant positive association with very large trees in the overstory, a feature of old-growth stands. It was found in stands dominated by very large western hemlock ($R = 0.31$, $P = 0.02$). The Douglas' squirrel was caught at sites with very large sugar pine ($R = 0.29$, $P = 0.03$), and incense-cedar ($R = 0.37$, $P = 0.005$).

The forest floor conditions at the capture sites differed. For example, the western red-backed vole, the red tree vole, and the deer mouse were all caught at sites with lichen (table 8). The Pacific jumping mouse's capture locations were significantly associated with ground cover of moss and logs of decay-classes 3 and 4. The understory components at Pacific jumping mouse capture sites included ferns, berry-producing, and deciduous shrubs (table 9) and tended to exclude broadleaf evergreen trees of all height-classes. The deer mouse

Table 5—Small mammal captures on the snap-trap grids, Oregon Cascades 1984

	Location			
Species	Rogue-Umpqua	Andrews	Mt. Hood	Total
Trowbridge's shrew	247	262	217	726
Western red-backed vole	165	54	47	266
Pacific shrew	52	121	2	175
Deer mouse	46	15	11	72
Sorex spp.	8	60	3	71
Montane shrew	0	2	50	52
Shrew-mole	11	11	17	39
Townsend's chipmunk	14	13	3	30
Vagrant shrew	0	4	11	15
Marsh shrew	0	3	11	14
Coast mole	3	3	4	10
Creeping vole	7	1	1	9
Pacific jumping mouse	3	3	2	7
Townsend's mole	0	1	1	2
Montane vole	0	1	0	1
Microtus spp.	1	0	0	1
Dusky-footed woodrat	1	0	0	1
Scapanus spp.	1	0	0	1
Western pocket gopher	0	1	0	1
Totals	559	555	379	1493

Table 6—Small mammal species-abundance values corrected for effort (number of captures per 1000 trap-nights) snap-trapped in the Oregon Cascades, 1984, showing significant (ANOVA) associations with location

Species	Capture location[a] association	F-value	P
Western red-backed vole	RRU>HJA, RRU>MTH	9.67	0.0003
Deer mouse	RRU>HJA	4.35	<0.02
Marsh shrew	MTH>RRU	3.51	<0.04
Montane shrew	MTH>HJA, MTH>RRU	20.03	<0.0001
Pacific shrew	HJA>RRU, HJA>MTH	13.23	<0.0001

[a] RRU = Rogue River-Umpqua; HJA = H.J. Andrews; MTH = Mt. Hood.

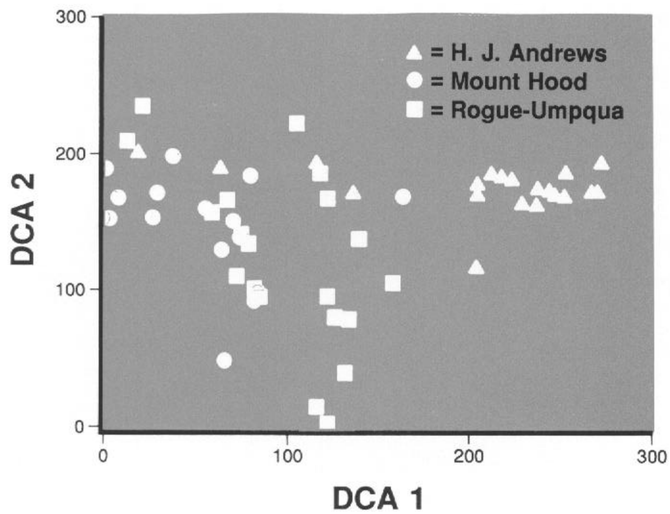

Figure 4—Detrended correspondence analysis of 1984 small mammal snap-trap capture data by location within the Oregon Cascade Range.

Table 7—Captures of individual mammals in snap traps (mean number captured per stand corrected for effort in parentheses) for age- and moisture-classes, Oregon Cascades, 1984

	Age			Moisture		
	Young	Mature	Old	Dry	Mesic	Wet
Western red-backed vole	32 (4.0)	104 (6.1)	101 (4.6)	28 (4.0)	58 (6.4)	34 (2.8)
Townsend's chipmunk	3 (0.4)	10 (0.6)	14 (0.6)	1 (0.1)	4 (0.4)	11 (0.9)
Montane vole	—	1 (0.1)	—	—	—	—
Creeping vole	3 (0.4)	2 (0.1)	4 (0.2)	—	4 (0.4)	—
Shrew-mole	2 (0.3)	10 (0.6)	13 (0.6)	4 (0.6)	2 (0.2)	19 (1.6)
Deer mouse	7 (0.9)	25 (1.5)	33 (1.5)	13 (1.9)	9 (1.0)	18 (1.5)
Coast mole	1 (0.1)	3 (0.2)	5 (0.2)	1 (0.1)	3 (0.3)	1 (0.1)
Townsend's mole	—	1 (0.1)	1 (0.1)	—	—	1 (0.1)
Marsh shrew	1 (0.1)	1 (0.1)	4 (0.2)	1 (0.1)	3 (0.3)	8 (0.7)
Montane shrew	8 (1.0)	15 (0.9)	7 (0.3)	1 (0.1)	6 (0.7)	21 (1.8)
Pacific shrew	9 (1.1)	92 (5.4)	63 (2.9)	18 (2.6)	21 (2.3)	24 (2.0)
Trowbridge's shrew	56 (7.0)	221 (13.0)	319 (14.5)	77 (11.0)	157 (17.4)	167 (13.9)
Vagrant shrew	2 (0.3)	3 (0.2)	3 (0.1)	—	3 (0.3)	6 (0.5)
Sorex spp.	—	5 (0.3)	6 (0.3)	2 (0.3)	1 (0.1)	4 (0.13)
Western pocket gopher	—	1 (0.1)	—	—	—	—
Pacific jumping mouse	—	1 (0.1)	4 (0.2)	1 (0.1)	1 (0.1)	3 (0.3)
Dusky-footed woodrat	—	—	1 (0.1)	—	1 (0.1)	

also was captured at sites with deciduous shrubs and trees (table 9). The western red-backed vole was positively associated with needleleaf evergreen trees in all height-classes.

The montane shrew was the most widely distributed shrew based on shrubs and understory trees. It was positively associated ($R = 0.51$-0.59; $P < 0.0001$) with berry-producing shrubs of all three height-classes and deciduous shrubs in the first two height-classes ($R = 0.42$-0.46; $P < 0.001$). The montane shrew was the only species associated with evergreen shrubs (0.5-2 m; $R = 0.36$; $P = 0.007$).

The northern flying squirrel was positively associated with large and medium sized (10-50 ± cm d.b.h.), tall (15-m) snags of decay-classes 3 and 4, as well as medium snags of decay class 5. The Douglas' squirrel was found in stands with various-sized snags of decay-class 5.

Pitfall results—In 1985, the red tree vole was captured at sites with small bigleaf maple, ($R = 0.53$, $P = 0.04$) large golden chinkapin, and very large grand fir. Also, it was highly correlated with sites with medium Pacific dogwood ($R = 0.995$; $P < 0.0001$). In 1984, it was associated only with

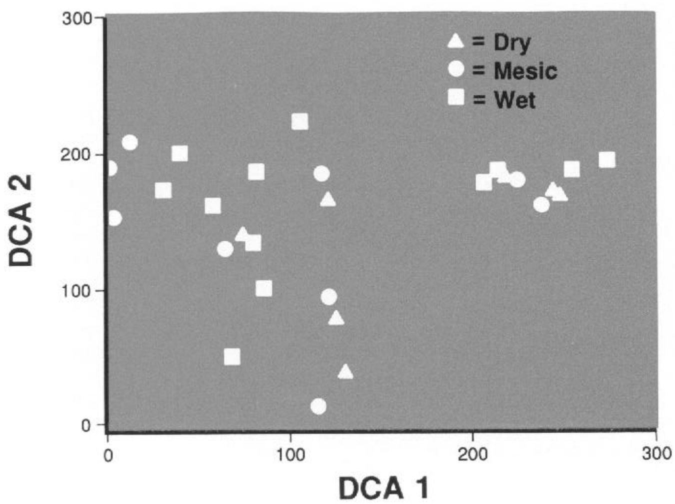

Figure 5—Detrended correspondence analysis of 1984 small mammal snap-trap capture data compared to moisture gradient of old-growth stands, Oregon Cascade Range.

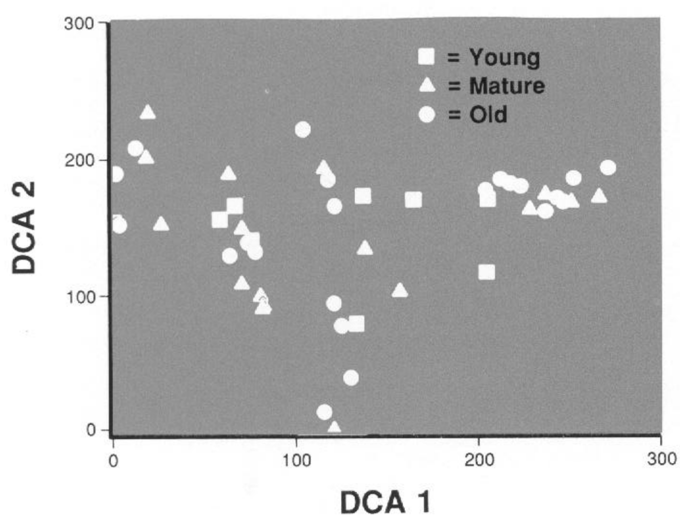

Figure 6—Detrended correspondence analysis of 1984 small mammal snap-trap capture data related to the age of stands, Oregon Cascade Range.

medium canyon live oak ($R = 0.29$; $P < 0.03$). Limited consistency was found in vegetative and physical characteristics with which the small mammal species were positively or negatively associated between years. The red-backed vole was negatively associated with moss ground cover ($R = -0.55$, $P = 0.04$) in 1985 as was Trowbridge's shrew ($R = -0.58$, $P = 0.02$). Both showed similar results in 1985.

Table 8—Significant Spearman rank correlations ($P \leq 0.05$) for forest floor characteristics at the pitfall grids and selected small mammals captured, Oregon Cascades, 1984

Species	Forest floor variable	*R*-value	*P*
Western red-backed vole	Bare rock	0.27	0.04
	Moss	–0.30	0.02
	Lichen	0.56	0.0001
	Down log, decay-class 5	0.31	0.02
Red tree vole	Lichen	0.38	0.004
	Down log, decay-class 2	0.27	0.04
Deer mouse	Lichen	0.46	0.0005
Pacific jumping mouse	Bare soil	–0.38	0.003
	Fine litter	–0.45	0.0006
	Moss	0.36	0.007
	Down log, decay-class 3	0.33	0.01
	Down log, decay-class 4	0.30	0.02

Table 9—Significant Spearman rank correlations ($P \leq 0.05$) for understory and ground-cover characteristics at the pitfall grids and selected small mammals captured, Oregon Cascades, 1984

Species	Vegetative variable	*R*-value	*P*
Western red-backed vole	Grasses (0-0.5 m)	0.45	0.0006
	Fern (0-0.5 m)	–0.47	0.0003
	Fern (0.5-2 m)	–0.44	0.0008
Red tree vole	Deciduous shrubs (0-0.5 m)	0.27	0.05
	Deciduous trees (0-0.5 m)	0.50	<0.0001
	Deciduous trees (0.5-2 m)	0.47	0.0003
	Needle-leaf evergreen (2 m-midstory)	0.34	0.01
Deer mouse	Berry-producing shrubs (0-0.5 m)	0.29	0.03
	Deciduous shrubs (0-0.5 m)	0.29	0.03
	Deciduous trees (0-0.5 m)	0.42	0.001
	Deciduous trees (0.5-2 m)	0.32	0.02
	Deciduous shrubs (2 m-midstory)	0.32	0.02
Pacific jumping mouse	Grass (0-0.5 m)	–0.43	0.001
	Fern (0-0.5 m)	0.31	0.02
	Berry-producing shrubs (0.0.5 m)	0.50	<0.0001
	Evergreen shrubs (0-0.5 m)	–0.42	0.0001
	Deciduous shrubs (0-0.5 m)	0.35	0.009
	Deciduous shrubs (0.5-2 m)	0.43	0.001
	Berry-producing shrubs (2 m-midstory)	0.54	<0.0001

Most species varied between years in the characteristics of the sites at which they were caught, but few significant changes (Spearman rank correlations) occurred from positive to negative or from negative to positive. The more common result was that some characteristics were significantly associated one year and not the other.

The montane shrew was positively associated with berry-producing shrubs up to the midstory level ($R = 0.26$-0.50; $P < 0.05$) and all deciduous shrubs ($R = 0.34$; $P = 0.001$) up to 2.0 m high (table 10). The montane shrew, the marsh shrew, and Trowbridge's shrew were caught at sites where ferns were a dominant ground cover. The Pacific shrew was associated with broadleaf evergreen trees in the 0.5- to 2.0-m zone ($R = 0.50$, P c 0.0001); it was negatively associated with berry-producing and deciduous shrubs ($R = 0.32$) and was caught at sites with evergreen shrubs ($R = 0.47$) up to 0.5 m tall (table 10). Forest floor characteristics associated with the marsh shrew were logs of decay-class 1 ($R = 0.26$) and 3 ($R = 0.26$), and with the montane shrew were lichen and aspect ($R = 0.30$; $P = 0.02$); the vagrant shrew was negatively associated ($R = -0.38$) with lichen (table 11). Townsend's mole was caught in traps with logs of decay-classes 2 to 5 ($R = 0.27$-0.32) nearby.

Discussion

The red tree vole, deer mouse, Trowbridge's shrew and the shrew-mole were the only small mammals positively associated with older stands in our study, and none seemed dependent on the availability of old growth. Corn and others (1988) generally concur with this and found that only the red tree vole was significantly associated with old-growth Douglas-fir stands in their study of the Oregon Cascades. Raphael (1984, 1988c) and Raphael and Barrett (1984) listed 10 small mammals significantly associated with old-growth Douglas-fir forests in northern California, an area not dissimilar to Rogue-Umpqua. Trowbridge's shrew can be discounted as an old-growth associate because it is a very common species that occurs in all ages of stands.

The mean species richness observed in this study was higher and more variable on the chronosequence than that observed by Corn and others (1988) or Raphael (1984). Species diversity studies are limited usually by the short temporal span of sampling the environment, and, because studies such as ours tend to rely on data gathered from many single sample surveys, erroneous correlations can be drawn (Wiens 1981b). Greater replication, especially between years, would have been useful. Temporal fluctuations in small mammal communities and their use of the environment are known to occur (Asher and Thomas 1985, McCloskey 1975, Nel 1978, Whitford 1976). The relations to habitat structure may be highly variable if temporal shifts are occurring. Yet many authors have shown or inferred that habitat factors are important in determining small mammal community structure (for example, Dueser and Shugart 1979, McCloskey 1975, Morris 1984, Rosenzweig and Winakur 1969). Generally, the animals we trapped were found associated with different vegetation conditions between years and between times of year.

Table M-Significant Spearman rank correlations for vegetative characteristics at snap-trap capture locations for small mammals, Oregon Cascades, 1984

Species	Vegetative characteristics	R-value	*P*
Western red-backed vole	Grass (0-0.5 m)	0.54	<0.00
	Fern (0-0.5 m)	-0.36	0.007
	Evergreen shrub (0-0.5 m)	0.26	0.05
	Fern (0-5.-2 m)	-0.28	0.04
	Berry-producing shrub (2 m-midstoty)	-0.28	0.04
	Deciduous shrubs (2 m-midstory)	0.29	0.03
	Needleleaf evergreen trees (super canopy)	0.39	0.003
Trowbridge's shrew	Fern (0-0.5 m)	0.40	0.002
	Fern (0.5-2 m)	0.40	0.002
Marsh shrew	Grass (0-0.5 m)	-0.31	0.02
	Fern (0-0.5 m)	0.35	0.007
	Fern (0.5-2 m)	0.28	0.04
	Berry-producing shrubs (0.5-2 m)	0.29	0.03
	Needleleaf evergreen tree (super canopy)	-0.37	0.005
Pacific shrew	Berry-producing shrubs (0-0.5 m)	-0.41	0.002
	Evergreen shrubs (0-0.5 m)	0.47	0.0003
	Deciduous shrubs (0-0.5 m)	-0.32	0.02
	Broadleaf evergreen trees (0-0.5 m)	0.50	<0.0001
	Broadleaf evergreen trees (0-0.5 m)	0.61	<0.000l
	Needle-leaf evergreen trees (0-0.5 m)	-0.28	0.04
	Needleleaf evergreen trees (2 m-midstory)	-0.28	0.03
Montane shrew	Grass (0-0.5 m)	-0.27	0.04
	Fern (0-0.5 m)	0.29	0.03
	Berry-producing shrubs (0-0.5 m)	0.49	<0.000l
	Evergreen shrubs (0-0.5 m)	-0.38	0.003
	Broadleaf evergreen trees (0-0.5 m)	-0.55	<0.0001
	Berry-producing shrubs (0.5-2 m)	0.50	<0.000l
	Deciduous shrubs (0.5-2 m)	0.34	0.001
	Broadleaf evergreen trees (0.5-2 m)	-0.40	0.002
	Berry-producing shrubs (2 m-midstory)	0.26	0.05
	Evergreen shrubs (2 m-midstory)	-0.27	0.05
	Broadleaf evergreen trees (2 m-midstory)	-0.41	0.002
	Broadleaf evergreen trees (main canopy)	-0.32	0.02
	Needleleaf evergreen trees (super canopy)	-0.45	0.0004

Table 11-Significant Spearman rank correlations for forest-floor characteristics at snap-trap capture sites for small mammals, Oregon Cascades, 1984

Species	Variable	R-value	*P*
Trowbridge's shrew	Logs, decayclass 2	*0.31*	*0.02*
Marsh shrew	Fine litter	**-0.30**	**0.03**
	Logs, decay-class 1	**0.26**	**0.05**
	Logs, decay-class 3	**0.26**	**0.05**
Pacific shrew	Lichen	-0.37	0.006
Montane shrew	Bare soil	*-0.33*	0.01
	Lichen	0.35	0.008
Townsend's mole	Bare rock	-0.29	0.03
	Coarse litter	0.28	0.04
	Logs, decay-class 2	0.39	0.02
	Logs. decay-class 3	0.30	0.03
	Logs, decay-class 4	0.27	0.04
	Logs, decay-class 5	0.32	0.02
Coast mole	Bare rock	**-0.26**	*-0.05*

This supports the speculation that temporal variation of habitat use occurred, which reduced the predictability of results based on physiognomy.

We captured too few red tree voles for meaningful statistical analysis or to conclude that they are related to older stands of Douglas-fir. Such a relation has been suggested for this species by other authors, and old-growth Douglas-fir is considered to be optimum habitat (Corn and Bury 1986, Franklin and others 1981, Meslow and others 1981). We, and the other authors, found the red tree vole primarily in mesic to wet old-growth stands but the strong associations with medium Pacific dogwood, berry-producing shrubs, and deciduous trees of smaller diameter may be a function of the small sample size. They may have been selecting such vegetation for food, however. Some of the animals we captured may have been dispersing; most of the males were juveniles, and the species is supposed to be arboreal and thus seldom found on the ground (Maser and others 1981). The females were mainly adult, and the sex ratio was almost equal. Although we cannot draw any conclusion as to the function of terrestrial activity in the species, it obviously occurs. Terrestrial nesting has been suggested for males (see Corn and Bury 1986). but we found equal numbers of females. Corn and Bury (1986) caught predominantly females in their pitfall traps.

The shrew-mole is an insectivore (Terry 1978, Whitaker and Maser 1976) and, in a study in King County, WA, it was found in forested areas with a high organic content to the soil (Terry 1981). We found no such clear delineation of habitat use, although the shrew-mole is a known shallow burrower (Dalquest and Orcutt 1942). What associations did exist in our study suggested an ubiquitous use of the environment, similar to the findings of Corn and others (1988).

Red-backed voles were negatively associated with sites with fern as a dominant ground cover. Ferns were often found with shrub or other understory cover, which suggests avoidance of such areas. As a mycophagist (Maser and others 1978, Ure and Maser 1982), the red-backed vole would be expected to occur in conifer-dominated locations, at least at the time of foraging for fungi. Negative associations with Pacific dogwood and golden chinkapin support this. Lichens are preferred food for red-backed voles in the Pacific Northwest (Vre and Maser 1982), and these voles were highly associated with areas of lichen ground cover in our study. Maser and others (198 1) say that the distribution of red-backed voles is influenced by the presence of rotting, punky logs. Hayes and Cross (1987) found capture of the species to be positively correlated with mean log diameter and size of the log overhang, suggesting they use this space as travel corridors. Our captures were positively associated with logs of decay-class 5, and many of our captures (Gilbert, pers. obs.) were in the space under log overhangs.

The Soricidae were segregated somewhat in the western Oregon Cascades. The vagrant shrew was found primarily in higher elevation stands in the northern Oregon Cascades. Although the montane shrew was also associated with Mt. Hood, it selected young stands and thus was significantly associated with shrubby areas. The Pacific shrew was restricted to the central and southern subprovince locations, and it was a generalist in its use of the habitat. A lot of the shrews from Andrews could not be identified to species (other than that they definitely were not Trowbridge's shrew) because of mixed characters. Hennings and Hoffman (1977) and Findley (1955) have discussed the taxonomic difficulties with the montane, Pacific, and vagrant shrews, and, until the taxonomic issue is resolved we decided to identify these individuals only to genus. Terry (1981) could not correlate the montane shrew with any vegetational factors and found the vagrant shrew may have been excluded competitively by Trowbridge's shrew. Dalquest (1941) considered the vagrant shrew to be dominant over Trowbridge's shrew. Our findings did not reject competitive exclusion by either species.

Although this study provided data on habitat usage by small mammals, it showed the difficulties that occur in time-restricted analyses of vertebrate communities. Three of the four species that had some old-growth association were either weakly linked (the shrew-mole), relatively abundant species in other age-classes (western red-backed vole and the deer mouse), or both (the deer mouse). The deer mouse is of interest because other authors (for example, Gashwiler 1970a, Hooven 1973, Hooven and Black 1976, Martell and Radvanyi 1977) consider the species to be most abundant in early successional forests. We trapped during a low in the population cycle of the deer mouse in the Oregon Cascades, and the species seemed to be related to older successional forests. Anthony and others (1987) had similar results trapping riparian zones at Andrews in 1983, as did Raphael (1984) in northem California. Scrivner and Smith (1984) found the species to be most associated with older successional stages (>80 yr) of spruce-fir forests in Idaho, and Monthey and Soutiere (1985) had similar results with a related subspecies in Maine conifer forests. Sullivan (1979) stated that clearcut areas may be population sinks for dispersing deer mice. Although the species is not restricted by any means to older successional stages, older forests may provide its best habitat.

Douglas' squirrels were not sampled adequately by trapping to provide any information on their dependence on old-growth. Data derived from avifauna surveys (Gilbert 1985) provided no evidence of dependence on old-growth, although Raphael (1984,1988) and Raphael and Barrett (1984) found a significant positive correlation with stand age for the Douglas' squirrel in Douglas-fir forests in northern California. Flying squirrel abundance was positively correlated with large-snag density (Volz 1986, this study), suggesting this habitat feature is necessary for suitable den trees and cavities and may be limiting for that species. Maser and others (1981), however, note that in locations in western Oregon where these more suitable nesting sites have been removed by logging, the species will build outside nests. We noticed some of these nests as well.

One cautionary note is that virtually all the stands we studied were natural and not the intensively managed stands that can be expected in the future. Even the young stands had large amounts of coarse woody debris and snag numbers almost equivalent to old-growth stands. Vegetational features and coarse woody debris in stands originating from logging rather than fire are considerably different. We did sample a few such stands with a previous history of logging, and these young and mature stands had fewer species and individuals in the small mammal communities than comparable natural stands (Gilbert 1985). Other evidence supports such impacts of logging on particular species; Corn and others (1988), state that we have probably already eliminated much of the red tree vole habitat by extensive logging of low elevation, old-growth forests. The habitat features supporting the abundance of small mammals we observed in the Oregon Cascades will be reduced or eliminated in managed forests, creating a risk that species richness will decline (compare to Weisbrod 1976) unless forest management practices provide opportunities for maintaining such elements as coarse woody debris and large trees in the managed Douglas-fir forests of the future. Some of the species we captured were definitely linked with these features of structural diversity (for example, the red tree vole, flying squirrel, and western red-backed vole). Therefore, although old-growth may not be itself limiting to very many species, the structural complexity of naturally regenerated forests may be required for maintaining small mammal diversity.

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Appendix

Table 12-Vegetation and site measurements for pitfall and snap trap grids, Oregon Cascades, 1984

I. Measurements on a 100 m^2 area (5.6-m radius)

Forest floor:

1. Cover of logs by decay-class (%) (>lO cm diameter).
2. Litter depth at three points (01, 02) (mm).
3. Coverage of forest floor by various substrates: exposed bare rock, exposed bare mineral soil, fine organic litter (<l0-cm diameter), coarse organic litter (>10-cm diameter), moss, lichen.
(Total - 100%).

A. Vegetation characteristics
4. Coverage of foliage by height interval and life form (%).
a. Height intervals
1. 0-0.5 m (100 m^2 area)
2. *0.5-2.0* m (100 m^2 area)
3. 2.0 m through midstory (shrubs and trees not entering main canopy) (707 m^2 area).
4. Canopy trees forming main canopy layer (707 m^2 area).
5. Super canopy trees (crowns extending well above main canopy layer) (707 m^2 area).

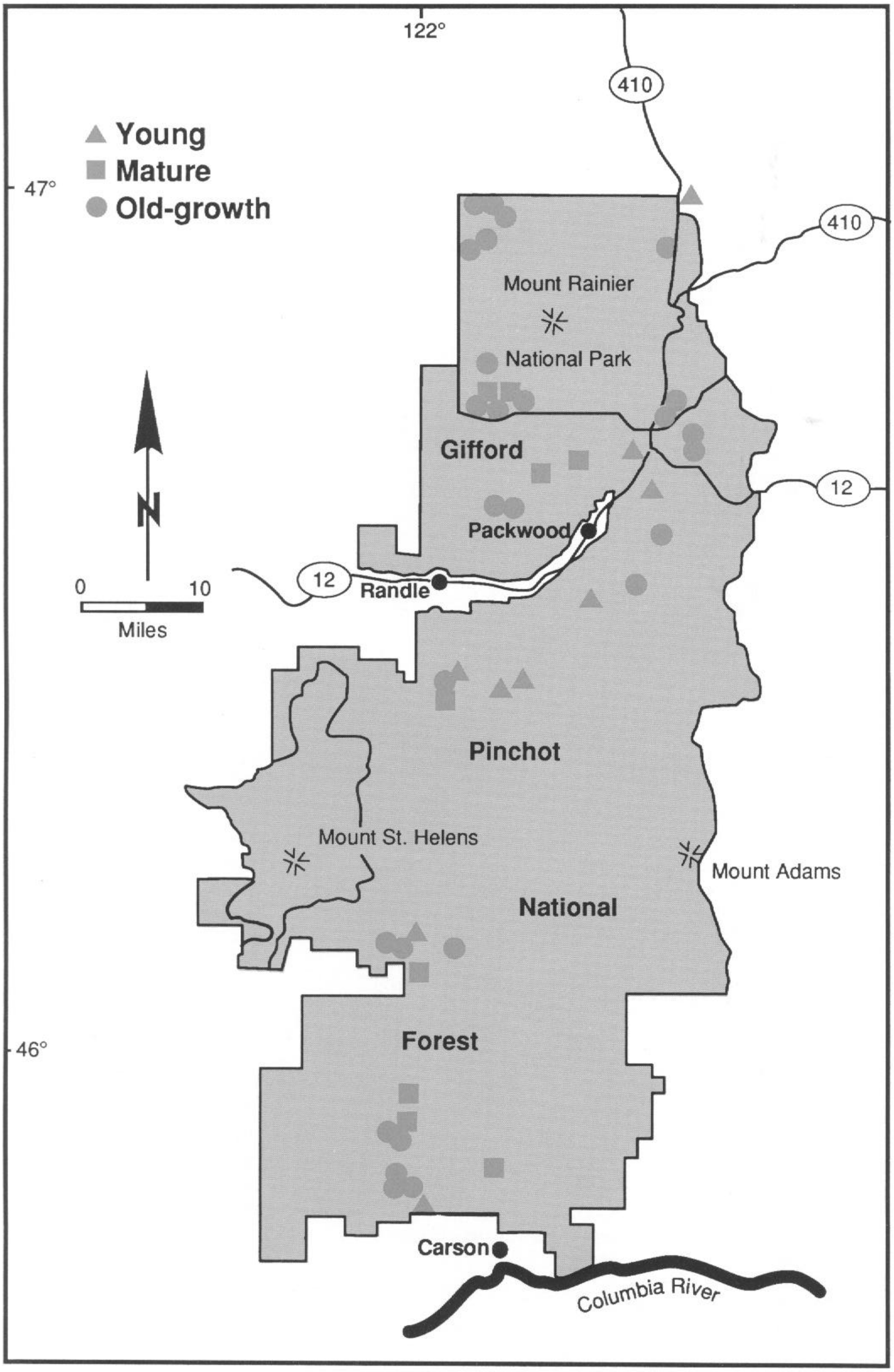
b. Life forms
1. Herbs
2. Graminoids (grass & grasslike plants including sedges)
3. Ferns
4. Berry-producing ericaceous shrubs ***(Vaccinium*** and ***Gaultheria)***
5. Evergreen shrubs (including shrubs of #4)
6. Deciduous shrubs (including shrubs of #4)
7. Deciduous trees
8. Broadleaf evergreen trees
9. Needleleaf evergreen trees

B Stand characteris tics
5. Number and species of small diameter, live trees (l-10 cm d.b.h.).
6. Number and species of medium diameter, live trees (l0-50 cm d.b.h.).
7. Number by decay-class of large diameter, medium tall snags (>50 cm d.b.h. and 5-15 m tall).
8. Number by decay-class of medium diameter, medium tall snags (l0-15 cm d.b.h. and 5-15 m tall).
9. Number by decay-class of short snags (any d.b.h., 1.5-5 m tall).
10. Number stumps (<l.5 m tall, natural or cut).

II. Measurements on a 707 m^2 area (15-m radius, the distance to next trap station).

A. Stand characteristics
11. Number and species of large live trees (50-100 cm d.b.h.).
12. Number and species of very large live trees (>l00 cm d.b.h.).
13. Number by decay-class of large diameter, tall snags (>50 cm d.b.h. and 15 m tall).
14. Number by decay-class medium diameter, tall snags (l0-50 cm d.b.h. and >15 m tall).

B. Site characteristics
15. Surface water (presence/absence).
16. Type of water: I (intermittent stream), P (perennial stream); S (seep); 0 (pool/pond).
17. Rock outcrop (>l% of area) (presence/absence).
18. Exposed talus (>l% of area) (presence/absence).
19. Number of recent tree-fall mounds-pits with exposed roots and mineral soil.



Location of study sites.

Small Mammal Communities in the Southern Washington Cascade Range

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Abstract

Small mammal faunas on the western slope of the southern Washington Cascade Range were sampled to describe patterns of abundance along gradients of forest age and moisture and to identify structural, vegetative, and environmental features associated with these patterns. Forty-five primary sites were sampled by snap and pitfall trapping in 1984 and 1985, resulting in the capture of 6751 individuals of 20 species, of which 11 were regularly caught and statistically analyzed. Four of these 11 species had different abundances between years. The abundance of two species differed between forest age-classes. The deer mouse was caught more often in old-growth than young forest, and the forest deer mouse was caught more often in mature and old-growth than young forest. The abundance of three species differed between moisture-classes of old-growth forest. The marsh shrew was caught more often in wet than in moderate old-growth forest, and the southern red-backed vole was caught more often in dry than in moderate or wet old-growth forest. In 1985 only, the deer mouse was caught more often in moderate than in wet old-growth forest. Elevation (404 to 1218 m) was not a strong factor influencing small mammal abundance. Clustering sites by similarity coefficients (Jaccard's) based on mammalian presence-absence data or by the abundance of frequently captured species (K-means) did not indicate a mammalian community that was strongly organized with respect to gradients of forest age or moisture. Habitat variables were weakly correlated with the abundance of mammalian species. The forest-floor small mammal community in these naturally regenerated forests appears adapted to a broad range of conditions related to forest age and moisture.

Introduction

The small mammal communities of the western slopes of the southern Washington Cascade Range are composed of species from two mammalian faunas (Dalquest 1948). Before the last glacial period (Vashon-Wisconsin), species characteristic of the temperate forests of the Pacific coast, such as the shrew-mole, Townsend's mole, Trowbridge's shrew, the marsh shrew, Townsend's chipmunk, the deer mouse, Townsend's vole, and the creeping vole, probably were the most common species in the region. As glacial advance proceeded, species associated with boreal conditions to the north, such as the water shrew, the yellow-pine chipmunk, the heather vole, the southern red-backed vole, the water vole, and probably the forest deer mouse, moved southward through the Cascades. At glacial maximum, species of both faunas inhabited this unglaciated region. With retreat of glacial ice, these species expanded their distributions generally north and east, colonizing the Cascades as habitats became suitable (Dalquest 1948).

Small mammals, therefore, have inhabited the southern portion of the Washington Cascades longer than areas farther north. If consistent associations occur between small mammals and naturally occurring gradients of forest age and moisture, they might be expected to occur in the south. Do unique species combinations occur along these gradients, or are the constituent species capable of persisting in an array of forest conditions? These questions have gained importance in recent years, with increasing attention to the issue of preserving old-growth forests. This study addresses the relationships between small mammal communities and naturally regenerated forests. Extrapolation of conclusions from this work to potential relationships in managed forests will be difficult, as discussed below.

The central objective of this paper is to describe the patterns of small mammal species abundances over a gradient of forest age, and within old-growth forests, to describe patterns of abundance over a gradient of moisture. This paper also will investigate correlations between small mammal abundances and selected environmental and vegetational variables.

Methods

Study Sites

This work was conducted on 54 sites on the western slopes of the southern Washington Cascade Range. Sites were located predominantly within the Western Hemlock Zone (Franklin and Dymess 1973) at elevations ranging from 404 to 1218 m. Some of the higher elevation sites extended into the Pacific Silver Fir Zone. Most forested sites had Douglas-fir as the dominant tree species, although wet old-growth forests had a large proportions of western redcedar. The sites chosen for small mammal studies form a subset of a large number of sites investigated botanically. For an extensive treatment of the vegetational composition and structure of the study stands, see Spies (this volume) and Spies and Franklin (this volume).

Of the 54 sites, 8 were on areas recently clearcut (cut 6-21 years previously). These sites were sampled for small mammals in 1984, but could not be included in sampling during 1985. One forested site was sampled only in 1985, and the remaining 45 sites were sampled in both years. These 45 sites (see frontispiece), which ranged in size from 51 to 1690 ha (mean size = 488 ha), are the focus of this paper.

Sites were chosen based on several physical and vegetational characteristics (Carey and Spies, this volume), and subsequently placed into classes along gradients of age and moisture (Spies and Franklin, this volume). Of the 45 sites, 36 were judged sufficiently similar in site moisture conditions (moderate vs. very wet or dry) to be compared along an age gradient. Elimination of very wet or dry sites resulted in a chronosequence consisting of 9 sites in young forest (55-75 years old), 9 sites in mature forest (80-190 years old), and 18 sites in old-growth forest (210-730 years old). All 27 old-growth sites were classified into moisture-classes, yielding 9 wet sites, 11 moderate sites, and 7 dry sites.

Small Mammal Sampling

Sampling techniques varied, reflecting the different natural histories of the small mammal fauna. This study used four techniques: vocalization frequencies of tree squirrels, track records from smoked aluminum plates, snap-trapping, and pitfall trapping. Vocalization frequency data were collected as part of the spring avian surveys, using variable circular plots (Manuwal, this volume). These data were used in conjunction with the other techniques to assess the presence or absence of squirrels on the study sites. Data on track frequency (Carey and Witt 1991) were used in the same fashion. They were particularly useful in establishing the presence of squirrels and chipmunks, species not sampled efficiently by snap or pitfall trapping. By far the most important techniques, and the ones yielding information on relative abundance, were snap-trapping and pitfall trapping.

As noted by Briese and Smith (1974), Bury and Corn (1987), and Williams and Braun (1983), capture efficiency differs consistently between snap and pitfall traps. In general, pitfall traps sample nonjumping rodents and insectivores more effectively than do snap traps, which sample more agile rodents most effectively. Species lists exclusively derived from one technique will reflect this sampling bias. Estimates of relative abundance in this paper consequently combined information from both techniques. West (in press) describes the snap-trapping methods used in this study and a rationale for developing this particular protocol. Briefly, we used two Museum-Special traps at each of 144 trapping stations. Most of the traps were new-model Museum Specials with plastic treadles (West 1985). Stations were arrayed on a 12 by 12 grid with 15-m interstation distances. Traps were baited with peanut butter and whole oats, and operated for four consecutive days. We trapped each site once during July and August in both years. Trapping grids were relocated within sites between years to avoid sampling potentially depleted populations in 1985. Corn and Bury (1990) also describe methods of pitfall trapping that were developed primarily for sampling amphibians and reptiles. Mammals and herpetofauna were sampled simultaneously. Pitfall arrays consisted of 36 traps on a 6 by 6 grid with 15-m spacing between traps. Pitfall traps were operated continuously for 30 to 34 days each fall, beginning in October. Traps were checked once a week and were relocated within sites between years. All captured animals were given to the Burke Memorial Museum at the University of Washington.

Vegetation Sampling

Information on the physical features of the sites and their vegetational composition and structure was gathered on the snap and pitfall trapping grids in a similar manner. Variables appropriately measured at a small scale, such as coverage of the forest floor by different substrates, percentage cover of logs by decay-class, and percentage cover of herbs, ferns, most shrubs, and small trees, were recorded on 100-m^2 circular plots. Variables of larger scale, such as large trees, large standing snags, and site characteristics (presence and type of water, rock outcrops, or talus) were measured on 707-m^2 circular plots centered on the smaller plots. Centers of the concentric plots were equidistant from four pitfall traps or snap-trapping stations, resulting in 9 vegetation plots on the pitfall grids and 16 plots on the snap-trapping grids. Because these grids were relocated between years, we collected data from different grids each year.

Data Analyses

This paper is concerned with the responses of small mammal populations at the site or stand scale. Abundance patterns were characterized, and correlations with habitat features were sought, from summations of snap and pitfall captures in each year with site and vegetation variables averaged over all plots in both years. Such an approach was taken to provide a comprehensive data set. As discussed above, combining snap and pitfall data enlarges sample sizes and helps reduce the known biases of each method. By combining information from all vegetation plots ($n = 50$), a good average value could be obtained for most variables. All statistical work was done with SYSTAT microcomputer programs (Wilkinson 1988).

Counts of captured animals are reported as numbers per 100 trap-nights. For snap-trap data, these counts were corrected for empty, snapped traps, and for traps occupied by another species. Because pitfall traps were multiple-capture traps, such adjustments to the capture totals were unnecessary. Before statistical analyses, capture data were transformed logarithmically ($ln(x+1)$).

All variables measured on the vegetation plots were inspected for statistical normality and transformed using logarithmic ($ln(x+1)$), square root ($(x+3/8)$), and arcsine ($asn(x)$) functions as appropriate. Redundant variables were either eliminated from further analysis or combined with similar variables after inspecting the Pearson correlation matrix of the data. Of the field-recorded variables, a subset of 31 variables consisting of original and combined variables was used to examine correlations between small mammal abundance and habitat features (appendix table 7).

Small mammal responses to forest-age and moisture gradients, and to selected environmental variables were investigated in three general ways. Analyses of variance (repeated measures ANOVA) of small mammal abundance with forest age (young, mature, and old-growth forest) and moisture-classes (dry, moderate, and wet old-growth forest) assessed the variation in abundance for successive years across both gradients. When significant class-by-year interactions were present, I used separate one-way ANOVAs with Tukey's HSD test for multiple comparisons. I used Pearson correlation coefficients to test for associations with selected environmental parameters, and multiple regression to assess the consistency and strength of association between vegetative physiographic variables and the abundance of mammals. The ANOVAs and correlation coefficients were calculated for species for which at least 40 individuals were captured. The composition of mammalian communities, based on the presence or absence of species for each site, was obtained by combining capture totals in both years with information from the avian surveys and the track plates. The resulting matrix of presence-or-absence data by sites (species in table 1 plus the Douglas' squirrel) was clustered hierarchically by Jaccard's similarity coefficients (Jaccard 1912) to reveal community pattern along the forest-age and moisture gradients. In addition, K-means clustering (Hartigan 1975) on the abundance of the most frequently captured species (11 species) was used to investigate community pattern from a different perspective.

Table 1—Small mammals captured in snap (July and August) and pitfall traps (October and early November) on 45 forested sites in the southern Washington Cascade Range

Common name	1984	1985	Total
Insectivora			
Vagrant shrew[a]	20	48	68
Montane shrew[a]	452	859	1,311
Water shrew	6	3	9
Marsh shrew	21	25	46
Trowbridge's shrew[b]	1,105	841	1,946
Unidentified shrew	26	12	38
Shrew-mole	116	115	231
Coast mole	11	10	21
Lagomorpha			
Pika	1	1	2
Rodentia			
Yellow-pine chipmunk	1	11	12
Townsend's chipmunk	26	16	42
Unidentified chipmunk	0	1	1
Northern flying squirrel	2	27	29
Northern pocket gopher	0	1	1
Deer mouse	101	125	226

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