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Response of Ground-dwelling Vertebrates to Thinning Young Stands: The Young Stand Thinning and Diversity Study

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6/00

INTRODUCTION

Over the past 50 years large amounts of mature and old-growth forests in western Oregon and Washington have been converted to young plantations. Currently, about 20-40% of federally-managed lands in western Oregon are <40-60 yrs old plantations originating from traditional clear-cut harvesting and underplanting (FEMAT 1993). Private-industrial lands have an even higher proportion (45-70%) of young (<40-yr old) plantations (Garman et al. 1999). Management strategies across all ownerships have historically emphasized timber production. This has led to structurally simple plantations which lack the broader range of features found in older forests or in stands originating from natural disturbances. These features include large boles, large snags and downed-dead wood, spatial variation in tree-canopy layers, and tree-species diversity.

Current objectives for federally-managed lands require balancing timber production and ecological diversity (Interagency ROD-S&G 1994). To achieve this balance, determining management strategies which can alter plantations to more closely resemble natural, young stands is paramount. This is because of the current acreage of young plantations and the potential for re-directing stand development in younger stands.

The Young Stand Thinning and Diversity Study (YSTDS) was initiated by the Willamette National Forest in the early 1990's to experimentally evaluate alternative thinning strategies for young management stands. This study consists of replicates of three thinning treatments differing in residual density and spacing plus unharvested controls. A range of ecological and timber-related attributes have been monitored before and after implementation of thinning treatments to determine short-term impacts. Continued monitoring is planned to evaluate long-term trends. An important objective of the plant and wildlife monitoring was to determine differences in thinning-induced habitat quality and/or species diversity. This paper reports the changes in habitat quality and diversity of ground-dwelling vertebrates 2-3 yrs after implementation of the thinning treatments.

STUDY AREA

A total of 16 Douglas-fir stands in the Willamette National Forest were selected for this study. Replicates consisting of 4 stands each are located in the Blue River Ranger District and the McKenzie Ranger District; two replicates are located in the Oakridge Ranger District (Fig. 1). Stands originated from clearcut harvesting followed by reforestation 35-42 yrs prior to this study. Stands were generally similar in structure and composition. Douglas-fir accounted for >88% of the basal area, followed by western hemlock and western red-cedar. Hardwood basal area varied among stands, but generally hardwoods were only a minor component in the pre-treatment stands. Total tree basal area of stands ranged from 24 to 48 m^2/ha; however, basal area only differed by 3-9 m^2/ha among stands within a replicate block (each set of 4 stands constitute a replicate block). Elevation differences are pronounced, ranging from 439 to 905 meters. With

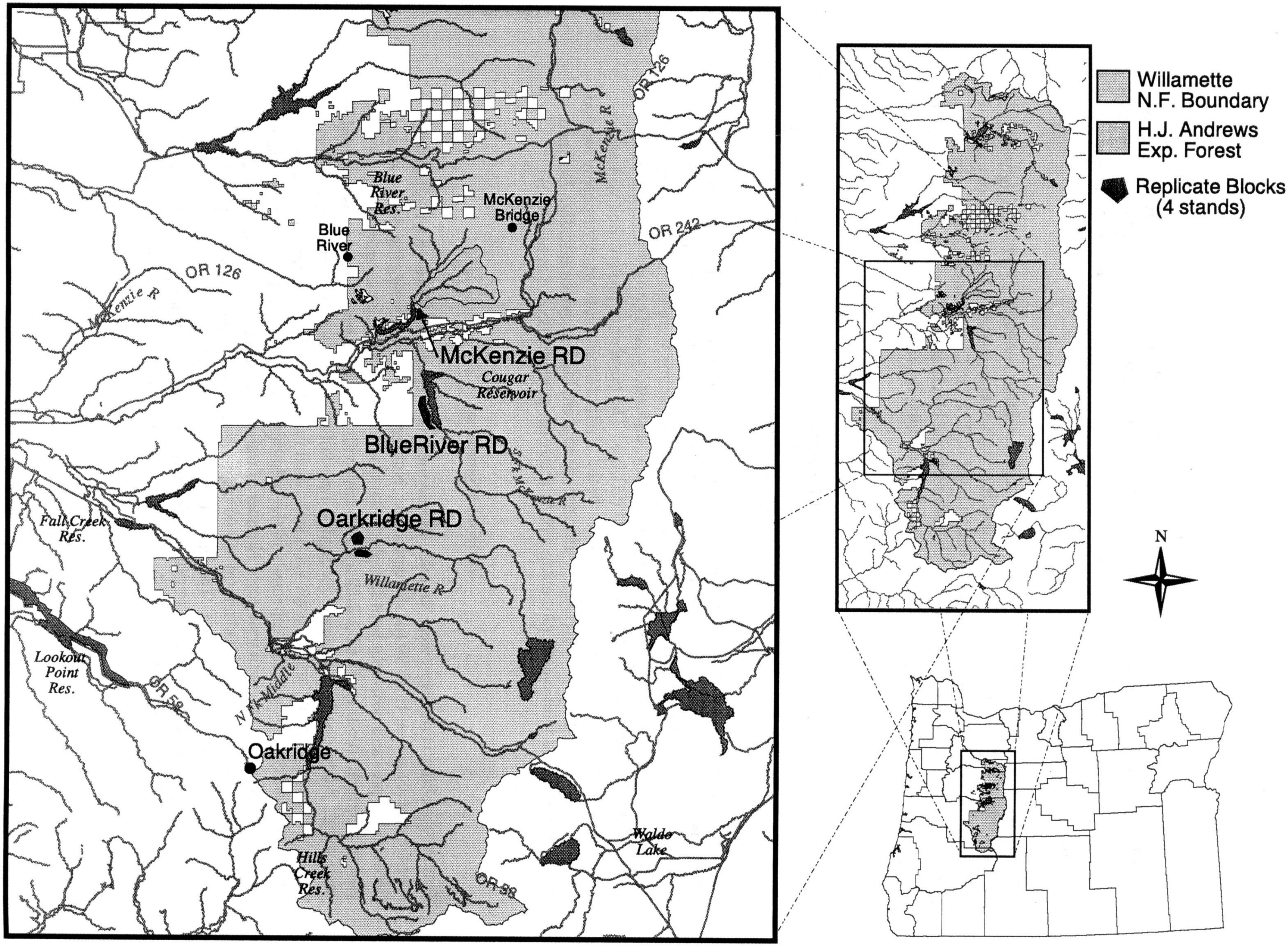

Figure 1. Location of stands of the Young-Stand Thinning and Diversity Study.

the exception of one replicate block, elevation of stands in a block differed by only 200 meters. Three of the stands in the McKenzie replicate block were at similar elevations (439-658 meters), but the control was located at 902 meters. Structure and composition of these four stands, however, were very similar. Stand sizes ranged from 19-30 ha for those assigned to a thinning treatment and up to 53 ha for control plots.

Thinning treatments consisted of a heavy thin (target retention level of 123 TPH), a light thin (target retention level of 271 TPH), and a light thin with evenly spaced 0.2-ha clearcut gaps comprising 20% of stand area (target retention level of 271 TPH in the forest matrix or a total stand-level target density of 217 TPH). In each replicate block, stands were randomly assigned to a thinning treatment and a control (unthinned). Thinning began in 1994 and was completed by 1996.

METHODS

Vegetative Sampling

Vegetative conditions of stands were sampled before and after thinning treatments were implemented. Prior to treatment implementation, trees were sampled in fixed radius plots (ca. 0.04-ha) and ground cover, shrub cover, and coarse-woody debris were tallied in belt transects up to 5-m long and 5-m wide. After thinning , overstory, understory, and ground-level conditions were sampled in permanent, fixed-radius plots (0.1 ha). The number of plots varied with stand size but about 7% of stand area was sampled. In the gap treatment, plots were purposely located in gaps and at the gap-forest interface. Otherwise, plots were located systematically. Downed wood was sampled within each plot using a planar transect method (Brown et al. 1982).

Vertebrate Sampling

Ground-dwelling vertebrates were sampled during the Fall (September-November) in 1991-92 (pre-treatment) and in 1998-99 (post-treatment). Numbers of traps and trapping design varied between the pre- and post-treatment sampling periods. In the pre-treatment sampling, a 10 x 10 grid of Sherman live-traps (7.62 x 8.89 x 22.86 cm) with 20-m inter-trap spacing was centered in each stand. Additionally, a separate 5 x 5 grid of pit-fall traps (two #10 cans stacked end-for-end) with similar spacing among traps was established in each stand. To better sample across the spatial variability of treatments, especially in the light thin with gap treatments, post-treatment sampling used variable-length transects. Number of transects in a stand varied with stand shape and size; however, each stand had a total of 100 trapping stations. Transects were spaced 30-m apart and >50-m from a stand edge. Trapping stations on a transect also were spaced 30-m apart. Pitfall traps were located at every other station for a total of 50 pitfall traps per stand. In each year of sampling, all stands of a replicate block were simultaneously trapped for 6-8 consecutive nights.

During a trapping period, one Sherman live-trap was placed at every trapping station, and pitfall traps were cleared of debris and made functional. All traps were baited with a standard mixture of peanut butter, rolled oats, and sunflower seeds. Polyfiber batting was placed inside each trap for insulation. Sherman traps were placed inside a half-gallon milk cartons for added insulation and to reduce exposure of traps and potential captures to rain water. A pint-sized juice carton was inserted into each pitfall trap for similar reasons. Traps were checked every day. Captures were identified to species, ear-tagged or toe clipped, weighed, sexed if possible, then released immediately at the site of capture. Dead specimens were removed from the site and stored. Upon termination of a trapping period, Sherman traps were removed; pitfall traps were de-activated.

Microhabitat Assessment

Sympatric species may segregate along microhabitat or other resource gradients to avoid competitive interactions. Additionally, the dispersion of fine-scale microhabitat features can play an important role in determining habitat quality for species. Understanding species' microhabitat requirements, the degree of overlap among species in microhabitat-use, and how forest-management influences fine-scale habitat features can aid in interpreting species' responses to stand-level manipulations. To assess fine-scale habitat associations, a microhabitat component was added in 1999. This assessment was conducted only for the post-treatment period and consisted of correlating captures of individuals with station-level measures of habitat. To increase the spatial independence of samples, only every other station on every other transect within a stand was considered. At each of these stations, basal area of trees and snags >3-m tall was measured with a 20 BAF prism, with softwood and hardwood species recorded separately. Other vegetative conditions were sampled within a 15-m radius circle centered on a trap station. At the trapping station and within each quadrant (determined by the orientation of the transect), percent cover of overstory, shrub (evergreen and deciduous), herbaceous, and downed-dead wood was estimated. Numbers of stumps were recorded by size classes (≤50, 51-100, >100-cm diameter at ground height [dgh]) as were logs (≤30, 31-50, >50-cm large end diameter). To date, all but the overstory measures have been recorded for all stands. For this analysis, only data from the four stands in the McKenzie replicate block and the light-thin stand in the Blue River replicate block were used.

Analyses

Statistical Assessment of Treatment Effects

A mixed-effect, repeated measures ANOVA was used to determine treatment effects on species' capture rates and species diversity as measured by the Simpson's Diversity Index (Kreb 1989). Capture rate was calculated as the number of individuals/1000 trap nights (TN). Simpson's Diversity Index is a combined measure of species richness and the apportionment of species, and was calculated using capture rates. In the ANOVA model, treatment, year, and treatment by year were the fixed effects; block and block by treatment were random effects. Data for each year of the study were used (2 years of pre-treatment, 2 years of post-treatment) in an ANOVA. If the treatment by year interaction term was statistically significant, additional contrasts were performed to determine treatment effects. Orthogonal contrasts evaluated differences between pre- and post-treatment, and between pre-treatment and each post-treatment year. If a contrast was significant, nonorthogonal contrasts were used to compare treatments vs. control means to determine specific treatment effects.

Absolute or relative abundance is sometimes a misleading indicator of habitat quality. Areas used primarily for dispersal habitat may record more individuals but lower recapture rates compared to higher quality habitat. Higher relative densities in sub-optimal habitat may be dominated by younger individuals displaced from optimal habitat by older, established individuals (Van Horne 1982). Gender bias also may be indicative of differential habitat suitability. To further evaluate habitat suitability, mean body mass (surrogate for age), recapture rate, and sex ratio were analyzed. Mean recapture rate and sex ratios were analyzed with the same ANOVA model used for analyzing capture rates. Recapture rate was calculated as the number of recaptures divided by the total number of observations (new and recaptures) and converted to a percentage. Sex ratios could not be used because not all stand-year combinations recorded both sexes. Thus, analysis of gender dominance was based on the percentage of male or of female individuals recorded in a stand. Only results for males are presented since trends and significant differences would be mirrored in the analysis of females. Mean body mass was analyzed with a mixed-effects ANOVA. Data for this analysis consisted of all individual observations of a species in a stand. Among the four years, there were some stands without records of captures or body mass, even for frequently recorded species. In the analysis of body mass, recapture rate, and male ratio, data were combined for the pre- and post-treatment periods. Thus, the year term in the ANOVAs simply equated to before and after thinning treatment. Even with this simplification, only certain species had suitable sample sizes for meaningful statistical analyses. In an ANOVA, if the treatment by year interaction was significant, nonorthogonal contrasts were performed to determine differences among treatments.

On the basis of residual analysis (Sabin and Stafford 1990), a square-root or logarithmic transformation was used for responses analyzed by ANOVA. A significance level of alpha= 0.05 was used for orthogonal contrasts. For nonorthogonal contrasts, Bonferroni's adjusted probabilities (Milliken and Johnson 1992) were used to constrain the overall alpha level to 0.05.

All ANOVAs determined treatment differences by comparing the mean difference between pre- and post-thinning for treated stands with the mean difference for control stands In other words, ANOVAs essentially evaluated changes in a response in a treatment type relative to the control. For instance, a 3-fold increase in capture rates between the pre- and post-treatment periods in a treatment would not be significant if the same level of increase occurred in the control. Conversely, a significant treatment effect would be concluded if mean capture rate of a treatment remained the same between sampling periods but the mean rate substantially decreased in the control. The comparison of responses before and after treatment with the difference in the control is essential given annual fluctuation in vertebrate populations independent of habitat quality.

Habitat Relations

Associations between capture rates and vegetative conditions were evaluated with stepwise linear regression. Two analyses were performed. Species' response to changes in habitat conditions were evaluated by regressing changes in species' capture rates with changes in vegetative variables between post- and pre-treatment periods. Stand-level capture rates were based on the total number of individuals and trapping effort over the two years of pre-treatment and over the two years of post-treatment. Individuals captured in previous years were not used. Habitat variables collected prior to thinning treatments and in 1999 were used in this analysis. Regressions were based on post-treatment minus pre-treatment values for species' capture rates and habitat variables for each of the 16 stands. Partial R-squares of variables were recorded to show strength of relationship. The second analysis evaluated habitat relations in the post-treatment period to evaluate stand-level characteristics associated with each species. Species' capture rates were regressed on post-treatment stand-level habitat measures Vegetative attributes included the full range of measures recorded in 1999. For all regressions, Spearman-rank correlations determined correlated variables. For correlated pairs of variables, the most biological meaningful one was considered.

Microhabitat-use

Principal Component Analysis (PCA) was used to ordinate microhabitat measures and species' use of microhabitat. Microhabitat variables used in a PCA were derived from Spearman-rank correlation of variables with the number of recorded individuals of each species at each station. PCA was used to reduce the selected variables to a smaller set of orthogonal principal components. For each species, habitat-use means and 90% confidence ellipses (Sokal and Rohlf 1969) weighted by the number of captures were projected into the multivariate space defined by the principal components. Use of weighted means emphasized microhabitat most used by a species. Separation of 90% confidence ellipses was considered to represent statistical difference between habitat-use means.

Pairwise overlap of microhabitat use was calculated using weighted PCA scores by the multivariate extension of Maurer's (1982) overlap formula for unequal variances. The multivariate form of Maurer's equation was first presented by Belk et al. (1988), but their derivation is incorrect. The correct formula was derived by Garman (1991):

$$A_{ij} = \mathrm{Sqrt}\left[\frac{2(|S_i|\,|S_j|)^{0.5}}{|S_i| + |S_j|}\right] \mathrm{EXP}[-.5(X_i-X_j)'(S_i+S_j)^{-1}(X_i-X_j)]$$

A_{ij} is the overlap between groups I and j; S is the covariance matrix and X is the mean vector for groups I and j. A_{ij} ranges from 0, no overlap, to 1, total overlap. The complexity of the sampling distribution of this equation prohibits calculation of confidence intervals around the point estimate (Maurer 1982).

Two spatially separate species may exhibit high overlap of microhabitat use if they are recorded in similar habitats. To better evaluate microhabitat-use overlap, I calculated spatial overlap between pairs of species by habitat and by year using Horn's index (Horn 1966). A value of zero indicates no stations in common for a pair of species and 1.0 indicates identical capture distributions. For each pairwise combination of species, numbers of trapping stations recording just one of the species and both species were used in calculating the index. Only data from stations considered in the microhabitat-use ordination analysis were used in calculating spatial overlap.

RESULTS

Vegetative Conditions

Selected vegetative attributes of stands before and after thinning (1999) are shown in Table 1. Thinning obviously reduced total stem density, softwood basal area, and overstory cover in proportion to thinning intensity. For all treatments, tree growth resulted in more larger stems (>50-cm dbh) in 1999 compared to the pre-treatment period. Also, although hardwood density decreased on all thinning treatments, basal area of these stems slightly increased in response to the more open canopy conditions. Percent herbaceous cover also positively responded to decreasing residual density. Moss and shrub cover decreased in thinned stands, with post-treatment means corresponding to the intensity of the thinning. Reduction in shrub cover was due to incidental removal and mechanical damage during thinning operations. Moss cover was also disturbed somewhat during thinning operations, but it is also likely that increased temperature and lower moisture content at ground level contributed to its reduction. Sapling density also decreased in thinned stands but post-treatment means were inversely related to overstory cover. Mean basal area of stumps (based on diameter at ground-height [dgh]) <100cm dgh increased on all thinning treatments, with higher amounts on the heavy and light-thin with gaps stands compared to the light-thin treatment. There were large increases in mean total log volume (>7.6-cm large-end diameter) between measurement periods. From comparisons with mean volume of large (>60-cm large-end diameter) logs, increases were attributed to log pieces <60-cm. The amount of these increases (ca. 50-100m^3/ha) is somewhat suspect, and likely is a confounding result from using different sampling methods. Trends in mean volume of >60-cm pieces seemed more reasonable. Mean volume of >60-cm pieces decreased on the control by ca. 17 m^3/ha and by 36 m^3/ha on the heavy-thin stand, but increased 30m^3/ha in the light-thin treatments. Using the pre- and post-treatment difference on the control as a measure of sampling error and to adjust trends on other treatments leads to a more interpretable assessment of log-

Table 1. Mean (se) vegetative conditions of treatments before and after thinning, the Young Stand Thinning and Diversity Study. Pre-treatment measures were recorded 1991-94. Post-treatment measures recorded in 1999, except for downed-wood and stumps (1997-98).

Treatment period/ treatment	Total tree density (no./ha)	Tree density, >12.7-30 cm dbh (no./ha)	Tree density , >30-50 cm dbh (no./ha)	Tree density, >50-cm dbh (no./ha)	Basal area of softwoods (m^2/ha)	Density of hardwood trees (no./ha)	Basal area of hardwood trees (m^2/ha)	Overstory cover (%)
Pre-treatment/								
Control	664.3 (96.47)	499.1 (90.49)	158.2 (15.77)	7.0 (3.79)	32.5 (3.20)	23.4 (4.30)	1.1 (0.55)	64.6 (3.73)
Heavy Thin	584.8 (123.55)	388.4 (97.19)	191.0 (31.14)	5.5 (5.53)	33.5 (5.94)	27.7 (16.39)	0.7 (0.43)	64.4 (6.12)
Light Thin	649.2 (13.25)	455.8 (28.66)	185.1 (37.04)	8.4 (6.30)	34.0 (3.66)	72.7 (27.83)	2.0 (0.97)	66.9 (4.44)
Light Thin w/gaps	599.1 (23.62)	399.9 (20.88)	192.6 (28.85)	6.5 (3.03)	34.4 (2.12)	58.2 (25.22)	1.0 (0.46)	66.7 (2.53)
Post-treatment/								
Control	617.6 (48.61)	358.7 (48.70)	232.2 (28.73)	26.8 (11.59)	45.9 (3.70)	18.4 (7.13)	0.6 (0.24)	78.9 (1.86)
Heavy Thin	147.0 (29.58)	42.7 (22.71)	89.0 (4.84)	15.3 (6.09)	15.8 (1.79)	18.5 (17.88)	0.7 (0.75)	34.7 (8.10)
Light Thin	260.8 (40.31)	106.2 (31.88)	133.2 (13.96)	21.3 (5.85)	23.8 (2.08)	47.9 (29.22)	2.2 (1.62)	58.2 (5.98)
Light Thin w/gaps	204.9 (21.54)	78.0 (23.67)	109.2 (10.62)	17.7 (7.85)	19.4 (1.65)	31.8 (15.68)	1.2 (0.70)	48.0 (2.57)

Treatment period/ treatment	Herbaceous cover (%)	Moss cover (%)	Low evergreen shrub cover (%)	Sapling density (no./ha)	Basal area of stumps <50-cm dgh (m^2/ha)*	Basal area of stumps >50-100 cm dgh (m^2/ha)*	Basal area of stumps >100 cm dgh (m^2/ha)*	Snag basal area (m^2/ha)
Pre-treatment/								
Control	10.2 (4.71)	26.8 (4.17)	28.2 (6.70)	323.7 (157.35)	0.2 (0.06)	1.8 (0.64)	9.1 (1.42)	1.0 (0.40)
Heavy Thin	8.6 (1.49)	27.9 (10.88)	31.3 (13.64)	401.0 (271.85)	0.2 (0.04)	1.5 (0.58)	8.1 (1.63)	3.1 (1.75)
Light Thin	5.6 (0.75)	41.7 (10.82)	30.1 (7.71)	182.7 (91.49)	0.2 (0.03)	1.4 (0.43)	9.1 (1.19)	3.4 (1.63)
Light Thinw/gaps	8.2 (2.52)	43.3 (13.30)	54.8 (19.25)	215.3 (77.29)	0.2 (0.03)	1.5 (0.40)	8.6 (1.41)	1.2 (0.95)
Post-treatment/								
Control	9.9 (3.19)	24.8 (4.80)	13.2 (4.73)	617.6 (405.88)	0.2 (0.07)	1.8 (0.64)	9.1 (1.42)	0.9 (0.42)
Heavy Thin	19.1 (6.63)	10.4 (4.94)	10.4 (3.42)	241.8 (180.14)	3.2 (0.61)	3.1 (0.52)	8.3 (1.70)	0.7 (0.53)
Light Thin	14.9 (3.60)	19.8 (5.62)	12.8 (2.91)	112.4 (51.54)	2.5 (0.41)	2.4 (0.45)	9.2 (1.20)	1.2 (1.14)
Light Thin w/gaps	16.7 (3.66)	16.0 (6.85)	12.4 (4.11)	138.6 (63.59)	3.1 (0.37)	3.1 (0.65)	8.9 (1.46)	0.6 (0.28)

Table 1. Cont'd

Treatment period/ treatment	Log volume, >7.6-cm large-end diameter (m^3/ha)	Log volume, >60-cm large-end diameter (m^3/ha)	Log volume, >60-80 cm large-end diameter (m^3/ha)	Log volume >80-cm large-end diameter (m^3/ha)
Pre-treatment/				
Control	261.6 (66.16)	205.7 (59.50)	(large logs recorded only as >60-cm in pre-treatment sample)	
Heavy Thin	252.4 (42.01)	189.8 (44.30)		
Light Thin	243.1 (62.33)	183.3 (60.35)		
Light Thinw/gaps	272.4 (44.70)	206.4 (32.10)		
Post-treatment/				
Control	360.4 (60.46)	188.9 (53.73)	94.4 (26.75)	94.5 (34.26)
Heavy Thin	303.1 (37.78)	152.8 (29.94)	85.4 (20.26)	67.4 (25.90)
Light Thin	348.5 (79.95)	213.8 (59.35)	90.0 (27.86)	123.8 (31.94)
Light Thin w/gaps	365.9 (48.76)	238.3 (36.67)	88.0 (10.86)	150.3 (30.55)

* basal area based on diameter at ground height

volume trends. The increase in mean log volume (>60 cm) on the stands receiving both light-thin treatments was likely due to residual boles and branches resulting from thinning operations. The decrease on the heavy thin can be attributed to removal of downed-wood during site preparation for underplanting.

Ground-dwelling Vertebrates

A total of 4669 captures were made of 11 species of small mammal, two mustelids (short-tailed weasel and spotted skunk) and nine species of amphibians (Table 2). Additionally, incidental captures of two vole (long-tailed and Richardon's) and two shrew species (vagrant and Baird's) were recorded, but species identification is questionable. Also, two species of brown shrews - the fog shrew (*Sorex sonomae*) and Pacific shrew (*S. pacificus*) - were recorded. Because distinguishing between these two species in the field is difficult, captures of brown shrews were recorded as *Sorex spp.* In both the pre- and post-treatment periods, the deer mouse was the most common mammal recorded and accounted for 34-43% of the individuals captured. Trowbridge's shrew was the second most common species recorded, accounting for 22-32% of the individuals captured, followed by Townsend's chipmunk which comprised 8-23% of the total number of recorded individuals. Ensatina was the most dominant amphibian species recorded, accounting for 75% of amphibian captures.

There were three general trends in capture rates (Table 3, Fig. 2.). First, mean capture rates across all treatments were noticeably higher in 1998 compared to pre-treatment levels for the deer mouse, Trowbridge's shrew, and Townsend's chipmunk. For the later two species, mean capture rates in 1999 generally exceeded those of the pre-treatment period. Second, relative densities on the control treatment noticeably differed between the pre- and post-treatment periods for four species. Mean capture rates on the control for the Pacific and fog shrew aggregate, the northern flying squirrel, and the shrew-mole were generally higher in the post-treatment than the pre-treatment period. The opposite trend was evident for ensatina and somewhat for the creeping vole. Third, a decline in mean capture rates on all treatment types between 1998 and 1999 was evident for the deer mouse, the Pacific and fog shrew aggregate, and generally for the Trowbridge's shrew. Weather conditions during the 1999 trapping period differed from the other three years of sampling. This trapping period was unseasonably dry and warm and preceded by a heavy winter snow pack and late summer. These weather conditions potentially lowered population densities or influenced species' activity levels and their susceptibility to capture in 1999 compared to previous years. Somewhat similar declines in these species were observed in another small-mammal study conducted in the Willamette National Forest (Garman 2000). The western red-backed vole exhibited a substantial decline in the post-treatment period of the study on all treatment types. This species comprised 13 .7% of the total number of recorded individuals prior to thinning, but only 0.7% of captures in the post-treatment period. Reasons for this decline are unclear. However, a similar decline over the past several years has been observed in 80-yr old Douglas-fir forests and recent clear-cuts in the Willamette National Forest (Garman 2000).

Table 2. Numbers of marked individuals and total captures by species, by pre- and post-treatment sampling periods, Young Stand Thinning and Diversity Study. Pre-treatment sampling was conducted Fall 1991-92; post-treatment sampling was conducted Fall 1998-99.

	Pre-treatment		Post-treatment	
Species	No. individuals	No. captures	No. individuals	No. captures
		Mammals		
Coast mole	7	8	4	5
Shrew-mole	6	6	14	14
Marsh shrew	2	2	1	1
Sorex spp. (Pacific & fog)	115	126	141	149
Sorex *	5	6	0	0
Trowbridge's shrew	378	396	824	846
Western red-backed vole	229	307	19	24
Microtus spp.**	2	2	0	0
Oregon/creeping vole	18	19	35	41
Bushy-tailed wood rat	0	0	3	4
Deer mouse	725	1610	866	1946
Townsend's chipmunk	137	285	588	1394
Northern flying squirrel	44	63	21	23
Douglas's squirrel	0	0	1	1
Short-tailed weasel	3	3	2	2
Western spotted skunk	1	1	0	0
Total Mammals	1672	2834	2519	4550
		Amphibians		
Northwestern salamander	4	4	6	6
Clouded salamander	2	3	0	0
Pacific giant salamander	1	1	5	5
Ensatina	41	41	88	88
Dunn's salamander	1	1	0	0
Rough-skinned newt	4	4	15	15
Red-legged frog	0	0	3	3
Tailed frog	0	0	1	1
Western toad	0	0	1	1
Total Amphibians	53	54	119	119

* Questionable identification - recorded as Baird's and vagrant shrews

** Questionable identification - recorded as long-tailed and Richardson's voles

Table 3. Mean (se) capture rates (no. individuals/1000 TN) of ground-dwelling vertebrates by treatment and year, Young Stand Thinning and Diversity Study. Means based on four replicates. Pre-treatment sampling was conducted in 1991-92; post-treatment sampling was conducted 1998-99. Note: means for 1991-92 under Thinning treatment were from stands assigned to receive the corresponding treatment but were untreated during this period.

			Thinning treatment		
Species	Year	Control	Heavy	Light	Light w/gaps
Deer mouse	91	17.0 (10.5)	27.4 (10.6)	30.7 (2.7)	28.8 (11.4)
	92	17.2 (3.3)	42.2 (10.1)	34.7 (11.6)	36.5 (14.6)
	98	29.9 (9.2)	74.8 (8.0)	98.9 (24.9)	102.3 (25.9)
	99	4.3 (4.9)	26.6 (19.0)	14.8 (14.3)	13.4 (6.0)
Ensatina	91	9.8 (2.1)	7.5 (3.7)	16.4 (1.4)	3.8 (2.8)
	92	6.3 (2.8)	3.8 (4.3)	0.0 (0.0)	3.8 (2.8)
	98	1.7 (1.1)	8.4 (5.8)	15.1 (3.4)	13.4 (7.7)
	99	4.4 (3.0)	7.7 (4.3)	8.3 (3.7)	4.4 (2.5)
Trowbridge's shrew	91	11.9 (3.9)	11.9 (5.7)	9.7 (0.7)	7.4 (2.6)
	92	10.5 (5.4)	17.4 (9.1)	15.3 (7.7)	13.6 (8.6)
	98	41.1 (4.3)	24.2 (4.4)	39.5 (3.5)	30.2 (3.6)
	99	29.2 (4.5)	12.3 (3.5)	12.9 (3.4)	28.0 (9.9)
Sorex spp.*	91	3.8 (1.5)	2.0 (1.0)	4.0 (2.3)	2.8 (1.6)
	92	6.9 (2.5)	3.5 (3.0)	6.1 (3.1)	8.5 (4.1)
	98	9.7 (2.6)	4.5 (1.2)	8.7 (2.8)	6.7 (2.0)
	99	5.1 (3.4)	0.2 (0.3)	1.1 (1.2)	4.1 (3.4)
Northern flying squirrel	91	0.0 (0.0)	0.3 (0.4)	4.8 (4.1)	2.6 (2.5)
	92	0.9 (1.1)	1.3 (1.5)	3.0 (3.5)	1.7 (1.9)
	98	0.9 (1.0)	0.0 (0.0)	0.5 (0.5)	0.0 (0.0)
	99	5.0 (3.4)	0.0 (0.0)	1.4 (1.6)	0.3 (0.4)
Townsend's chipmunk	91	0.0 (0.0)	8.3 (8.2)	3.1 (3.1)	7.5 (7.2)
	92	4.0 (2.7)	5.8 (3.1)	7.2 (5.7)	9.6 (6.3)
	98	26.0 (16.0)	27.8 (4.6)	33.8 (19.0)	32.5 (9.9)
	99	15.7 (9.3)	32.0 (6.8)	28.6 (14.7)	38.0 (18.2)
Shrew-mole	91	0.3 (0.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	92	0.3 (0.3)	0.5 (0.3)	0.5 (0.6)	0.0 (0.0)
	98	0.6 (0.4)	0.8 (1.0)	0.3 (0.3)	0.8 (1.0)
	99	0.7 (0.5)	0.0 (0.0)	0.0 (0.0)	0.5 (0.3)
Oregon vole	91	1.8 (2.1)	1.3 (1.1)	0.8 (0.9)	0.5 (0.6)
	92	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	98	0.8 (0.6)	1.4 (0.8)	0.9 (0.6)	0.6 (0.4)
	99	0.0 (0.0)	1.5 (0.6)	1.7 (1.3)	1.5 (0.7)

Table 3. Cont'd

Species	Year	Control	Thinning treatment: Heavy	Light	Light w/gaps
Western red-backed vole	91	3.8 (2.6)	5.4 (3.3)	3.2 (2.7)	3.8 (2.5)
	92	6.4 (4.0)	10.4 (4.9)	10.8 (5.8)	14.9 (11.6)
	98	1.1 (0.5)	1.4 (1.0)	0.3 (0.3)	0.9 (0.6)
	99	1.3 (0.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

* Pacific and fog shrews

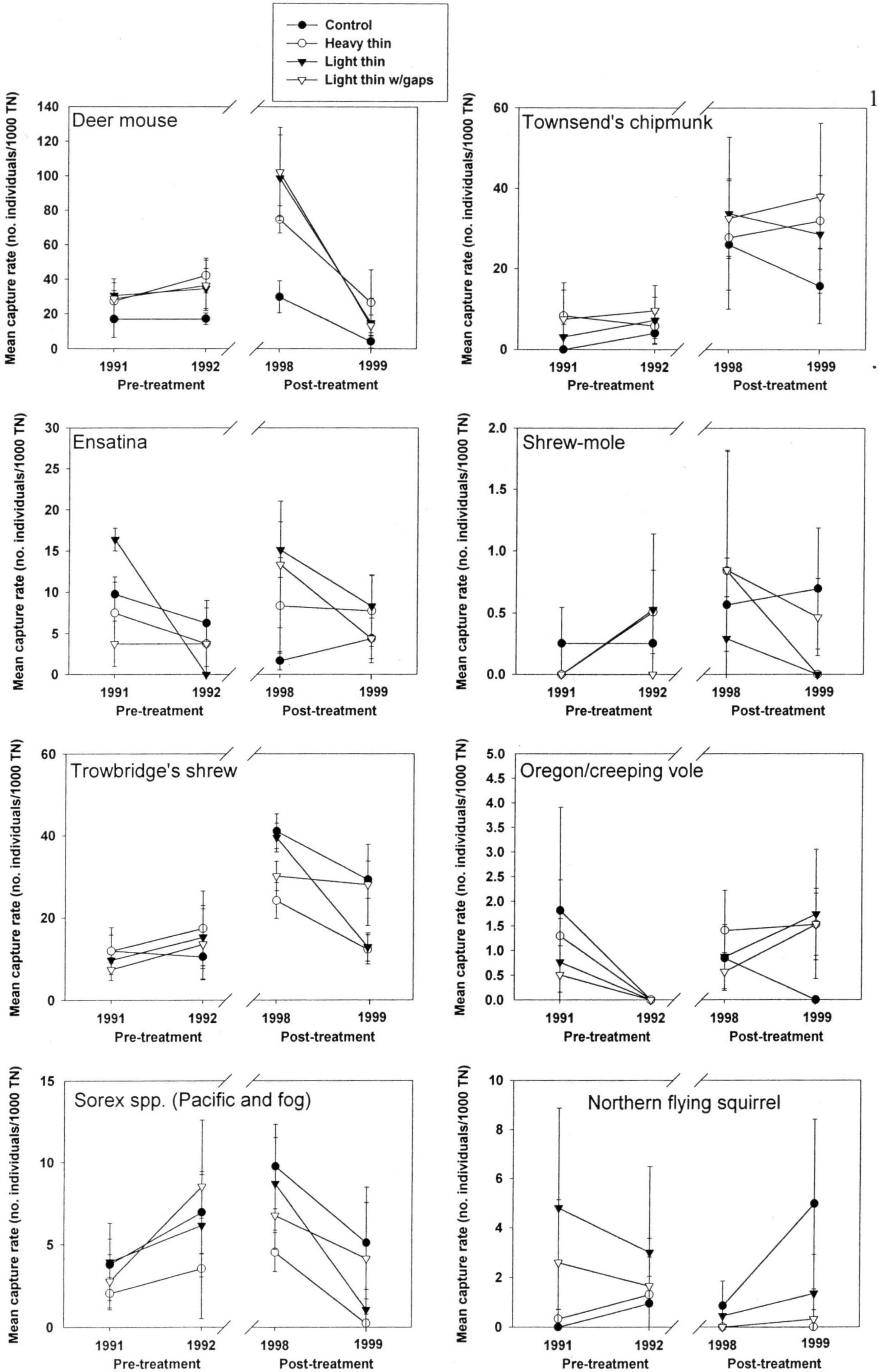

Fig. 2. Mean capture rate of small mammals and ensatina in 2 pre- and 2 post-treatment years, Young Stand Thinning and Diversity Study.

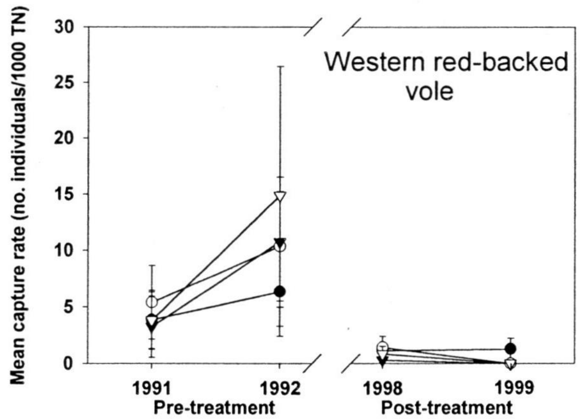
Mean capture rate (no. individuals/1000 TN)
30
25
20
15
10
5
0
Western red-backed vole
1991
1992
Pre-treatment
1998
1999
Post-treatment

Fig. 2. Cont'd.

ANOVA Results

Capture Rates

Only eight small mammal and one amphibian species had suitable sample sizes for meaning analysis of capture rates (Table 3). Of these, only the deer mouse, ensatina, and Trowbridge's shrew exhibited a statistically significant numerical response to thinning treatments (Table 4, Fig. 2). The relative abundance of the deer mouse increased in the two light thin treatments in 1998. The decline in captures of this species in all treatments in 1999 (Fig. 2) overshadowed the increase observed the year before. This led to the non-significant Pre - Post contrast. The same trend was evident for ensatina, with a significant increase in capture rates in the two light-thin treatments only in 1998 (Table 4, Fig. 2). Trowbridge's shrew exhibited the strongest, consistent response to thinning. Capture rate of this species was significantly lower in the heavy thin treatment across both years of post-treatment sampling compared to the control. This occurred despite a general increase in capture rates on all treatments between the pre- and post-treatment sampling periods (Table 3, Fig. 2). All contrasts of pre-treatment vs. 1999 means were not significant (*P*s>0.10).

Species' Diversity

Diversity measures were derived using only the positively identified small mammal species - the limited data for amphibians prohibited meaningful analysis. Mean species' diversity differed between the pre- and post-treatment periods ($F_{3,36} = 3.43$, P=0.027), and significantly increased in the light-thin with gap treatment ($F_{1,36} = 4.12$, P= 0.049) (Fig. 3). Closer inspection of the data indicated this increase resulted from greater equity of species in the post-treatment sample.

Recapture Rate, Sex Ratio, and Body Mass

There were no significant (*P*s > 0.2) differences in mean recapture rate and mean percentage of males between pre- and post-treatment periods for any species. General trends in recapture rates included a decrease for shrew species (Table 5), similar rates between periods for the deer mouse, and about a two-fold increase for Townsend's chipmunk. The mean percentage of males decreased between these periods for the deer mouse and generally increased for the Townsend's chipmunk (Table 6). Mean body mass for the deer mouse increased between pre- and post-treatment periods except in the heavy-thin treatment which was significantly (*P*= 0.013) lower in the post-treatment period (Table 7). Mean body mass was not significantly different (*P*s >0.2) between treatment periods for the other species analyzed.

Table 4. Repeated measures ANOVA and contrasts of ground-dwelling species capture rates (no. individuals/1000 TN), Young Stand Thinning and Diversity Study. Pre-treatment sampling was conducted 1991-92; post-treatment sampling was conducted 1998-99.

	Treatment X Year	*P* values for Pre - Post treatment contrast				*P* values for Pre - 1998 Post treatment contrast			
			Contrast of CN* with:				Contrast of CN* with:		
Species	*P*	Pre - Post	HT	LT	LTw/gaps	Pre - 1998	HT	LT	LTw/gaps
Deer mouse	0.049	0.258	-	-	-	0.006	0.119	0.004	0.002
Ensatina	0.016	0.119	-	-	-	0.046	0.124	0.027	0.009
Trowbridge's shrew	0.036	0.016	0.002	0.106	0.394	0.049	0.011	0.711	0.188
*Sorex spp.***	0.934	-	-	-	-	-	-	-	-
Townsend's chipmunk	0.988	-	-	-	-	-	-	-	-
Shrew-mole	0.756	-	-	-	-	-	-	-	-
Oregon/creeping vole	0.381	-	-	-	-	-	-	-	-
Northern flying squirrel	0.311	-	-	-	-	-	-	-	-
Western red-backed vole	0.924	-	-	-	-	-	-	-	-

NOTE: for contrasts; df = 9,36 for Treatment X Year interaction; df=3,36 for Pre - Post and for Pre - 1998; df=1,36 for contrasts of CN with the 3 thinning treatments.

* CN = control; HT = heavy thin; LT = light thin; LTw/gaps = light thin with gaps.

** Pacific and fog shrews

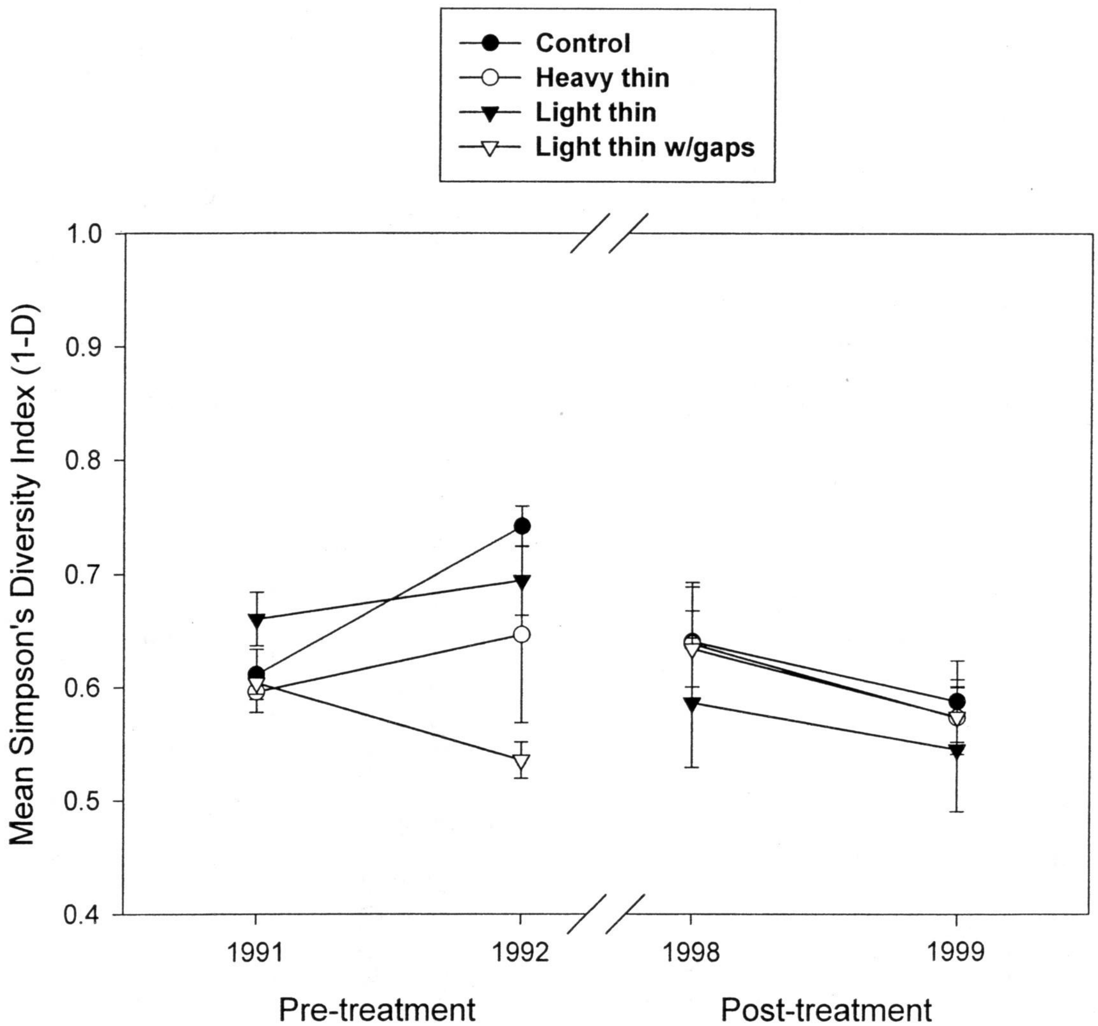

Fig. 3. Mean (se) Simpson's Diversity Index for small-mammal species by treatment and year, Young Stand Thinning and Diversity Study.

Table 5. Mean (se) recapture rate ((no. recaptures/total captures) *100) of four species of small mammals, Young Stand Thinning and Diversity Study. Pre-treatment means based on combined data from 1991-92 (4 replicates per treatment); post-treatment means based on combined data from 1998-99 (4 replicates per treatment).

	Pre-treatment				Post-treatment			
Species	Control	Heavy	Light	Light/gaps	Control	Heavy	Light	Light/gaps
Trowbridge's shrew	7 (4.1)	1 (1.2)	3 (2.2)	2 (2.8)	3 (1.3)	1 (0.9)	2 (1.1)	3 (1.9)
Sorex spp.*	13 (2.6)	0 (0.0)	13 (8.2)	5 (3.9)	5 (3.6)	4 (4.8)	4 (4.1)	1 (1.4)
Deer mouse	54 (6.7)	44 (17.3)	31 (11.7)	40 (15.7)	51 (2.6)	46 (16.2)	41 (16.1)	39 (14.4)
Townsend's chipmunk	28 (22.6)	36 (22.1)	32 (20.2)	27 (22.3)	47 (6.6)	57 (6.9)	53 (9.0)	60 (4.4)

* Pacific and fog shrew combined

Table 6. Mean (se) percentage of males ((no. males /total no. individuals) *100) of two species of small mammals, Young Stand Thinning and Diversity Study. Pre-treatment means based on combined data from 1991-92 (4 replicates per treatment); post-treatment means based on combined data from 1998-99 (4 replicates per treatment).

	Pre-treatment				Post-treatment			
Species	Control	Heavy	Light	Light/gaps	Control	Heavy	Light	Light/gaps
Deer mouse	55 (4.4)	48 (5.4)	54 (6.7)	51 (5.4)	33 (8.6)	39 (3.4)	48 (3.8)	51 (6.3)
Townsend's chipmunk	20 (28.3)	74 (15.8)	20 (16.3)	61 (24.5)	43 (11.6)	41 (6.3)	46 (6.2)	47 (5.2)

Table 7. Mean body mass of five species of ground-dwelling vertebrates, by thinning treatment, Young Stand Thinning and Diversity Study. Pre-treatment means based on combined data from 1991-92; post-treatment means based on combined data from 1998-99.

	Pre-treatment												Post-treatment											
	Control			Heavy			Light			Light/gaps			Control			Heavy			Light			Light/gaps		
Species	X	se	n	X	se	n	X	se	n	X	se	n	X	se	n	X	se	n	X	se	n	X	se	n
Deer mouse	15.3	(0.36)	101	15.0	(0.24)	207	15.1	(0.22)	188	15.5	(0.25)	189	16.2	(0.37)	81	14.6	(0.22)	261	15.9	(0.20)	273	15.5	(0.19)	241
Townsend's chipmunk	71.9	(7.49)	10	78.1	(1.29)	42	83.0	(1.97)	27	79.9	(0.99)	50	82.4	(0.89)	105	81.2	(0.73)	161	79.8	(0.71)	159	81.0	(0.63)	172
Trowbridge's shrew	4.5	(0.08)	41	4.3	(0.08)	45	5.1	(0.85)	43	4.7	(0.37)	34	4.5	(0.06)	237	4.7	(0.07)	125	4.6	(0.08)	154	4.4	(0.06)	206
*Sorex spp.**	6.4	(0.40)	18	6.0	(0.40)	5	10.2	(3.87)	17	7.2	(0.67)	10	7.0	(0.35)	51	6.0	(0.29)	15	6.1	(0.23)	31	6.4	(0.37)	35
Ensatina	2.3	(0.43)	12	8.5	(6.86)	5	2.5	(0.23)	6	3.0	(0.37)	4	2.9	(0.80)	7	7.2	(4.77)	18	3.1	(0.43)	13	3.5	(0.43)	17

* Pacific and fog shrews

Table 8. Results of regressing differences (post-treatment minus pre-treatment) in species' capture rates on differences in habitat variables, Young Stand Thinning and Diversity Study. Species' capture rates were averages from the two years of sampling in the pre-treatment and in the post-treatment periods. The sign indicates the slope of the relationship between changes in capture rate and a habitat variable.

Species	Sign	Partial R^2	Variable
Trowbridge's shrew	-	0.226	density (no./ha) of hardwood trees
	+	0.159	percent overstory cover
Sorex spp. *	+	0.464	percent moss cover
Deer mouse	+	0.383	basal area (m^2/ha) of stumps <30-cm dgh
	+	0.177	log volume (m^3/ha) (>60-80 cm large-end diameter)
	-	0.145	percent moss cover
Oregon/creeping vole	-	0.527	density (no./ha) of saplings (<3-m tall)
	-	0.120	log volume (m^3/ha) (>60-80 cm large-end diameter)
	-	0.133	basal area (m^2/ha) of stumps <50 cm dgh
Townsend's chipmunk	-	0.668	density (no./ha) of hardwood trees
	-	0.158	percent moss cover
Ensatina	+	0.415	basal area (m^2/ha) of hardwood trees
	-	0.145	percent low-evergreen shrub cover
	-	0.131	snag basal area (m^2/ha)

* Pacific and fog shrews

Habitat Relations

Only six species had sufficient data for analyzing changes in capture rates and habitat conditions (Table 8). Capture rates for shrew species were essentially directly correlated with decreasing differences in moss and overstory cover between the post- and pre-treatment periods. The deer mouse positively responded to stands with more basal area of smaller stumps, more volume of large (>60-cm) downed wood, and less moss cover after thinning than before. Given these trends for the deer mouse, the decrease in mean volume of large downed-wood on the heavy-thin treatment partly explains the lack of a significant response to this treatment. Capture rates for the Townsend's chipmunk increased with increasing loss of moss cover and hardwood tree density. The creeping vole exhibited a similar trend with increasing reduction of sapling density, log volume (60-80 cm), and basal area of smaller stumps (<50-cm dgh). Increases in the basal area of hardwood trees and decreases in evergreen shrub cover were correlated with increasing capture rates for the ensatina.

Table 9. Results of regression analysis of species' capture rates on habitat variables of the post-treatment stands, Young Stand Thinning and Diversity Study. Capture rates were averages of the two post-treatment sampling years; habitat data were collected in 1999. The sign indicates the slope of the relationship between mean capture rate and a habitat variable.

Species	Sign	Partial R^2	Variable
Trowbridge's shrew	+	0.335	percent moss cover
	+	0.285	basal area (m^2/ha) of stumps >100-cm dgh
Sorex spp. *	+	0.344	percent moss cover
	-	0.211	percent low-evergreen shrub cover
	+	0.165	log volume (m^3/ha) (>80-cm large-end-diameter)
	+	0.082	density (no./ha) of trees >50-cm dbh
Deer mouse	+	0.648	basal area (m^2/ha) of hardwood trees
	-	0.219	density (no./ha) of trees >30-50 cm dbh
Oregon/creeping vole	+	0.265	basal area (m^2/ha) of hardwood trees
	-	0.162	percent overstory cover
Townsend's chipmunk	+	0.262	log volume (m^3/ha) (>7.6-cm large-end diameter)
	+	0.238	basal area (m^2/ha) of stumps >50-100 cm dgh
Northern flying squirrel	+	0.525	basal area (m^2/ha) of softwood trees
	-	0.096	density (no./ha) of saplings (<3-m tall)
Ensatina	+	0.326	basal area (m^2/ha) of hardwood trees
	-	0.169	density (no./ha) of trees ≤30-cm dbh
	-	0.146	log volume (m^3/ha) (>7.6 cm large-end diameter)

* Pacific and fog shrew

Habitat relations in the post-treatment period are shown in Table 9 for the seven species with suitable data for meaningful analysis. Shrew species were positively associated with closed-canopy conditions typified by moss cover but an open ground layer with dead-wood in the form of stumps and logs. Both the deer mouse and the creeping vole were associated with hardwood basal area and open-canopy conditions. Similarly, ensatina was positively related to hardwood basal area, but negatively correlated with total log volume and density of small trees. The noticable difference in hardwood basal area between the heavy thin and the other thinning treatments helps to explain the lack of a significant response by the deer mouse and ensatina to this treatment. Capture rates for the Townsend's chipmunk were positively associated with dead wood features. Not surprisingly, capture rates for the northern flying squirrel were positively correlated to size and density of softwood trees, but negatively to sapling density. Overstory conditions are of course important to flying squirrels; a dense understory tree layer can impede gliding and is often avoided (Bendel and Gates 1987).

Microhabitat Use

The PCA ordination of trap stations used in the microhabitat assessment is shown in Fig. 4. The primary gradient (Axis I) corresponds to obvious effects of the thinning treatments, but only accounted for 21% of the variance. The secondary axis (II) only accounted for an additional 13% of the variance. The primary axis represented a gradient in overstory conditions, and in density of stumps and shrub cover. Percent deciduous shrub cover was correlated with increased thinning level which contradicts findings of the more extensive vegetative survey (e.g., Table 1). Given that only five stands were included in this analysis, this probably reflects localized conditions and not the overall trend among treatment replicates. Stations from the light thin and light thin with gap stands tended to cluster in the center of the multivariate space, and the other two treatments were at opposite extremes of this space. Overlap in microhabitat conditions was greatest for the light-thin treatments. Also, stations located in or near the gaps in the light-thin with gaps stand tended to be similar to those of the heavy-thin stand.

Only four species had sufficent data for analysis of microhabitat use (Fig. 5). Overlap in microhabitat-use among species was relatively high (>0.90), with the congeneric shrew species having the lowest degree of overlap (0.80). Also, the confidence ellipses of all species included the origin of the PCA space, indicating little difference from a random sample. Qualitative differences in habitat preferences were, however, somewhat evident. The deer mouse and Townsend's chipmunk generally used open canopy sites with deciduous shrub cover characteristic of the thinned stands (compare with Fig. 4). This contrasts with the shrew species which showed greater preference for overstory, log, and shrub cover characteristic of the control stand and limited use of especially the heavy-thin stand.

Spatial overlap also was relatively low among species (Table 10). The overlap index exceeded 0.5 for only the deer mouse and Trowbridge's shrew. The congeneric shrew species only exhibited 46% spatial overlap.

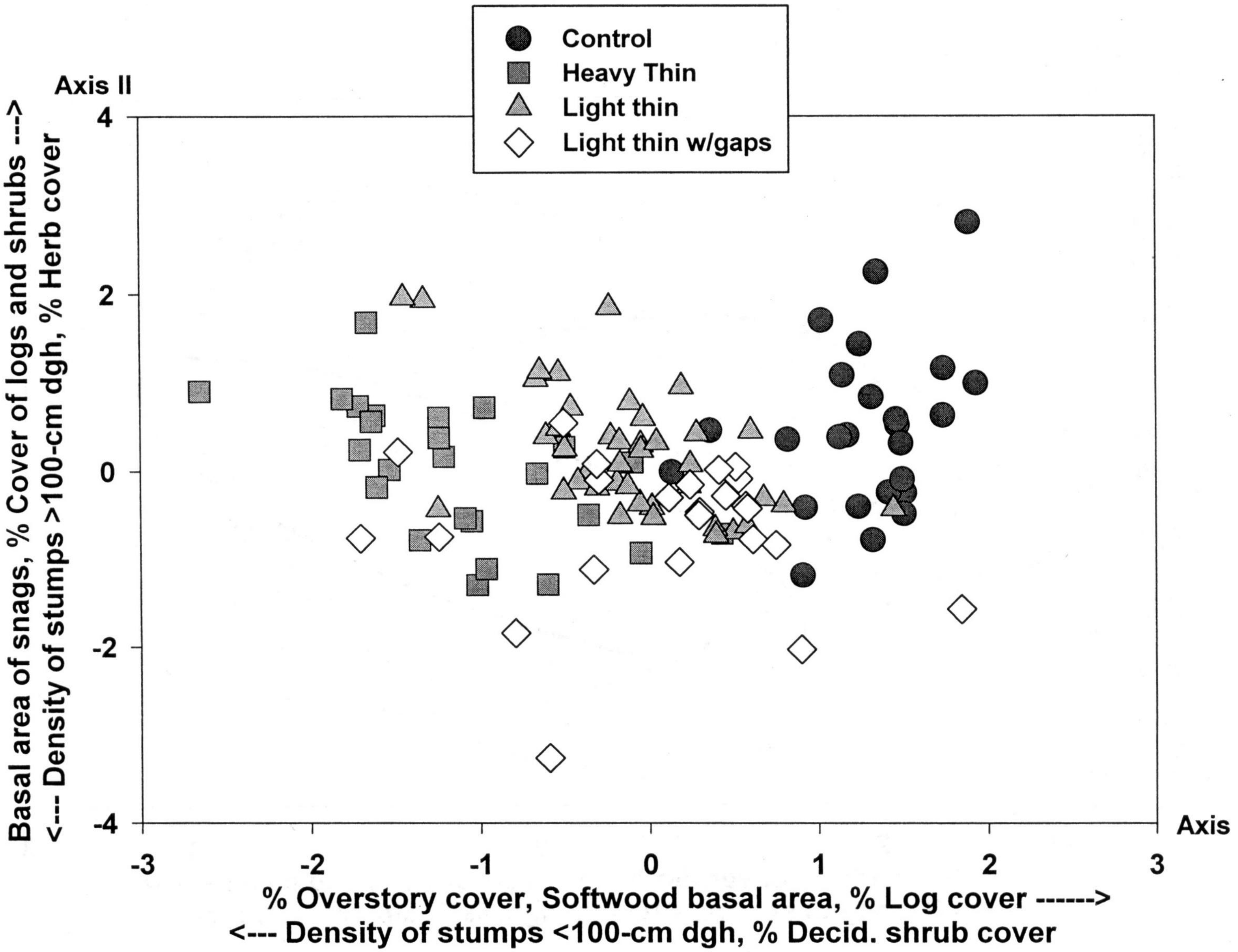

Fig. 4. Principal component ordination of microhabitat measures from five stands of the Young Stand Thinning and Diversity Study. Measures were recorded in 1999.

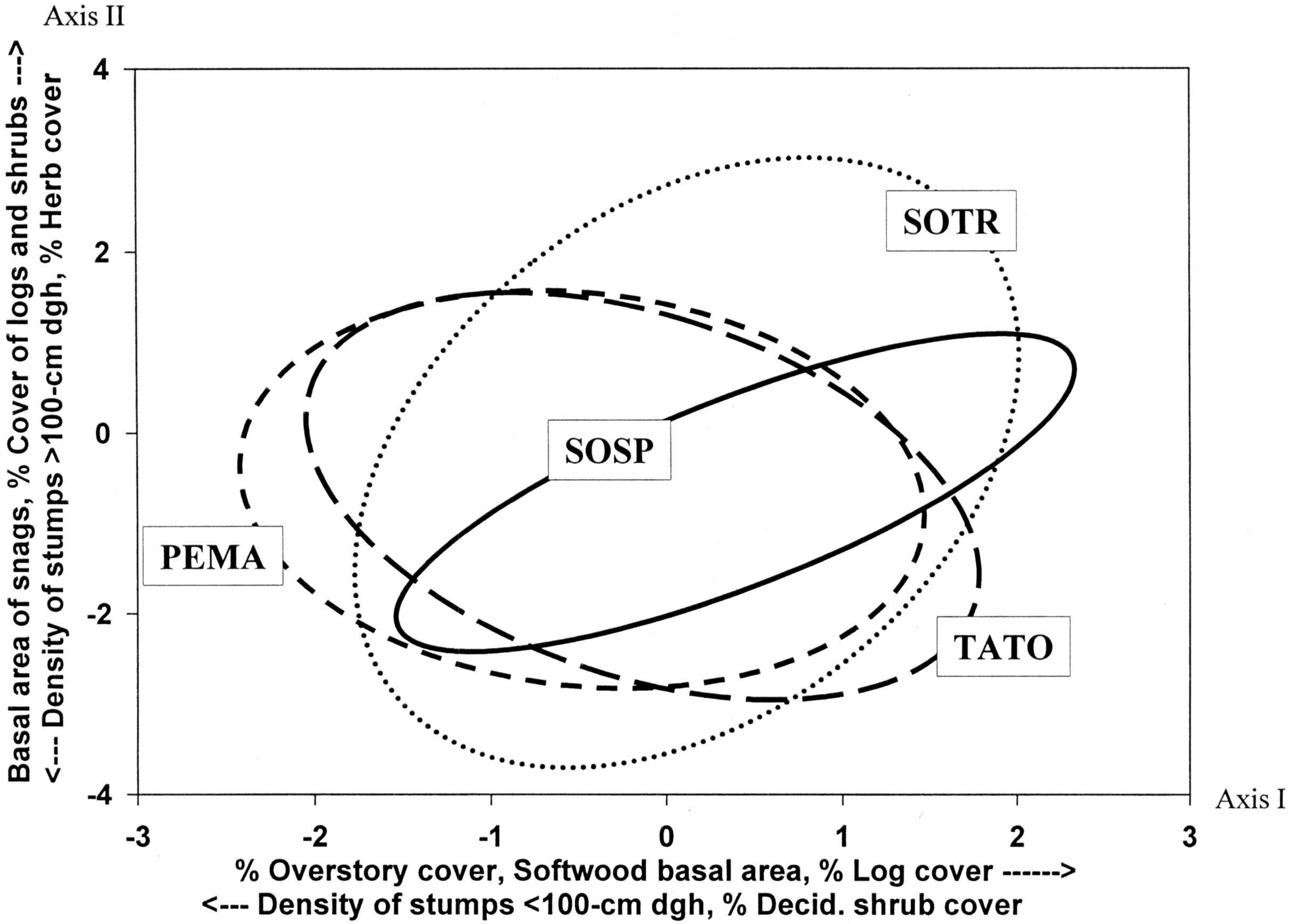

Fig. 5. Ninety-percent bivariate confidence intervals about observations of species on principal components I and II.

Table 10. Spatial overlap of four small-mammal species in 1998-99 (post-thinning) based on Horn's (1966) overlap metric, Young Stand Thinning and Diversity Study. Data used to calculate spatial overlap were from the four stands in the McKenzie Ranger District replicate block and the light-thin stand in the Blue River Ranger District replicate block. Overlap was based on frequency of stations recording just one of a pair of species and recording both species.

	Species		
Species	Townsend's chipmunk	*Sorex spp.*	Trowbridge's shrew
Deer mouse	0.4412	0.3445	**0.5450**
Townsend's chipmunk		0.3055	0.4009
Sorex spp. (Pacific & fog)			0.4586

DISCUSSION

Species Diversity

Thinning young Douglas-fir stands had little impact on the composition of the small mammal community. Mammalian species' diversity only slightly increased in the light-thin with gap stands between pre- and post-treatment periods. This increase was primarily due to higher equity of species as opposed to a substantial increase in species richness. On average, species' diversity was unaffected by the other treatments. Of the nine more commonly captured species, the shrew-mole was the only species which first appeared in a set of treatment stands after thinning. Its absence in the light-thin with gap stands prior to thinning, however, was likely a sampling artifact. Captures of this species were low in all treatments and years. It was recorded prior to thinning in stands similar in composition and structure and spatially adjacent to those assigned to the gap treatments. Excluding the northern flying squirrel, no species was eliminated from a thinning treatment. Relative abundance of the northern flying squirrel generally declined with thinning, especially in the heavy thin treatment where it was not recorded in 1998-99. A decline in abundance with increased thinning would be expected given dependence of this arboreal squirrel on trees for nesting and resting (Carey 1991, 1995). However, ground-based traps are not optimal for recording this species, and the variability in captures in both pre and post-treatment samples resulted in no statistical treatment effect. It is likely that thinning young stands to <271 TPH lowered densities of this species, but its extirpation from the heavy-thin treatment can not be definitively ascertained based on sampling methods used in this study.

Species' Relative Abundance

Of the nine species analyzed, only two exhibited a significant positive numerical response to any of the thinning treatments. The deer mice and ensatina exhibited a positive response to the light-thin treatments, at least in 1998, and captures of both were positively related to increasing hardwood basal area. The deer mouse is a habitat generalist with an extensive range in western Oregon (Csuti et al. 1997). Studies have found abundance of this species to be higher on clearcuts compared to closed-canopy forests (Gashwiler 1970; Hooven 1973; Galindo and Krebs 1985; Garman 2000). Other studies have found similar densities on forested and clearcut areas (Sullivan 1979; Cole et al. 1998). Ensatina is an upland species (Gomez 1992; McComb et al. 1993a,b) and is also found throughout western Oregon in Douglas-fir forests (Csuti et al. 1997). Studies have found abundance of this species to be similar among a range of forest age classes (Corn and Bury 1991; Gilbert and Allwine 1991), but inversely related to moisture conditions (Aubry and Hall 1991; Gilbert and Allwine 1991; Welsh and Lind 1991). Although the hardwood basal area was relatively minor across stands (Table 1), hardwood seeds provide an important food source for the deer mouse, and leaf litter of especially bigleaf maple provides important ground cover for both species. The neutral response exhibited by the deer mouse and ensatina to the heavy-thin treatment correlates with the lower mean hardwood basal area of this treatment. Proportional changes between treatment periods in mean hardwood density were relatively similar (55-66%) among thinning treatments; however, hardwood basal area changed little on the heavy-thin treatment compared to the other thinning treatments. In general, the lower hardwood component on the heavy-thin stands after implementation of the thinning treatment reflected lower initial densities.

The shrew species analyzed are denizens of mid to late-seral coniferous forests in the Pacific Northwest (Whitaker and Maser 1976; Brown 1985). Decaying litter and shrub cover are important habitat features for these species (Hooven and Black 1976; Whitaker and Maser 1976). The heavy thin treatment reduced shrub cover due to incidental removal and damage during logging. Surface-litter depth also was likely reduced due to compaction during thinning operations or due to higher decay rates afforded by the more open and warmer conditions. The reduction of these or other features was evidently sufficient for a consistent decrease in relative abundance of the Trowbridge's shrew over the two post-treatment sampling years. Why the brown shrews did not respond in a similar manner is unclear.

The lack of a significant response by other species to thinning treatments occurred for several possible reasons. An obvious reason is that although thinning noticeably affected stand conditions, key habitat features for certain species may have remained sufficiently unaltered. For instance, the Townsend's chipmunk is generally found in forest or shrub-edge habitats (Brown 1985). Studies looking at responses on clearcuts have found this species to decrease in numbers with the removal of the forest canopy (Garman 2000), and subsequently increase in abundance with the development of a tall-shrub layer (Gashwiler 1970; Hooven and Black 1976). Additionally, this species has been found to be relatively abundant in younger stands with a diverse understory and relatively high levels of residual woody debris (Doyle 1990; Rosenberg and Anthony 1993; Carey 1995). Although tree and shrub cover were reduced on the treated stands in this study, they were not totally eliminated. Given that the Townsend's chipmunk exhibited a neutral response to the thinning treatments, residual levels of these and other habitat features were evidently above some threshold level sufficient to maintain chipmunk densities comparable to the untreated control.

Another reason is that interactions among key habitat features may have confounded species' response to treatments. The creeping vole prefers grass-forb areas and has been found to be common in clearcuts after the reestablishment of ground cover (Hooven 1973; Corn and Bury 1981; Sullivan and Boateng 1996). Although herbaceous cover increased in treated stands, other ground covering features such as moss and low shrubs decreased. The net effect may have been a limited change in habitat quality. As ground and shrub cover develop in the thinned stands, however, abundance of this species is likely to increase.

Population declines independent of habitat quality also affected the ability to detect treatment effects. This was especially true for the western red-backed vole. This species prefers moist microclimates of closed-canopy forests and negatively responds to the loss of overstory and log cover (Gomez 1992; Doyle 1987). Abundance was expected to decline especially on the heavy-thin treatment. However, the overall decline in relative abundance of this vole in the post-treatment period effectively prohibited a meaningful assessment of treatment effects. The paucity of captures of deer mouse across all treatments in 1999 also limited the ability to evaluate treatment differences for that year. Additionally, insufficient sample sizes across all years limited a meaningful assessment of the response of the shrew-mole to thinning treatments.

Microhabitat-use

The microhabitat-use and spatial overlap assessment were only based on five stands and four species of small mammals. However, these preliminary results suggested little difference in microhabitat features associated with captures of species. Differences in dietary requirements may account for this similarity - deer mice are omnivorous, Townsend's chipmunk prefers seeds, and shrews are insectivores (i.e., insect eaters). Species also differ in activity periods, with the deer mouse and shrews being primarily nocturnal compared to the chipmunk which is diurnal. Overlap was lowest for the congeneric species of shrews but was still relatively high. Although general prey items are similar among these species, brown shrews are larger (ca. 2.5 g heavier) than the Trowbridge's shrew and likely consume larger prey. Thus, these species may separate along a prey-size gradient. An additional explanation for similarity in microhabitat-use may be that habitat measures were insufficient to distinguish important differences in station-level features. However, the dispersion of trapping stations in ordination space (Fig. 4) suggests that measures were representative of treatment differences in fine-scale features.

Low spatial overlap among species resulted primarily from differential preference of treatments. The deer mouse and Townsend's chipmunk were more common on treated stands than on the control in the post-treatment periods in contrast to the shrew species which exhibited the opposite trend (Fig. 2). The sample of stands used in this assessment generally reflected these differences. Combining stand-level and microhabitat-use results suggests a hierarchical selection of habitat. At the stand level, the overall amount of overstory or understory cover or the dispersion of these attributes may be the proximal factors selected for by species. But within a treatment, species used relatively similar fine-scale features.

Overstory conditions of trap stations in the remaining 11 stands will be sampled in spring 2000. Although these overstory measures will not directly overlap with the sampling efforts of 1998-99, overstory attributes will have changed little since the 1998-99 trapping efforts. Once completed, a more complete assessment of microhabitat-use and spatial overlap will be completed and reported.

SUMMARY

Thinning of young managed Douglas-fir stands had only nominal impacts on habitat quality for ground-dwelling vertebrates. The deer mouse and ensatina positively responded to the light-thin treatments in at least in one of the post-treatment years. Relative density of the Trowbridge's shrew decreased in response to heavy thinning. Responses by these species reflected noticeable changes in habitat conditions, and presumably, habitat quality. The more open canopy conditions of the thinned stands increased the amount of hardwood basal area and herbaceous cover but reduced, of course, overstory cover and associated features such as moss and shrub cover. Numerical increases by the deer mouse and ensatina were associated with the more open canopy conditions and increased hardwood-basal area. The dominance of younger deer mice on the heavy thin treatment suggests that the extensive reduction of overstory cover in concert with lower hardwood basal area and levels of large-log volume lowered habitat quality for this species compared to other treatments. Lower log volume and higher ground-level temperatures on the heavy-thin treatment likely led to the decline of Trowbridge's shrew on this treatment. It is unclear why brown shrews (*Sorex pacificus* and *S. sonomae*), which have relatively similar habitat requirements, did not respond in a similar manner. Other species analyzed lacked a measurable response to thinning treatments. In general, thinning treatments had little effect on the richness and apportionment of species, although a significant increase in diversity was detected on the light-thin with gap treatment. This increase was due primarily to greater equity of species rather than substantial changes in species richness.

Preliminary analysis indicated that shrew species, the deer mouse, and the Townsend's chipmunk exhibited extensive overlap in microhabitat-use, but low spatial overlap. Habitat-use results collectively suggest that species preferentially use areas on the basis of stand-scale features, such as the dispersion of overstory or ground cover, but are associated with fairly similar fine-scale features within a stand. Completion of the microhabitat-use analysis in combination with a spatial assessment of vegetative conditions will be essential to better determine the role of stand-level and microhabitat features in the response of ground-dwelling vertebrates to thinning young managed Douglas-fir stands.

ACKNOWLEDGMENTS

This study would not have possible without the efforts of numerous and dedicated field assistants who I sincerely thank. I thank W. McComb for his efforts in initiating this study, and L. Ganio, M. Huso, and J. Hagar for assistance with statistical analyses. Vegetation data were provided by G. Tucker and M. Duane; J. Boyle and T. Buford provided data on dead wood for the post-treatment period. This study was funded by the Cascade Center for Ecosystem Management.

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Appendix A. Common and latin names of ground-dwelling vertebrate species recorded in the Young Stand Thinning and Diversity Study.

Baird's shrew	*Sorex bairdi*
Bushy-tailed wood rat	*Neotoma cinerea*
Clouded salamander	*Aneides ferreus*
Coast mole	*Scapanus orarius*
Deer mouse	*Peromyscus maniculatus*
Douglas' squirrel	*Tamiasciurus douglasii*
Dunn's salamander	*Plethodon dunni*
Ensatina	*Ensatina eschscholtzii*
Ermine (short-tailed weasel)	*Mustela erminea*
Fog shrew	*Sorex sonomae*
Pacific & fog shrew	*Sorex spp. (S. pacificus, S. sonomae)*
Long-tailed vole	*Microtus longicaudus*
Marsh shrew	*Sorex bendirii*
Northern flying squirrel	*Glaucomys sabrinus*
Northwestern salamander	*Ambystoma gracile*
Oregon/creeping vole	*Microtus oregoni*
Pacific giant salamander	*Dicamptodon tenebrosus*
Red-legged frog	*Rana aurora*
Richardson's/water vole	*Microtus richardsoni*
Rough-skinned newt	*Taricha granulosa*
Shrew-mole	*Neurotrichus gibbsii*
Tailed frog	*Ascaphus truei*
Townsend's chipmunk	*Tamias townsendii*
Trowbridge's shrew	*Sorex trowbridgii*
Vagrant shrew	*Sorex vagrans*
Western red-backed vole	*Clethrionomys californicus*
Western spotted skunk	*Spilogale gracilis*
Western toad	*Bufo boreas*