AN ABSTRACT OF THE THESIS OF

Sally R. Butts for the degree of Master of Science in Forest Science presented on November 20, 1997. Title: Associations of Forest Floor Vertebrates with Coarse Woody Debris in Managed Forests, Western Oregon Cascades

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Forest floor vertebrate species presence and abundance may be influenced by the volume and cover of coarse woody debris (CWD) in managed forests. I studied macro- and microhabitat associations of vertebrate species in 18 closed-canopy stands ranging in CWD volume from 14 to 859 m^3/ha. Pitfall traps were used to capture small mammals and amphibians in spring and fall 1996 and spring 1997. Timed, area-constrained ground searches also were used to sample amphibians in spring 1996 and 1997.

In general, macrohabitat associations indicated amphibian captures increased with CWD volume (m^3/ha) but small mammal captures did not increase with CWD volume. Capture rates (#/1,000 trap nights) of Trowbridge's shrew (*Sorex trowbridgii*) were positively associated with fern cover and small diameter log cover (< 50 cm diameter) and negatively associated with moss cover. Fog shrew (*Sorex sonomae*) capture rates were positively associated with herb cover, with rate increases similar in thinned and unthinned stands, but lower overall capture rates in unthinned stands. Capture rates of shrew-moles (*Neurotrichus gibbsii*) were positively associated with woody plant cover and negatively associated with large diameter log cover (> 50 cm diameter). Ensatina (*Ensatina

eschscholtzii) capture rates were positively associated with total CWD volume and fern cover and negatively associated with grass cover. Ensatinas captured during timed, area-constrained ground searches were positively associated with total CWD volume and average live tree dbh (cm). Capture rates of rough-skinned newts (*Taricha granulosa*) were positively associated with bare ground cover. Clouded salamanders (*Aneides ferreus*) captured during timed, area-constrained ground searches were positively associated with total CWD volume.

In general, microhabitat associations indicated the odds of detecting ensatina and Trowbridge's shrew presence increased with CWD cover; fog shrew detection was not related to CWD cover. The presence of Trowbridge's shrew was negatively associated with moss and fern cover and positively associated with woody plant and small diameter log cover. Fog shrew presence was positively associated with herb cover. Ensatina presence was positively associated with fern and large diameter log cover and negatively associated with herb and twig cover. On average, amphibians captured during timed, area-constrained ground searches were 0.5 m from the nearest CWD, compared with 1 m between random points and the nearest CWD. My results suggest that current minimum guidelines and regulations for leaving CWD after harvest for state, private, and federal forest lands in western Oregon may not provide adequate habitat for some forest floor vertebrates, particularly terrestrial amphibians. Future research may provide additional information to evaluate minimum CWD retention guidelines for other species.

Associations of Forest Floor Vertebrates with Coarse Woody Debris in Managed Forests, Western Oregon Cascades

by

Sally R. Butts

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To my loving and supportive family.

ASSOCIATIONS OF FOREST FLOOR VERTEBRATES WITH COARSE WOODY DEBRIS IN MANAGED FORESTS, WESTERN OREGON CASCADES

INTRODUCTION

Forests managed primarily for wood resources may not provide adequate habitat for some wildlife species. Changes from natural to managed forests often result in shorter rotations and less structural diversity, including fewer snags and less coarse woody debris (CWD) (Spies and Cline 1988). These changes can impact wildlife by altering or eliminating their habitat. Alternative management schemes have been developed that incorporate the structural components missing from young, managed forests (McComb *et al.* 1993). With specific information on how particular species respond to different structural characteristics, managed forests may be able to provide sustainable wood resources and suitable habitat for wildlife. By identifying wildlife habitat associations, researchers can develop hypotheses regarding how species might respond to management, and then test these relationships in an adaptive management process.

Forests cover approximately 11 million hectares in Oregon (Oregon Dept. of Forestry 1995) and provide habitat for many small mammal and amphibian species (Maser *et al.* 1981, Blaustein *et al.* 1995). These groups contribute to forest food webs, vegetation dynamics, and biodiversity. Small mammals consume large quantities of invertebrates and plants. Amphibians also consume invertebrates, and species such as Pacific giant salamanders (*Dicamptodon tenebrosus*) may consume small mammals and other amphibians. In turn, larger mammals, reptiles, and birds prey on both groups. In addition to herbivory, small mammals and amphibians influence forest nutrient cycling and soil fertility, regulating invertebrates that decompose litter, mixing litter during travel, and burrowing in the soil (Blaustein *et al.* 1995, Burton and Likens 1975, Maser *et al.* 1981). Nutrient cycling may be enhanced by dispersal of mycorrhizal spores by western red-backed voles (*Clethrionomys californicus*) (Maser *et al.* 1978, Ure and Maser 1982). Spores are dispersed into soil through vole fecal pellets and form tuberculate mycorrhizae of conifer roots, which aid the trees in nutrient and water uptake (Maser and Trappe 1984, Trappe 1965). Furthermore, several species of small mammals and amphibians are endemic to Pacific Northwest forests, contributing to regional biodiversity (Bury 1994).

CWD (decaying logs and log pieces) provides habitat for some small mammals and amphibians (Maser *et al.* 1981, Stebbins 1954*a*). Certain decay stages and diameters of CWD are associated with the occurrence of several species (Aubry *et al.* 1988, Bury and Corn 1988, Corn *et al.* 1988, Raphael 1988). However, research that directly relates CWD volume and distribution within forest stands to vertebrate presence and abundance is lacking.

Currently, the Oregon Forest Practices Act, which regulates state and private lands, requires that 5 downed logs/ha remain in harvested areas exceeding 10 ha, if the remaining standing basal area of trees $\geq$ 28 cm dbh is < 7.6 m^2/ha (Oregon Dept. of Forestry 1996). Logs must be $\geq$ 1.8 m in length and contain a gross volume $\geq$ 0.3 m^3. Thus, 5 downed logs/ha, of 0.3 m^3/log, yields a minimum required volume of 1.5 m^3/ha (Appendix A). CWD management for federal lands in the range of the northern spotted owl (*Strix occidentalis*), is guided by the Record of Decision and Standards and Guidelines in the Northwest Forest Plan (United States Department of Agriculture (USDA), Forest Service and United States Department of Interior (USDI), Bureau of Land Management (BLM)1994). Specific guidelines are prescribed for CWD retention in harvested, regeneration areas on federal matrix lands in western Oregon; 181 linear meters of logs ($\geq$51 cm diameter)/ha should be left after harvest, for a minimum volume of 37 m^3/ha (Appendix A). However, these guidelines are only interim until plans can be developed that "provide a renewable supply of large down logs...in a manner that meets the needs of species and provides for ecological functions" (USDA, Forest Service and USDI BLM 1994:Standards and Guidelines C-40). While state and federal guidelines are a starting point in CWD management, a better understanding of the relationship between CWD and wildlife presence and abundance is needed to evaluate existing regulations and assist with developing future recommendations.

My objectives were to determine forest floor vertebrate associations at the stand level (macrohabitat) and near the site of capture (microhabitat) to provide information that could be used to develop CWD management guidelines. Results from macrohabitat associations may be more easily interpreted by forest managers, however, microhabitat associations may be more relevant to some small mammals and amphibians, because of their size and mobility, for survival, acquiring resources, and other life activities. For example, the home range of female ensatinas (*Ensatina eschscholtzii*) was estimated to be 10 m at its greatest dimension (Stebbins 1954*b*) and female western red-backed voles were estimated to spend the majority of time in areas approximately 0.02 ha (Thompson 1996).

I estimated macro- and microhabitat associations of forest floor vertebrates in managed forests of the western Oregon Cascades. I used pitfall trapping and timed, area-constrained ground searches to capture small mammals and amphibians in 18 closed-canopy stands ranging in CWD volume from 14 to 859 m^3/ha. For macrohabitat associations of individual vertebrate species, I tested the null hypothesis that capture rates (pitfall trapping) and total number of captures (timed, area-constrained ground searches) would not increase with increasing CWD volume. For microhabitat associations of individual vertebrate species, I tested the null hypothesis that the odds of detecting species presence in a pitfall trap would not increase with increasing cover of CWD. In addition, I tested 2 related amphibian microhabitat hypotheses: (1) I tested the null hypothesis that amphibian use of different decay classes of CWD was equal to the availability of different decay classes of CWD, and (2) I tested the null hypothesis that the distances between amphibians captured during timed, area-constrained ground searches and the nearest CWD were equal to distances between random points and the nearest CWD.

STUDY AREA

The study was conducted in the western Oregon Cascades on managed forest land between 43°32' and 44°16' latitude (Figure 1 and 2). This region is within the western hemlock (*Tsuga heterophylla*) vegetation zone, characterized by a moist climate and favorable growing conditions for coniferous trees (Franklin and Dyrness 1973). Annual temperatures average 8-9° C with annual precipitation averaging 150-300 cm. Forest stands selected for study spanned the uplands of three watersheds, the Mohawk River, the McKenzie River, and the Willamette River, within Lane and Douglas counties, on Weyerhaeuser Company and BLM lands.

Sample grids were established in closed-canopy stands dominated by Douglas-fir (*Pseudotsuga menziesii*), a subclimax species in the western hemlock zone, typical of second-growth commercial forests in the region. Stands were similar in overstory species composition and canopy cover but differed in age, basal area, trees/ha, average live tree dbh, and CWD volume (Table 1). Other overstory species present in some sample grids included western red-cedar (*Thuja plicata*), western hemlock, and bigleaf maple (*Acer macrophyllum*). Vine maple (*Acer circinatum*) and red huckleberry (*Vaccinium parvifolium*) were the most common shrubs. Understory species composition and abundance varied among sample grids. However, common species included salal (*Gaultheria shallon*), Oregon-grape (*Berberis nervosa*), and swordfern (*Polystichum munitum*). Stands ranged 300-750 m in elevation and 0-45% in slope.

Silvicultural history and management prescriptions differed among stands (Table 1). Many stands were harvested and prescribed burned in the past, while some burns were natural, thus influencing the severity of burns and subsequent residual CWD volume and distribution. Regeneration also varied among plots: some were naturally regenerated and others artificially seeded or planted with seedlings (R. Gerhman, retired Weyerhaeuser Co. area forester, pers. comm.).

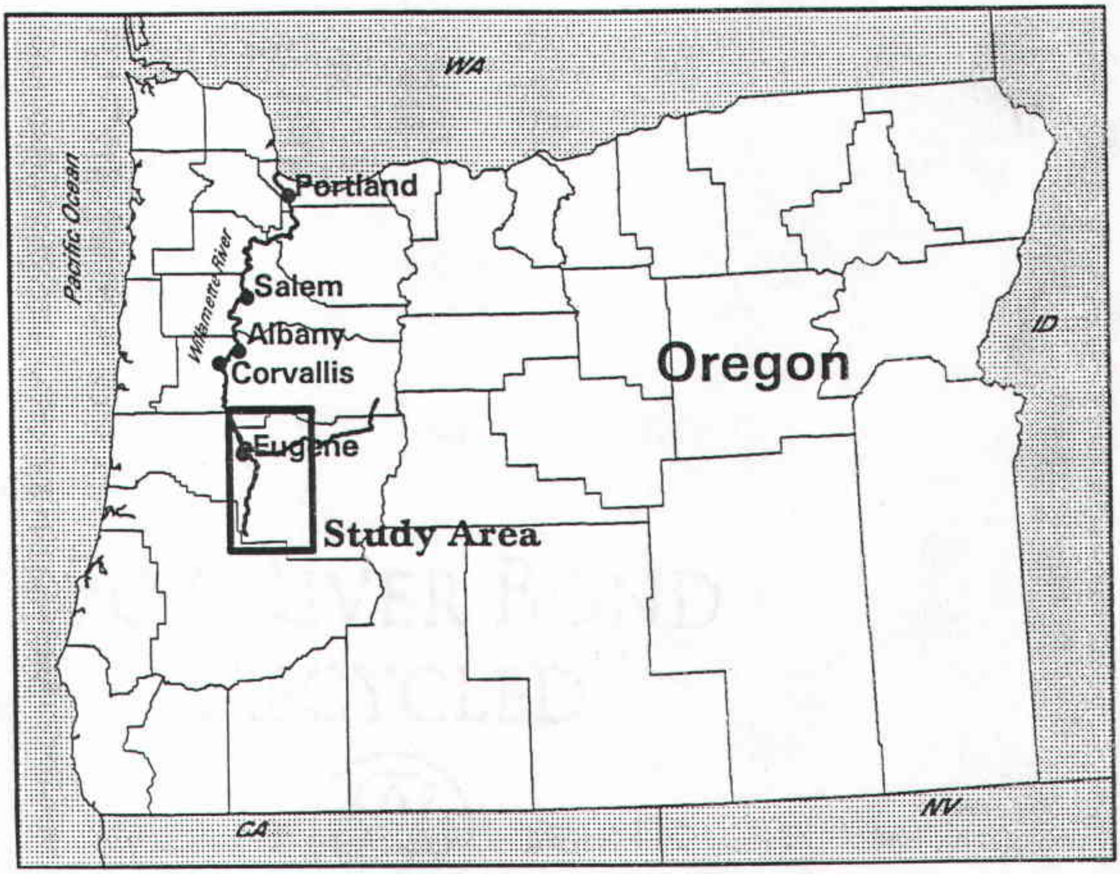

Figure 1. General location of study area in the western Oregon Cascades.

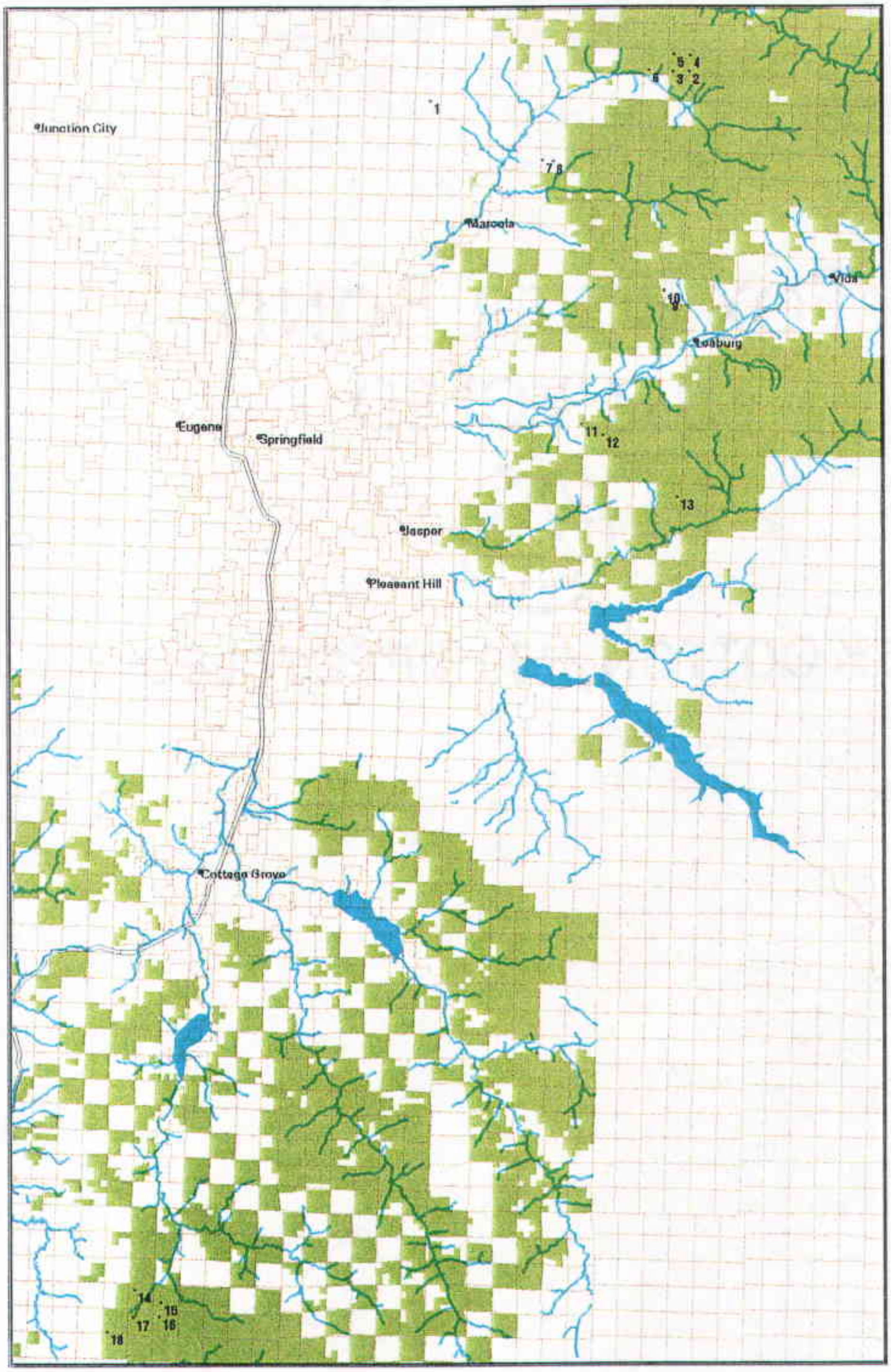

Figure 2. Sample grid locations in the western Oregon Cascades. Grids are marked with numbers corresponding to stand numbers in Table 1. Numbers overlaying green areas indicate Weyerhaeuser Company stands and white areas indicate BLM stands.

Table 1. Stand characteristics and management prescriptions of sample grids in the western Oregon Cascades.

Stand number/ Ownership[a]	Stand age (years)	Basal area (m^2/ha)	Trees/ha	Average live tree dbh (cm)	CWD volume (m^3/ha)[b]	Management prescriptions[c]
1/b	56	90	713	32.4	446 (97)	NT
2/w	28	49	568	33.0	80 (40)	PCT-1978
3/w	28	55	835	29.0	14 (9)	PCT-1978
4/w	27	34	472	30.0	67 (47)	PCT-1978, CT-1993
5/w	27	41	596	29.7	33 (18)	PCT-1978, CT-1993
6/w	43	34	235	42.9	132 (37)	CT-1992
7/b	57	46	453	34.5	80 (16)	NT
8/b	57	39	283	39.4	75 (33)	NT
9/b	53	60	297	49.4	304 (61)	NT
10/b	53	65	357	47.1	734 (194)	NT
11/w	76	40	240	46.2	43 (12)	CT-1993
12/w	48	53	776	29.5	176 (54)	NT
13/w	23	25	460	26.7	39 (11)	CT-1993, pruned
14/w	48	52	588	33.8	671 (175)	NT
15/w	51	53	457	38.6	450 (11)	PCT-1969
16/w	49	38	289	40.9	859 (119)	PCT-1969, CT-1993
17/w	38	62	941	29.0	584 (111)	PCT-1974
18/w	43	43	316	41.4	401 (57)	PCT-1970, CT-1995

[a] b = Bureau of Land Management stand, w = Weyerhaeuser Company stand.
[b] Volume (standard error).
[c] NT = no treatment, PCT = pre-commercial thinning, and CT = commercial thinning.

METHODS

Site Selection

Initially, I conducted a reconnaissance survey of potential stands and visually estimated CWD volume as low, moderate, or high. This process ensured that I sampled stands with a wide range of CWD volumes. Stands scheduled for commercial thinning or harvest during the study were not available for selection. I selected 9 stands in each CWD volume category, and then randomly selected 6 stands from each category to sample (n = 18). Random selection was compromised in the low CWD volume category because of thinning operations; I replaced 3 of the 6 stands with 3 non-randomly selected stands in this category. I rejected stands for study with extremely dense ground vegetation (>1 m in height and ~100% coverage) or steep slopes (>60 %) because pitfall traps and ground searches are not well suited to these conditions. Ground searches in areas with extremely dense vegetation would not be thorough and pitfall traps placed on steep slopes would likely fill up with rain water, killing amphibians. This limited my statistical inference to areas with extremely dense vegetation and steep slopes.

Sample Grid Design

Sample grids, for collecting data on vertebrates and habitat, measured 10,000 m^2 and were buffered from roads, water, and stands of another age to limit influence from disturbed and wet areas (Figure 3 and 4). The buffer distance from roads and stands of another age was $\geq$30 m, based on an estimate of the average height of Douglas-fir trees at 40 years. This assumed that the average height of trees, measured horizontally from the stand edge, buffered plots from light filtering from roads or very young stands. Grids were buffered $\geq$100 m from water and were established in a random orientation; either north-south or northeast-southeast.

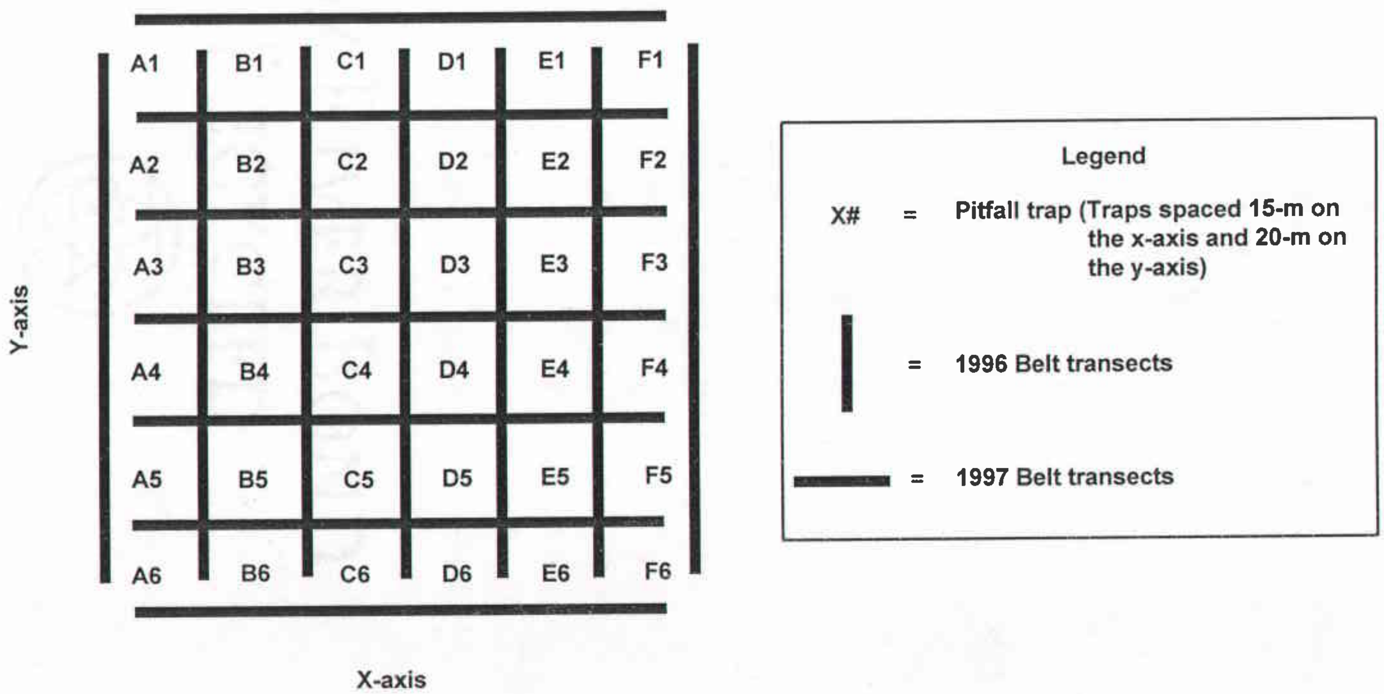

Figure 3. Vertebrate sampling scheme for sample grids in the western Oregon Cascades (grid = 10,000 m^2).

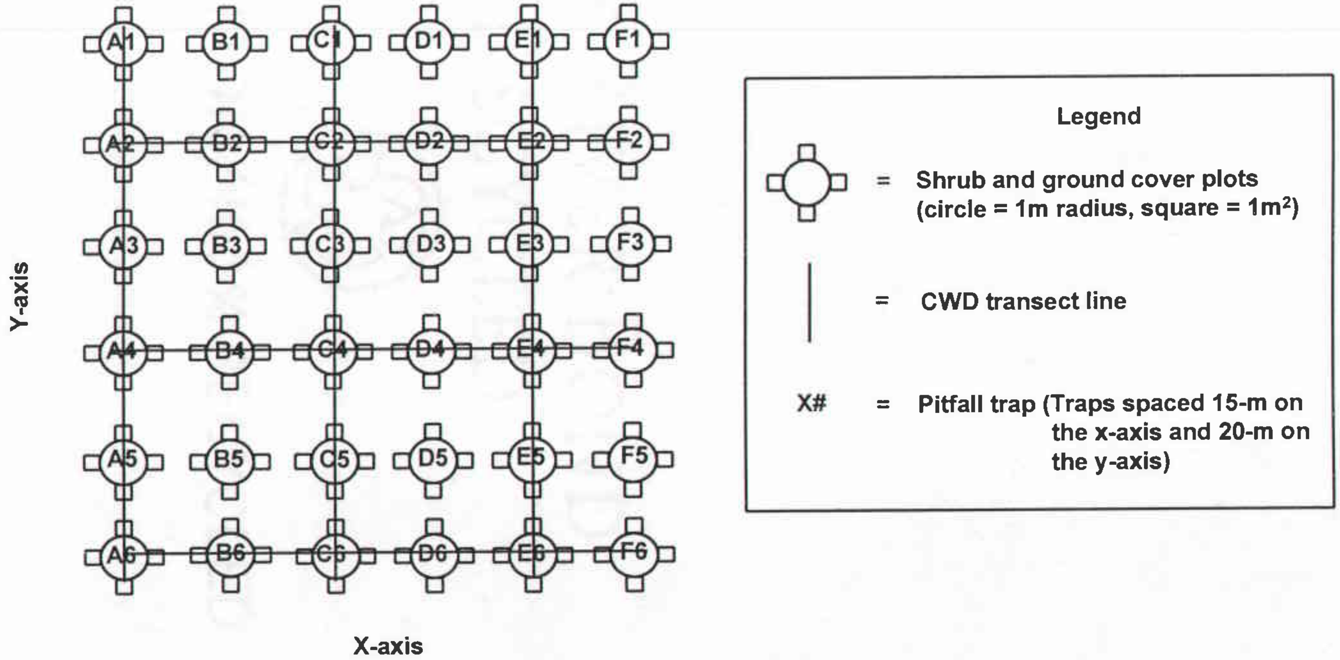

Figure 4. Habitat sampling scheme for sample grids in the western Oregon Cascades (grid = 10,000 m^2).

Pitfall Trapping

Pitfall traps were established in a 6 x 6 rectangular array and labeled with an x-y coordinate system (Figure 3). Traps were spaced 15 m on the x-axis and 20 m on the y-axis. Construction of traps followed specifications in Corn and Bury (1990), using plastic funnels and wood covers. Traps were checked weekly. While traps were open, <2 cm of water was placed in the bottom of each trap. This allowed survival of most amphibians and presumably killed mammals by hypothermia (Corn and Bury 1990). Pitfall capture data were translated into capture rates for each species (captures/1,000 trap nights[1]) for each sample grid. Sampling occurred during spring and fall 1996 and spring 1997. Traps were open for 42 nights in spring and 21 nights in fall 1996, and for 35 nights in spring 1997. Fall trapping was cut short because of logistical constraints. Following spring 1997 trapping, all traps were permanently filled with soil.

Timed, Area-Constrained Ground Searches

Timed, area-constrained, ground searches were used to sample amphibians that may be underrepresented in pitfall traps (Corn and Bury 1990) during spring each year. At each sample grid, 7 rectangular transects were established adjacent to pitfall trap lines (Figure 3). Transects measured 1 x 100 m and were flagged at 10-m intervals. Each 1- x 10-m section was searched once for 8 minutes by 1 person. The 8-minute survey period was determined by testing 2 other time periods. A 6-minute period was inadequate to complete searching in test areas. A 10-minute period was suitable to complete searching in test areas with time left at the end. A longer time period, in areas with very dense CWD and/or dense ground vegetation, may have been more appropriate. However, these areas would have required significantly more time and equipment to search

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[1] One trap night equals one trap open for one night.

thoroughly. Based on available crew and searching equipment, I chose 8 minutes as an appropriate compromise. Within the 1- x 10-m sections, ground cover, CWD, and stumps were searched for amphibians. Sampling was aided by the use of small garden rakes and attempts were made to reach bare soil under litter, pull apart logs and stumps, and move logs when possible. When an amphibian was found, the timer was stopped and data collected for that individual. Timing resumed after data collection until 8 minutes had elapsed and then a new section was searched. All 7 transects within a sample grid were surveyed in 1 day, with few exceptions due to logistical constraints. Grids were sampled in random order to limit bias of weather variability. Timed, area-constrained ground searches followed pitfall trapping in spring 1996 and 1997 to avoid ground disturbance during trapping. To survey new ground in 1997, transects were established perpendicular to the arrangement in 1996.

Vertebrate Data Collection

Amphibians captured during pitfall trapping and timed, area-constrained ground searches were identified by species and sex, if possible. Total length (mm), snout-vent length (mm), and weight (g) were measured and gravid females noted. Individuals were toe-clipped to avoid recounting in subsequent seasons and released near the capture site. However, the capture site, during ground searches, was often disturbed and some individuals were released to a new location, $\leq$1 m from the original site. Seventeen amphibians were found dead during pitfall trapping. They were identified and removed from the site.

Nearly all mammals were dead. They were identified to species and placed in plastic bags with tags indicating the sample grid and trap number and date of capture. Identification was later verified in the lab. Seven mammals were found alive during all pitfall trapping. They were identified and released near the capture site, however they were not toe-clipped and possibly recounted if recaptured; otherwise all amphibian and mammal recaptures were excluded from results.

Habitat Sampling

Twenty-three habitat variables (22 continuous, 1 categorical) were sampled in summer and early fall of 1996 (Table 2). Habitat was sampled once for each sample grid during this time and used in analyses with all 3 seasons of vertebrate capture data. This assumed little change in measured characteristics during the project, excluding seasonal variation. Ground cover, shrubs, canopy cover, stumps, and CWD were sampled and visual estimates of percent cover and volume were determined. Percent cover was estimated by two people. When cover estimates differed between observers, a mutual decision was reached following a more thorough look at the measurement in question.

Overstory

Overstory characteristics, including average live tree dbh (cm), trees/ha, and basal area (m^2/ha), for stands on Weyerhaeuser land were taken from existing stand inventory records. These data were unavailable for BLM stands, but were measured using 3 randomly placed plots within each BLM sample grid. A 17.8-m radius (1000-m^2 area or 1/10 ha) circular plot was used to measure dbh of trees (Wenger 1984). Average live tree dbh was estimated from plots by averaging dbh measurements within and then among plots. Trees/ha were estimated by tallying the number of trees/plot and averaging tallies among plots, then multiplying plot area by 10 to get trees/ha. Basal area was estimated from dbh measurements using the following formula

$$\textit{Basal area } (m^2) = \pi\, (d^2) / 4(10{,}000)$$

where d is the dbh (cm) for individual trees (Wenger 1984). Basal area/ha was estimated by summing basal area estimates for individual trees within plots then averaging among plots and multiplying plot area by 10 to get basal area/ha.

Table 2. Habitat variables measured at 18 sample grids in the western Oregon Cascades.

Habitat variable[a]	Variable definition
Ground cover[b] (%)	
herbs	herbs
ferns	ferns
grass	grass
woody plants	woody plants
moss	moss on ground
litter	organic litter layer (leaves, needles, humus) on ground
twigs	twigs and thinning slash (<10 cm diameter)
bare ground	exposed soil
rocks	rocks or stones, part-fully visible from ground surface
small logs	logs (10-50 cm diameter)
large logs	logs (>50 cm diameter)
small stumps	stumps (<50 cm diameter)
large stumps	stumps (>50 cm diameter)
Litter depth[b]	depth (cm) of organic litter layer (leaves, needles, humus)
Shrub[b]	
shrubs	percent cover of shrubs
shrub height	maximum height (cm)
Woody material[b]	
logs[d]	volume of logs >10 cm diameter (m^3/ha), decay class 1-5
stumps	volume of stumps >50 cm diameter (m^3/ha), decay 1-5
Overstory[b]	
canopy cover	percent canopy cover
basal area	basal area (m^2/ha)
tree density	number of trees/ha
dbh	average live tree dbh (cm)
Management prescriptions[c]	no thinning prescription = 0, pre-commercially thinned stands = 1, pre- and commercially thinned stands = 2

[a] all variables were visually estimated except litter depth, woody material, overstory, and management prescriptions.
[b] continuous habitat variables in multiple linear regression.
[c] categorical habitat variable in multiple linear regression.
[d] variable was transformed to its natural logarithm.

Ground Cover and Shrubs

Ground cover, litter, and canopy cover were sampled using 4 1-m^2 plots around each pitfall trap (Figure 4). A plastic frame was placed 1-m from a pitfall trap in each cardinal direction. Litter depth was measured to the nearest 0.5 cm at each corner of the plastic frame; totaling 4 measurements per 1-m^2 plot, 16 per pitfall trap. Estimates were averaged for each trap site (16/trap site) and then averaged among trap sites within each sample grid. Ground cover was divided into 13 variables. For each variable, percent cover was visually estimated using a percent cover class scheme (Table 2 and 3). Ground cover was averaged for each sample grid by averaging cover class estimates for each trap site (4/trap site) and then averaging among trap sites within each sample grid. Cover class estimates were averaged, rather than cover class midpoints (%), approximating an arcsine-squareroot transformation, improving normality and homogeneity of variances among cover classes (Muir and McCune 1988). Canopy cover (%) was sampled in the middle of each 1-m^2 plot using a Moosehorn cover scope (Cook *et al.* 1995). Estimates were averaged for each trap site and then averaged among trap sites. Percent cover and maximum height of shrubs were estimated in a 1-m radius circular plot around each pitfall trap (Figure 4) using a percent cover class scheme (Table 3). Cover class estimates were averaged among trap sites.

CWD and Stumps

CWD was sampled and volume (m^3/ha) estimated for each sample grid using 6 line transects, similar to methods outlined in Van Wagner (1968) and Harmon and Sexton (1996). Pitfall trap lines A, C, E, and 2, 4, and 6 were walked and for each log (>10 cm diameter) encountered, the diameter and decay class were recorded (Figure 4). Decay class was determined using a 5-class system where class 1 logs were solid with intact bark and class 5 logs were structurally weak, sunk into the ground with no bark and elliptical diameters (Sollins 1982).

Table 3. Percent cover classes (Daubenmire 1959) used to estimate ground and shrub cover on 18 sample grids in the western Oregon Cascades.

Class	Percent cover range of measured variable
1	0-5
2	6-25
3	26-50
4	51-75
5	76-95
6	96-100

CWD volume was estimated using the formula

$$V = \pi^2 \Sigma d^2 / 8L$$

where V is the volume (m^3/m^2), d is the piece diameter (m), and L is the transect length (m) (Van Wagner 1968, Harmon and Sexton 1996). Volume estimates (m^3/m^2) were multiplied by area to estimate total CWD volume for each of the 6 transects. These estimates were averaged to calculate total CWD volume for each sample grid (m^3/ha).

All stumps >50 cm diameter were measured within each sample grid's 10,000 m^2 boundary, which allowed all old-growth stumps to be included and virtually all recently cut stumps from thinning operations to be excluded from volume estimates. I assumed that recent stumps did not provide habitat for small mammals or amphibians because of their intact structure. Diameter, height, and decay class were recorded for each stump and volume was estimated using the formula

$$V = \pi r^2 h$$

where V is the volume (m^3), r is the radius (m), and h is the height of a stump (m). Volume estimates were summed for all stumps to estimate total stump volume (m^3/ha) for each sample grid.

Statistical Analyses

Macrohabitat

Associations of vertebrate capture rates (pitfall trapping) and total captures (timed, area-constrained ground searches) with stand-level habitat variables were analyzed with multiple linear regression using SAS® statistical software and the PROC REG and GLM procedures for regression and general linear models (SAS Inst. Inc. 1990). Repeated observations made on the same variable, such as seasonal vertebrate data collection in this project, require repeated measures analysis to study time trends (Ramsey and Schafer 1997). Because the objective of this project was to analyze habitat associations and not time trends, seasons were analyzed separately to avoid violation of independence assumptions among observations. Vertebrates sampled using different methods also were analyzed separately.

As an initial step in understanding the association among variables and reducing the number used in regression modeling, I used Pearson's product-moment correlation analysis. This technique identified multicollinearity among explanatory variables and strong correlations between response and explanatory variables. Potential explanatory variables used in regression were selected when Pearson's correlation coefficients (*r*) were 0.40 to 1.0 or -0.40 to -1.0 and significant to $P \leq 0.05$. This resulted in 3-5 potential explanatory variables for each response variable that I examined with stepwise selection methods. In addition, a categorical explanatory variable for thinning treatment was included in models to assess vertebrate response differences between thinned and unthinned sites (Table 2). I examined residual plots to assess linearity, non-constant variance, and outliers. When these assumptions were not met for a particular regression model, corrective measures were applied (i.e transformation, outlier examination). Based on the analyses of ensatinas[2] captured during timed, area-constrained ground searches in 1996 and 1997, total captures were transformed their natural logarithm to satisfy normality and constant variance assumptions. In selected models with more than one explanatory variable, t-tests were used to test null hypotheses that parameter estimates were equal to zero.

Microhabitat

Associations of vertebrates, captured during pitfall trapping, with ground cover habitat variables (Table 2) surrounding the site of capture were analyzed

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[2] Natural logarithm of total ensatina captures +1.

with logistic regression using SAS® statistical software. The PROC LOGISTIC procedure for logistic regression and the PROC GENMOD procedure for generalized linear models were used to select model parameters and assess model fit (SAS Inst. Inc. 1997). Again, seasons were analyzed separately to avoid violation of independence assumptions among observations (Ramsey and Schafer 1997).

For a particular species, within a season of trapping, I recorded presence (1) or absence (0) in each pitfall trap. Regardless of presence or absence of a particular species in a trap, I randomly selected 9 traps per sample grid per season to include in analyses, for a total of 162 observations for each season. I randomly selected one quarter of the observations for each sample grid (9 out of 36 traps) to minimize lack of independence among observations. It is likely that pitfall traps in close proximity are not statistically independent; vertebrates captured in them could be correlated because of species movement patterns, intra- or interspecific competition, or other life history factors. Random selection of observations was a way to attempt independence among observations, and avoid violation of model assumptions. Individual species presence or absence were response variables and ground cover and litter depth were potential explanatory variables. I used stepwise selection methods to identify significant model parameters in logistic regression. Selected models with multiple explanatory variables were compared with reduced models using the drop-in-deviance chi-square test (Ramsey and Schafer 1997). The PROC GENMOD procedure in SAS® was used to generate deviance statistics (SAS Inst. Inc. 1997).

Microhabitats of amphibians captured during timed, area-constrained ground searches in spring 1996 and 1997 were summarized into 10 distinct variables, including separate variables for each decay class of CWD. I compared the distribution of amphibians (#/decay class) with the distribution of available CWD (# of pieces/decay class) surveyed during habitat sampling using a χ^2 test. In addition, distances between amphibian capture sites and the nearest CWD piece were compared with distances between random points and the nearest CWD piece using two-sample t-tests.

RESULTS

Vertebrate Captures

During 3 seasons of sampling, 1,944 vertebrates of 18 species were captured (Appendix B). Species richness within sample grids varied among seasons for pitfall trapping and timed, area-constrained ground searches (Appendix C). Trowbridge's shrews (*Sorex trowbridgii*) were the most frequently captured mammal species during the 3 seasons of pitfall trapping. Fog shrews (*Sorex sonomae*) were the second most frequently captured mammal species. For both pitfall trapping and timed, area-constrained ground searches, ensatinas (*Ensatina eschscholtzii*) were the most frequently captured amphibian species. No other amphibian species were captured with any regularity. Average mortality for mammals was 99.6%. However, average amphibian survival was 91.8%. Amphibian recaptures were very low, with only 6 in 395 captures; 3 during pitfall trapping and 3 during timed, area-constrained ground searches.

Macrohabitat Associations

Habitat associations were determined for 6 vertebrate species (Table 4): Trowbridge's shrews, fog shrews, shrew-moles (*Neurotrichus gibbsii*), ensatinas, rough-skinned newts (*Taricha granulosa*), and clouded salamanders (*Aneides ferreus*). The regression model for clouded salamanders was made with 4 stand observations, all other models developed had observations in $\geq$ 8 stands.

Table 4. Multiple linear regression associations for vertebrate species captured during pitfall trapping and timed, area-constrained ground searches in the western Oregon Cascades.

Season/ Method[a]	Species[b]	Variable[b]	Slope Estimate[c]	SE[d]	t[e]	$P > \|T\|$[f]	Par. R^2 [g]	R^2 [h]	F[i]
Spr 1996/P	Trowbridge's shrew	fern cover	6.04	1.87	3.23	0.006	0.43	0.75	13.71
		moss cover	-3.03	1.04	-2.92	0.011	0.38		
		small diameter log cover	10.55	3.84	2.75	0.016	0.35		
Spr 1997/P	Trowbridge's shrew	fern cover	2.87	0.86	3.35	0.004		0.41	11.24
Spr 1996/P	Fog shrew	herb cover	1.36	0.34	4.01	0.001		0.70	11.10
		CAT unthinned stands[j]	-1.57	0.72	-2.16	0.048			
Spr 1996/P	Shrew-mole	large diameter log cover	-1.04	0.35	-2.95	0.010	0.37	0.62	12.09
		woody plant cover	0.45	0.12	3.86	0.002	0.50		
Spr 1996/P	Ensatina	LN CWD volume	0.44	0.18	2.36	0.031		0.26	5.56
Fall 1996/P	Ensatina	LN CWD volume	1.31	0.37	3.52	0.003		0.44	12.36

Table 4. Continued.

Season/ Method[a]	Species[b]	Variable[b]	Slope Estimate[c]	SE[d]	t[e]	$P > \|T\|$[f]	Par. R^2 [g]	R^2 [h]	F[i]
Spr 1997/P	Ensatina	fern cover	2.17	0.56	3.89	0.001	0.50	0.60	11.08
		grass cover	-2.41	1.05	-2.30	0.036	0.26		
Spr 1996/T	LN Ensatina	LN CWD volume	0.46	0.09	5.40	< 0.001	0.63	0.76	23.29
		average live tree dbh	0.04	0.02	2.36	0.032	0.27		
Spr 1997/T	LN Ensatina	LN CWD volume	0.66	0.09	7.03	< 0.001		0.76	49.36
Spr 1997/P	Rough-skinned newt	bare ground cover	3.81	0.85	4.48	< 0.001		0.56	20.04
Spr 1997/T	Clouded salamander	LN CWD volume	0.32	0.11	2.87	0.011		0.34	8.21

[a] sampling method: P = pitfall trapping, T = timed, area-constrained ground searches.
[b] acronyms: LN = natural logarithm, CAT = categorical variable.
[c] estimate of explanatory variable slope (β_x).
[d] standard error of slope estimate.
[e] t-statistic testing H_o: slope estimate = 0.
[f] probability to reject H_o (two sided *p*-value).
[g] percentage of total response variation explained by an individual explanatory variable at a given value of other explanatory variables in the model.
[h] percentage of total response variation explained by the explanatory variable(s) in the model.
[i] F-value for testing the hypothesis that all parameters in the model are zero except the intercept.
[j] model term for the change in intercept (β_0) in unthinned stands.

Mammals

Capture rates of Trowbridge's shrews were positively associated with fern cover (*P* ≤ 0.006, in spring 1996 and 1997, Figure 5), positively associated with small diameter log cover (*P* = 0.016, spring 1996) and negatively associated with moss cover (*P* = 0.011, spring 1996). Capture rates of fog shrews were positively associated with herb cover (*P* = 0.001, spring 1996, Figure 6), with rate increases similar in thinned and unthinned stands, but lower overall capture rates in unthinned stands (*P* = 0.048, t-test for different intercepts in multiple linear regression). Capture rates of shrew-moles were positively associated with woody plant cover (*P* = 0.002, spring 1996) and negatively associated with large diameter log cover (*P* = 0.01, spring 1996).

Amphibians

Ensatina capture rates were positively associated with total CWD volume (*P* ≤ 0.03, spring and fall 1996, Figure 7) and fern cover (*P* = 0.001, spring 1997), and negatively associated with grass cover (*P* = 0.036, spring 1997). Ensatinas captured during timed, area-constrained ground searches were positively associated with total CWD volume (*P* = 0.0001, spring 1996 and 1997, Figure 8) and positively associated with average live tree dbh (*P* = 0.032, spring 1996). Capture rates of rough-skinned newts were positively associated with bare ground cover (*P* <0.001, spring 1997). Clouded salamanders captured during timed, area-constrained ground searches were positively associated with total CWD volume (*P* = 0.011, spring 1997).

Based on associations with total CWD volume, ensatina capture rates increased 1.00 captures/1,000 trap nights (95% CI[3] = 0.10-1.91, spring 1996) and 3.02 captures/1,000 trap nights (95% CI = 1.20-4.84, fall 1996) when total CWD

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[3] 95% confidence interval expressed on the original scale, back transformed from natural logarithm.

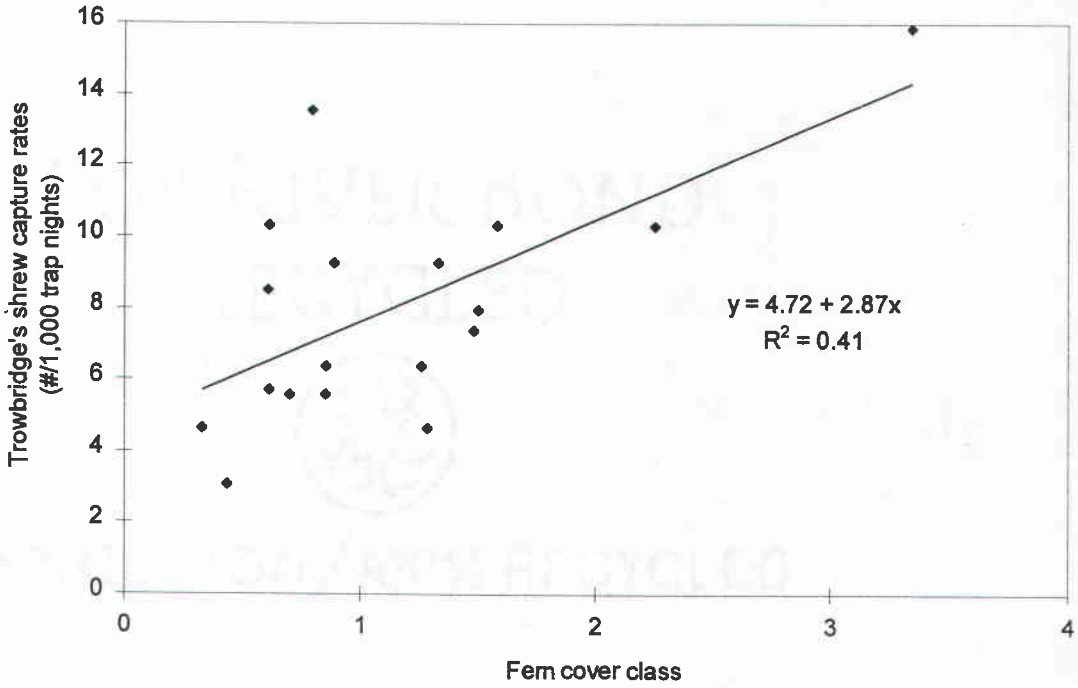

Figure 5. Response of Trowbridge's shrew capture rates (#/1,000 trap nights) as a function of fern cover class in spring 1997 pitfall trapping in the western Oregon Cascades. Refer to Table 3 for cover class ranges.

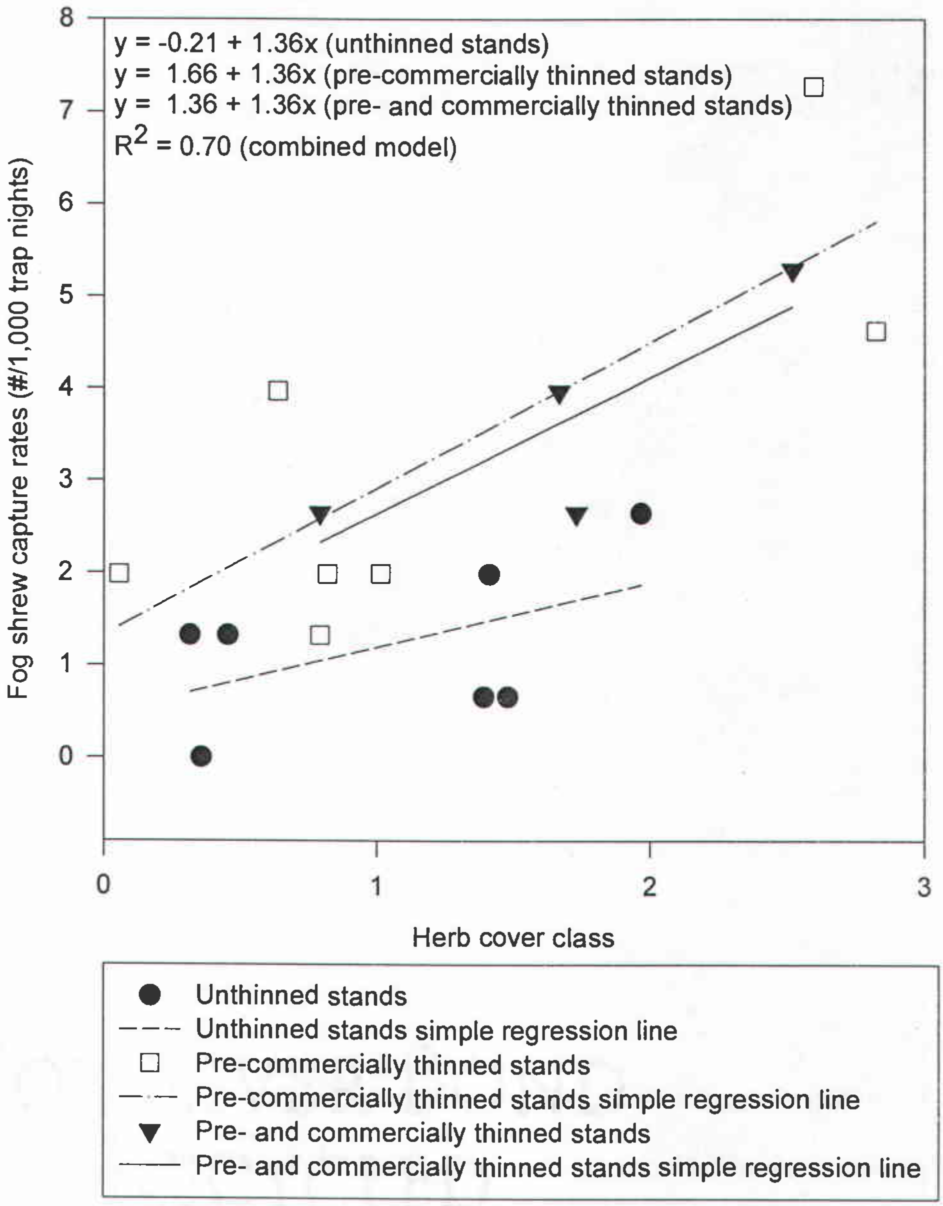

Figure 6. Response of fog shrew capture rates (#/1,000 trap nights) as a function of herb cover class in spring 1996 pitfall trapping in the western Oregon Cascades. The regression model has a common slope among all stand types, but different intercepts for unthinned stands *(P* = 0.05) and pre-commercially thinned stands *(P* = 0.73, non-significant but part of the model); created with a 3-way categorical variable for thinning treatment (Table 2). Refer to Table 3 for cover class ranges.

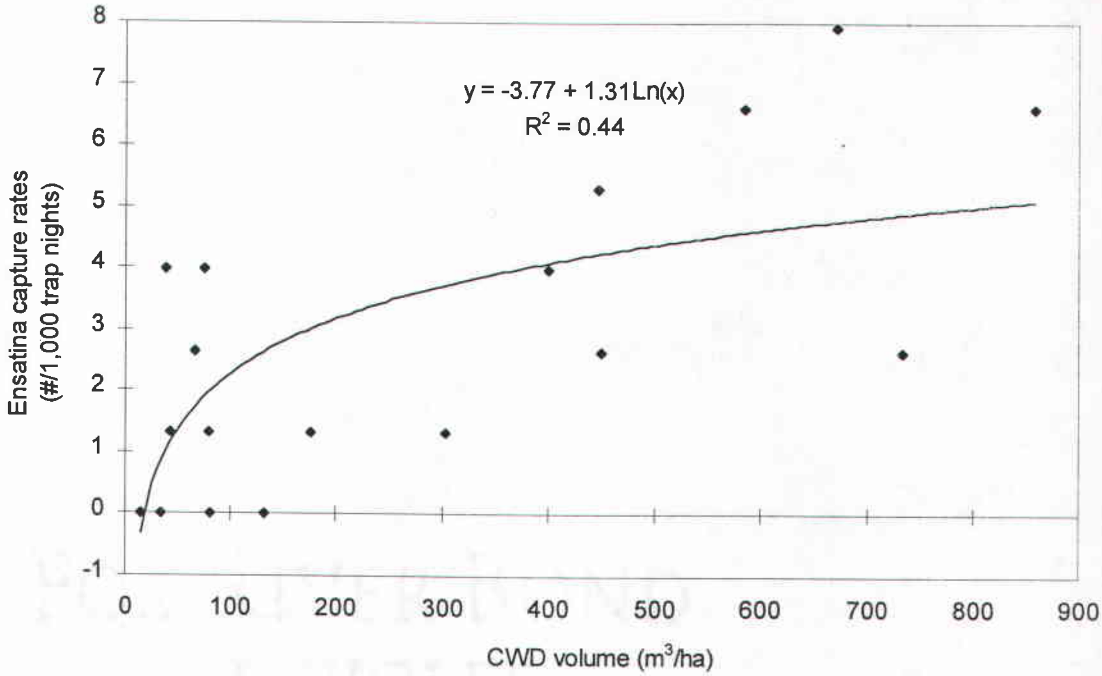

Figure 7. Response of ensatina capture rates (#/1,000 trap nights) as a function of CWD volume (m^3/ha) in fall 1996 pitfall trapping in the western Oregon Cascades. CWD volume was transformed to a natural logarithm to model this association, indicated by the logarithmic function, however data points are displayed on the original scale.

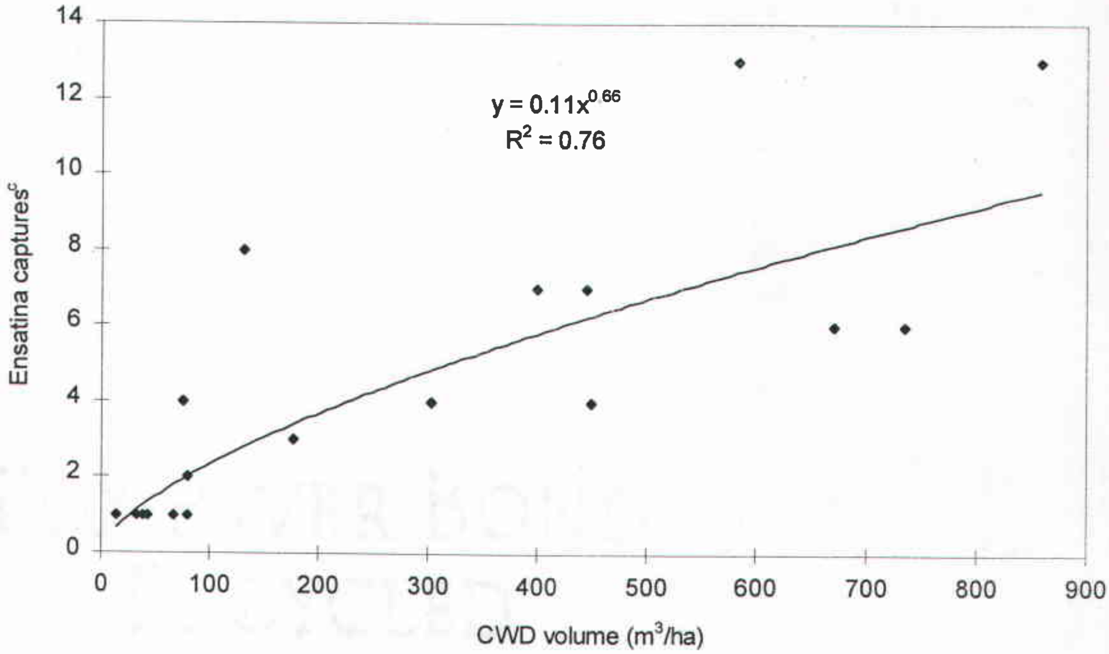

Figure 8. Response of total ensatina captures as a function of CWD volume (m^3/ha) in spring 1997 timed, area-constrained ground searches in the western Oregon Cascades. [c] # of captures + 1. Ensatina captures and CWD volume were transformed to their natural logarithm to model this association, indicated by the power function, however data points are displayed on the original scale.

volume (m^3/ha) increased ten-fold. In timed, area-constrained ground searches the median[4] number of ensatina captures increased 2.88 (95% CI = 1.90-4.37, spring 1996) and 4.53 (95% CI = 2.86 to 7.16, spring 1997) when total CWD volume increased ten-fold. The mean number of captures of clouded salamanders increased 0.73 captures/1,000 trap nights (95% CI = 0.19 to 1.27, spring 1997), in timed, area-constrained ground searches, when total CWD volume increased ten-fold.

Microhabitat Associations

Microhabitat associations were determined for 3 vertebrate species: Trowbridge's shrews, fog shrews, and ensatinas (Table 5), the only species with >10 observations (n=162) of presence per season. Trowbridge's shrew presence was negatively associated with moss cover *($P \leq 0.022$, spring (Figure 9) and fall 1996)*, negatively associated with fern cover *($P = 0.004$, fall 1996)*, and positively associated with woody plant cover *($P = 0.01$, fall 1996)*, and small diameter log cover *($P = 0.027$, fall 1996)*. Figure 10 shows the decrease in probability of Trowbridge's shrew presence as a function of moss cover in spring 1996. Fog shrew presence was positively associated with herb cover *($P = 0.002$, spring 1996,* Figure 11), indicating the increase in probability of fog shrew presence as a function of herb cover (Figure 12). In spring 1996, ensatina presence was negatively associated with herb cover *($P = 0.041$)*, and twig cover *($P = 0.039$)*. I developed a second model that included large diameter log cover and again found a negative association with herb cover *($P = 0.009$)*, but positive associations with

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[4] Interpretations on the original scale must be in terms of median changes (Ramsey and Schafer 1997) when both the response and explanatory variable are transformed to their natural logarithm.

Table 5. Logistic regression associations for vertebrate species captured during pitfall trapping in the western Oregon Cascades.

Season	Species	Variable	Estimate[c]	SE[d]	χ^2 [e]	$P > \chi^2$ [f]
Spring 1996[a]	Trowbridge's shrew	moss cover	-0.24	0.10	5.23	0.022
Fall 1996[a]	Trowbridge's shrew	moss cover	-0.31	0.12	7.35	0.007
		fern cover	-0.50	0.17	8.27	0.004
		woody plant cover	0.34	0.13	6.64	0.010
		small diameter log cover	0.61	0.28	4.86	0.027
Spring 1996[a]	Fog shrew	herb cover	0.70	0.22	9.69	0.002

Table 5. Continued.

Season	Species	Variable	Estimate[c]	SE[d]	χ^2 [e]	$P > \chi^2$ [f]
Spring 1996[a]	Ensatina	herb cover	-1.07	0.57	4.17	0.041
		twig cover	-1.08	0.52	4.26	0.039
Spring 1996[b]	Ensatina	herb cover	-1.69	0.64	6.85	0.009
		fern cover	0.66	0.34	3.71	0.053
		large diameter log cover	0.65	0.36	3.39	0.066
Spring 1997[a]	Ensatina	large diameter log cover	0.70	0.26	7.10	0.008

[a] regression model developed with stepwise methods.
[b] regression model developed with CWD deliberately placed in the model.
[c] estimate of explanatory variable slope (β_x).
[d] standard error of slope estimate.
[e] χ^2 statistic testing H_o: slope estimate = 0.
[f] probability to reject H_o (one sided p-value).

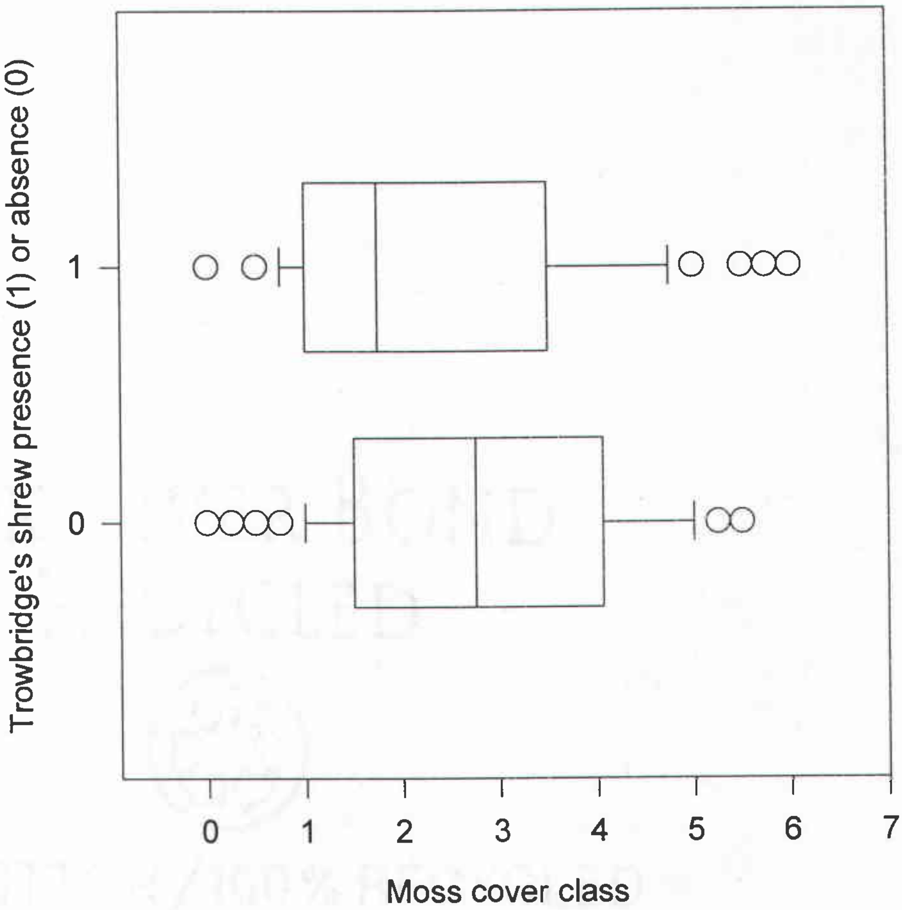

Figure 9. Box and whisker plots of Trowbridge's shrew presence (1) and absence (0) as a function of moss cover class in spring 1996 pitfall trapping in the western Oregon Cascades. Each box represents the middle 50% of the data with a vertical line marking the 50th percentile. Whiskers extend to the 10th and 90th percentiles and extreme values are marked with open circles. Refer to Table 3 for cover class ranges.

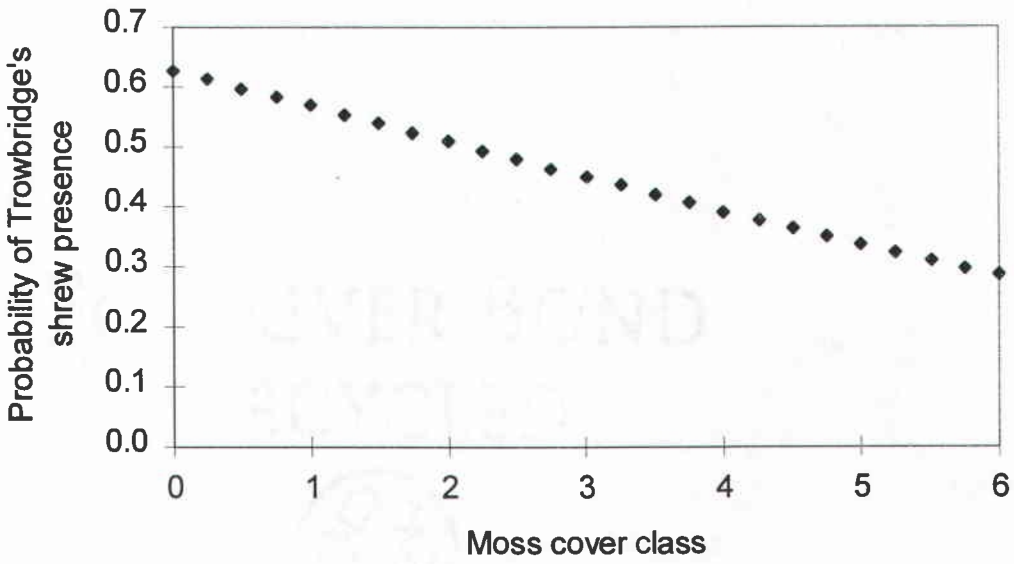

Figure 10. Probability of Trowbridge's shrew presence as a function of moss cover class in spring 1996 pitfall trapping in the western Oregon Cascades. Refer to Table 3 for cover class ranges.

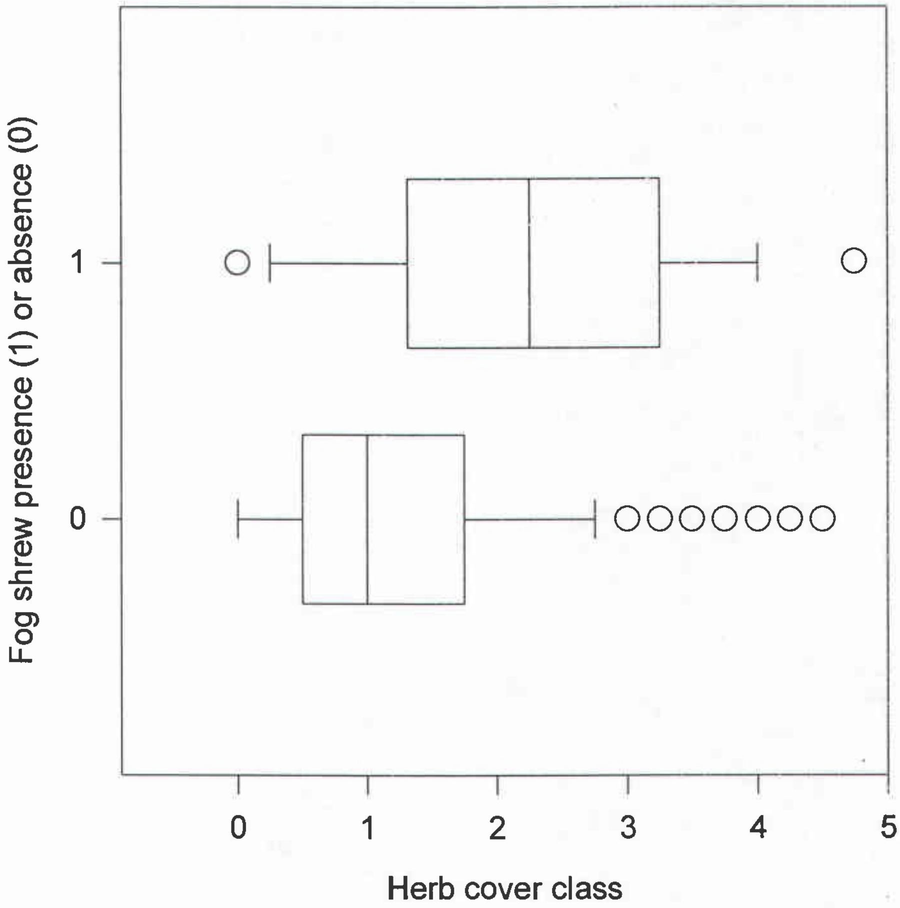

Figure 11. Box and whisker plots of fog shrew presence (1) and absence (0) as a function of herb cover class in spring 1996 pitfall trapping in the western Oregon Cascades. Each box represents the middle 50% of the data with a vertical line marking the 50th percentile. Whiskers extend to the 10th and 90th percentiles and extreme values are marked with open circles. Refer to Table 3 for cover class ranges.

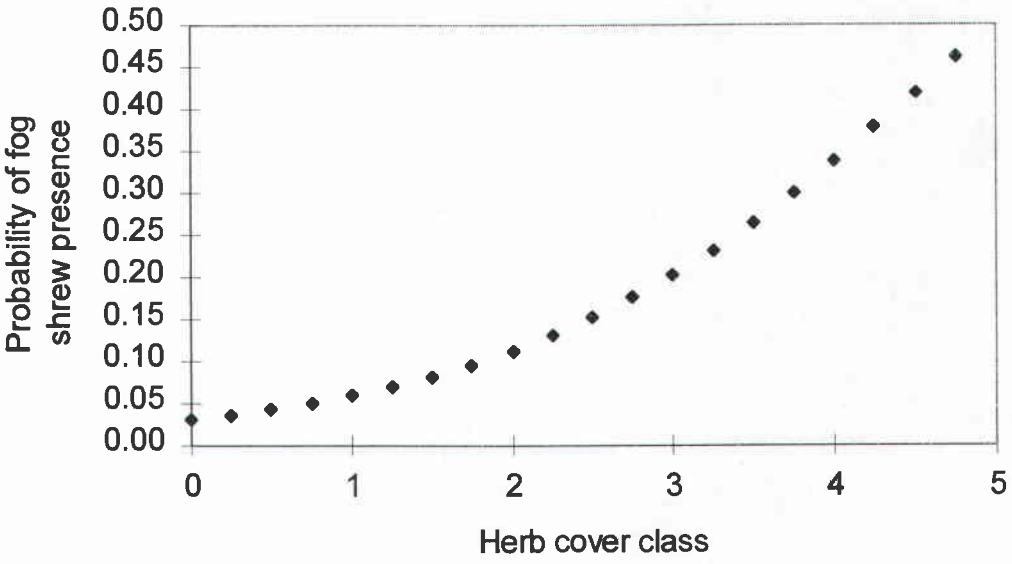

Figure 12. Probability of fog shrew presence as a function of herb cover class in spring 1996 pitfall trapping in the western Oregon Cascades. Refer to Table 3 for cover class ranges.

fern cover ($P = 0.053$), and large diameter log cover ($P = 0.066$). In spring 1997, ensatina presence again was positively associated with large diameter log cover ($P = 0.008$, Figure 13). Figure 14 shows the increase in probability of ensatina presence as a function of large diameter log cover in spring 1997.

Timed, Area-Constrained Ground Searches

Microhabitat of amphibians captured in timed, area-constrained ground searches in spring 1996 and 1997 is summarized in figure 15. The majority of amphibians were found in, or under the bark of, decay class 3 and 4 CWD. However, amphibians also were frequently found under loose bark (separate from logs), moss, and litter. The distribution of amphibians among decay classes of CWD differed from the distribution of CWD available in sample grids ($\chi^2 = 53.06$, $P < 0.01$, spring 1996; $\chi^2 = 12.01$, $P < 0.02$, spring 1997). In both years, the number of amphibians observed in decay class 2 CWD was less than expected and in 1996, the number of amphibians observed in decay 4 CWD was more than expected, resulting in the large χ^2 values. Distances between amphibians and the nearest CWD compared with distances between random points and the nearest CWD indicated that amphibians were significantly closer to the nearest CWD piece than random points (Table 6). On average, amphibians were captured 0.5 m from the nearest CWD whereas random points were 1 m from the nearest CWD.

DISCUSSION

Forest Floor Vertebrate Associations

Previous research on forest floor vertebrates in the Pacific Northwest has not directly addressed the question of vertebrate presence and abundance in areas ranging in CWD volume, such as this project (deMaynadier and Hunter

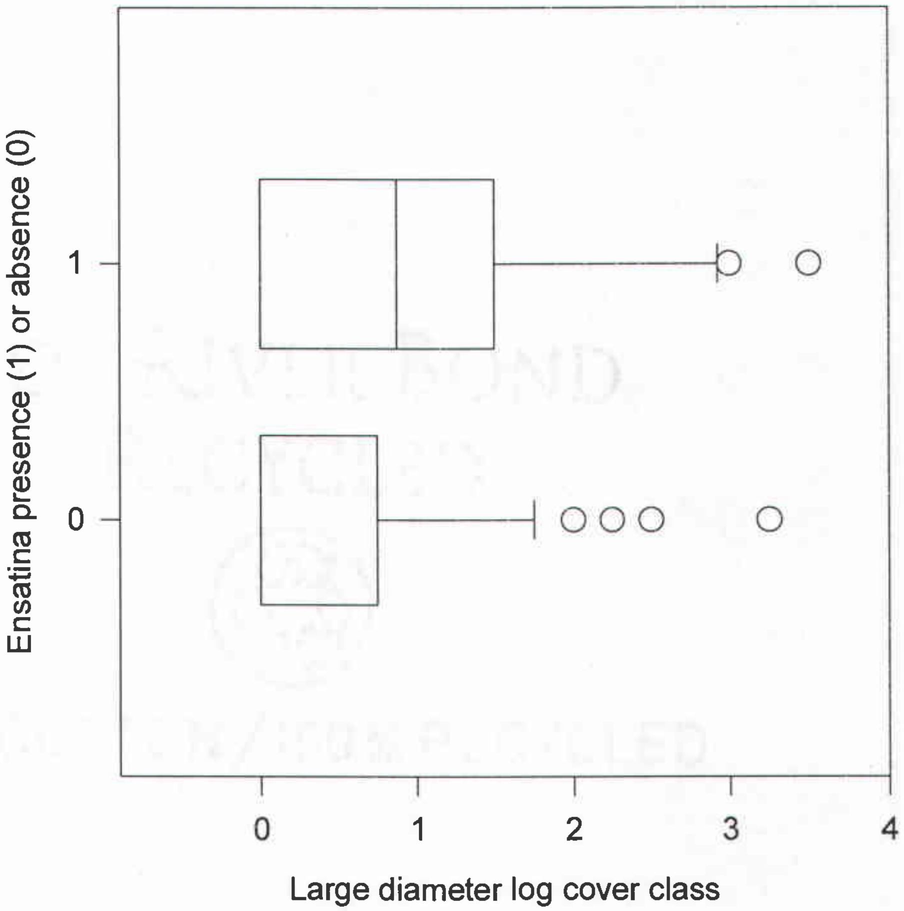

Figure 13. Box and whisker plots of ensatina presence (1) and absence (0) as a function of large diameter log cover class in spring 1997 pitfall trapping in the western Oregon Cascades. Each box represents the middle 50% of the data with a vertical line marking the 50th percentile. Whiskers extend to the 10th and 90th percentiles and extreme values are marked with open circles. Refer to Table 3 for cover class ranges.

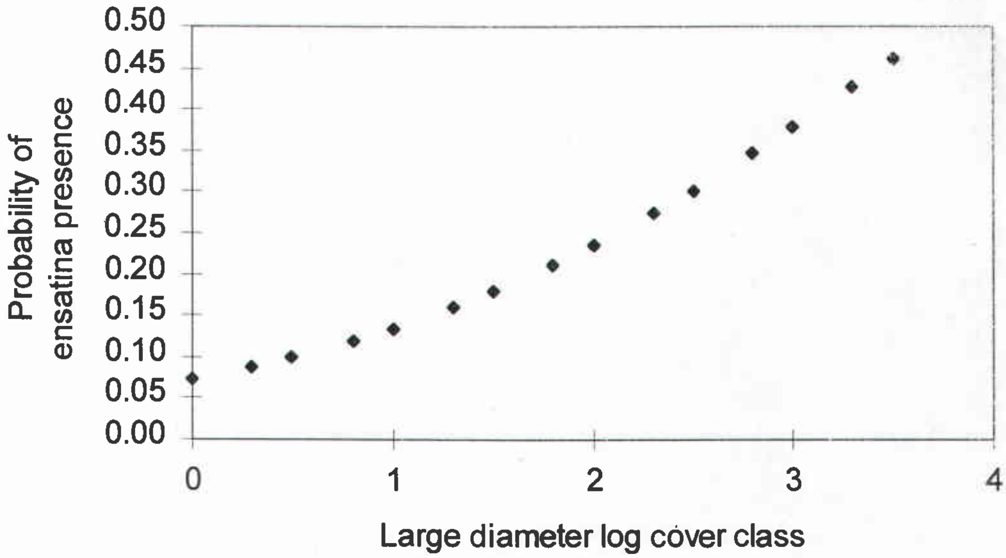

Figure 14. Probability of ensatina presence as a function of large diameter log cover class in spring 1997 pitfall trapping in the western Oregon Cascades. Refer to Table 3 for cover class ranges.

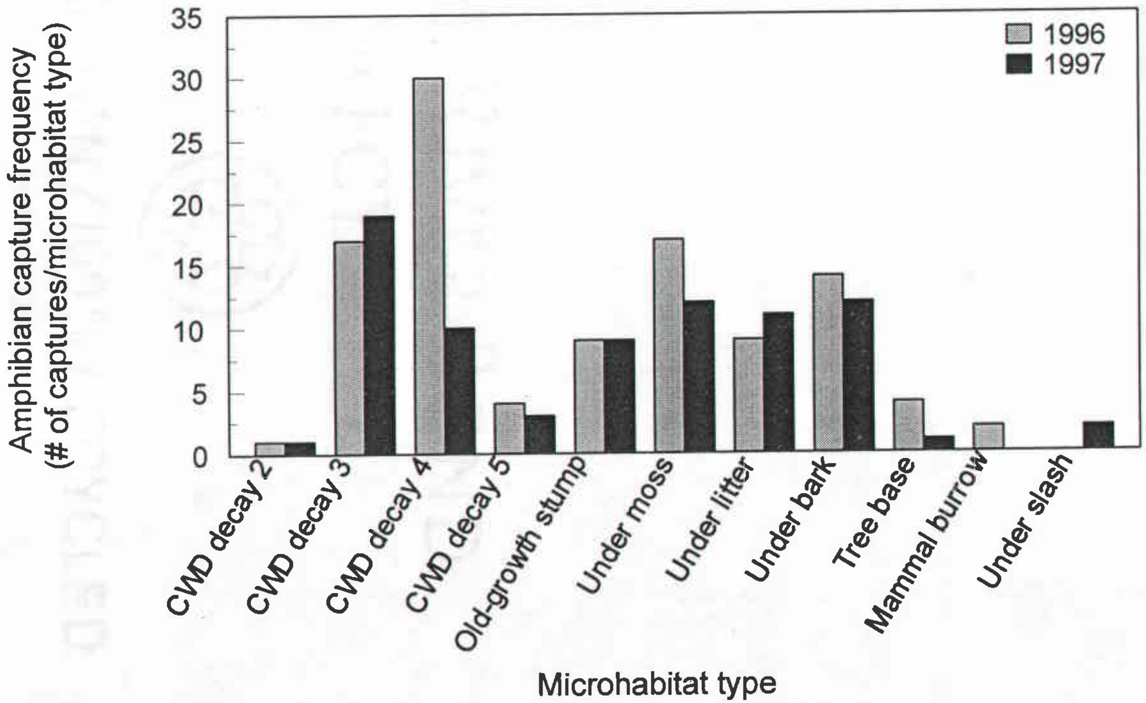

Figure 15. Microhabitats of amphibians captured during timed, area-constrained ground searches in spring 1996 and 1997 in the western Oregon Cascades. Results for all sample grids are combined.

Table 6. Comparison of mean distances between amphibians and the nearest CWD, captured during timed, area-constrained ground searches, and mean distances between random points and the nearest CWD, in the western Oregon Cascades.

Season/Year	Mean distance to the nearest CWD	SE[a]	t[b]	P > |T|[c]
Spring/1996	0.51 (amphibians)	0.09	3.22	0.0016
	1.10 (random points)	0.17		
Spring/1997	0.56 (amphibians)	0.13	3.00	0.0031
	1.10 (random points)	0.12		

[a] standard error of mean estimate.
[b] t-statistic testing H_o: difference in means = 0.
[c] probability to reject H_o (two-sided p-value).

1995). However, past studies have identified associations between forest floor vertebrates and habitat (Aubry *et al.* 1988, Aubry and Hall 1991, Bury and Corn 1988, Corn and Bury 1991*a*, Corn and Bury 1991*b*, Raphael 1988). The positive association I found between Trowbridge's shrews and fern cover, at the stand level, in spring 1996 and 1997 (Figure 5) is similar to Corn and Bury's (1991*b*) results that indicated a positive correlation with fern cover ($r = 0.32$, $P < 0.05$). However, in microhabitat analyses, I found a contradictory, negative association with fern cover, but a positive association with woody plant cover (Table 5). Trowbridge's shrews may use vegetative cover, in part, for protection (Maser *et al.* 1981). The same rationale may be applicable to the negative association I found with moss cover, in both macro- and microhabitat analyses, which affords little protection during surface activity (Table 4 and 5). The positive association with small diameter log cover may be related to pre-commercial thinning residue and increases in understory vegetation, like ferns and woody plants that result from opening the canopy.

Little has been reported on habitat of fog shrews since its distinction as a separate species from Pacific shrew (*Sorex pacificus*) in 1990 (Carraway 1989). Maser *et al.* (1981:53) described Pacific shrew habitat as "alder (*Alnus spp.*)/salmonberry (*Rubus spectabilis*), riparian alder, and skunk cabbage (*Lysichitum americanum*) marsh..., less often found in the mature conifer and immature conifer habitats". Corn and Bury (1991*b*) found Pacific shrews associated with denser growth of shrubs and ferns. The positive association I found between fog shrews and herb cover, in macro- and microhabitat analyses, suggests slightly different habitat than that of Pacific shrews (Table 4 and 5). Additionally, all my captures were made in stands buffered from riparian habitat, which may be typical habitat for Pacific shrews (Maser *et al.* 1981). While the rate of increase, with respect to herb cover, was similar for fog shrews in thinned and unthinned stands, overall capture rates were lower in unthinned stands (Figure 6). However, herb cover did not significantly differ between thinned and unthinned stands. I suggest the relationship with herb cover may be related to selection of vegetation for nest-building materials, based on similar behavior noted for captive Pacific shrews (Maser and Hooven 1974). The only habitat association I found for shrew-moles in other studies was a positive association with herbaceous cover (Corn and Bury 1991*b*). I found a positive association with woody plant cover in spring 1996. Both results indicate a general association between shrew-moles and vegetative cover, possibly important for protection. Also, shrew-moles have been observed climbing into low-growing vegetation to search the foliage for food (Dalquist and Orcutt 1942). This also may explain the association I found with woody plant cover. The negative association I found with large diameter log cover has not been documented in other studies.

The positive associations I found between ensatinas and total CWD volume were expected (Table 4), and supported other studies (Aubry *et al.* 1988, Corn and Bury 1991*a*, Gilbert and Allwine 1991). Corn and Bury (1991*a)* found the highest densities of ensatinas in decay classes 3-5 CWD. I also found positive correlations between ensatina captures and decay classes 3-5 CWD volume, however, the correlation was stronger when all decay classes were combined, hence, I used the combined volume in multiple regression analyses. Additionally, I observed the majority of ensatinas in decay classes 3 and 4 CWD during timed, area-constrained ground searches. Based on the available decay classes of CWD, their use of decay class 4 CWD was greater than expected, in 1996, and their use of decay class 2 CWD was less than expected in 1996 and 1997. Use of decay class 3 CWD, both years, closely followed the availability of this class. Figure 7 shows that there may be a saturation effect for ensatina abundance with increasing CWD volume, where abundance reaches a plateau even though CWD volume continues to increase. This may be explained by competition for resources, territoriality, or perhaps a limit to the number of preferred microsites on a given log. The positive association between ensatinas and fern cover, and the negative association with grass cover in spring 1997 pitfall trapping is not supported by other research. However, Aubry and Hall (1991) found a positive correlation with berry-producing shrubs. Both results indicate a general positive association between ensatinas and understory vegetation. In the microhabitat analyses, I developed 2 logistic regression models for ensatina presence in spring 1996. Using stepwise selection methods, I found negative associations with herb and twig cover in detecting presence. In the second model, I deliberately placed large diameter log cover in the model. I found that large diameter log cover was almost as good a predictor of presence ($P = 0.066$) as twig cover was of absence ($P = 0.039$) (Table 5). In addition, ensatina presence also was negatively associated with herb cover and positively associated with fern cover. Adding further strength to the model I developed with log cover in spring 1996, my microhabitat results also suggested a positive association with large diameter log cover in 1997 ($P = 0.008$, Figure 13).

Only 2 other associations were developed for amphibians. I found a positive association between rough-skinned newts and bare ground cover in spring 1997. The association with bare ground cover might be attributable to the migrations of rough-skinned newts to spring breeding ponds and the selection of unobstructed pathways. Although I had few observations (n = 4 stand observations) to determine an association between clouded salamanders and total CWD volume, this relationship is well documented by other studies (Bury and Corn 1988, Corn and Bury 1991*a*, Gilbert and Allwine 1991).

Seasonal and Methodological Variation

Capture rates varied among seasons. Average mammal capture rates varied from 27.8/1,000 trap nights in spring to 39.8/1,000 trap nights in fall 1996, but dropped to 11.0/1,000 trap nights in spring 1997. The decline in spring 1997 is probably a removal effect. Declines in mammal capture rates limited statistical analyses to one mammal species, Trowbridge's shrew, in spring 1997. Average amphibian capture rates also varied from 1.5/1,000 trap nights in spring to 5.0/1,000 trap nights in fall 1996, and remained similar in spring 1997, with 4.2/1,000 trap nights. Differences between sampling methods for amphibians were seen in the capture of 7 clouded salamanders during 2 seasons of timed, area-constrained ground searches compared with only 1 capture during 3 seasons of pitfall trapping. Captures of ensatinas also were greater with ground searches than pitfall trapping in spring 1996 (102 vs. 32) but not in 1997 (65 vs. 75). These results have implications to future studies and the selection of methods for sampling terrestrial amphibians. Pitfall trapping is more costly and labor intensive over a longer period of time than timed, area-constrained ground searches. However, ground searches may not be as thorough in sampling amphibian species that migrate long distances, like rough-skinned newts or northwestern salamanders (*Ambystoma gracile*).

Comparison of Species and Capture Rates with Other Studies

The majority of vertebrates captured during my project are common to the region. Two terrestrial amphibian species that were not captured during my project were Oregon slender (*Batrachoseps wrighti*) and western red-backed salamanders (*Plethodon vehiculum*). Range maps in Leonard *et al.* (1993), Nussbaum *et al.* (1983), and Blaustein *et al.* (1995) indicate that both species occur within the study area. Gilbert and Allwine (1991) captured a few individuals of both species in their study of the Oregon Cascade Range, however, Corn and Bury (1991*a*) found substantial numbers of western red-backed salamanders in their Oregon Coast Range study. The reasons for the absence of these 2 species from my study is unclear but possible explanations may include: (1) their geographical distribution does not actually extend within the study area, (2) the sampling methods I used were inadequate for detection, or (3) the habitat sampled was unsuitable to support these species.

A comparison of capture rates (#/1,000 trap nights) between my results and the results from Corn and Bury's (1991*a* and *b*) Oregon Coast Range studies showed differences in capture rates among species. I averaged their results among wet, moderate, and dry sites and old-growth, mature, and young sites and converted their rate (#/100 trap nights) to (#/1,000 trap nights). I averaged my results among sample grids and seasons. Pitfall trapping methods were similar between their studies and mine. Capture rates for Trowbridge's shrews were higher in my study (21.22 vs. 16.60/1,000 trap nights), but rates for shrew-moles were virtually identical (0.93 vs. 0.92/1,000 trap nights). For other species, capture rates were lower in my study: ensatinas (2.43 vs. 4.89/1,000 trap nights), rough-skinned newts (0.54 vs. 1.17/1,000 trap nights), and western red-backed voles (0.48 vs. 6.16/1,000 trap nights).

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Forest Floor Vertebrate Associations

The results from macro- and microhabitat associations were similar for ensatinas and fog shrews, but were somewhat different for Trowbridge's shrews. Ensatina presence and abundance were positively associated with increased cover and volume of CWD. They were most often found in decay class 3 and 4 CWD; preferentially selecting decay class 4 CWD based on availability in 1996. In addition, ensatinas were often found under litter, moss, and bark (separate from logs). Clouded salamander abundance also was positively associated with CWD volume. I did not find an association between rough-skinned newts and CWD, but they were positively associated with bare ground cover, perhaps related to the selection of unobstructed pathways for migrating to spring breeding ponds. On average, amphibians captured during timed, area-constrained ground searches were 0.5 m from the nearest CWD, however, individuals were often found in direct contact with CWD.

Macro- and microhabitat associations were somewhat contradictory for Trowbridge's shrews. In 2 seasons, I found positive associations with fern cover at the stand level, but I found a negative association with fern cover at the microhabitat level. Still, I found a positive association with woody plant cover. In general, vegetative cover was positively associated with Trowbridge's shrew presence and abundance. However, the association with fern cover at the stand level may only indicate an overall condition of Trowbridge's shrew habitat, but not a direct association, as seen in the negative association at the microhabitat level. Fog shrews were positively associated with herb cover at the stand and microhabitat levels of analyses. Shrew-moles were positively associated with woody plant cover, but negatively associated with large diameter log cover. In general, presence and abundance of the mammals analyzed in my project were not associated with CWD.

Inference from this project should be confined to the uplands of managed forests in the western Oregon Cascades with moderate slopes, sparse to moderate understory vegetation, and stand ages between 23 to 76 years. Because this project was an observational study, without manipulation of stand habitats, cause and effect determination of results cannot be made (Hurlbert 1984). Future research efforts to understand relationships between wildlife and CWD should include studies in a wider range of stand ages and geographical distributions, in managed and natural forests under a variety of silvicultural options. Additional information is needed on species that were captured infrequently during this study and other species that were absent to assess relationships with CWD volume, decay classes, and distribution.

Coarse Woody Debris Management

The main objective of my project was to provide information on forest floor vertebrate associations with CWD to improve existing CWD management guidelines and regulations. The stands sampled in my project ranged in CWD volume from 14 to 859 m^3/ha. In the stands with the lowest CWD volumes, few ensatinas were captured and no clouded salamanders were observed throughout sampling. Current minimum retention regulations for state and private lands in Oregon require 1.5 m^3/ha CWD volume (Appendix A) (Oregon Dept. of Forestry

1996), while federal interim retention guidelines for western Oregon matrix lands suggest a minimum of 37 m^3/ha CWD volume (Appendix A) (USDA, Forest Service and USDI BLM 1994). Based on my results, these minimum guidelines may not be adequate to provide habitat for terrestrial salamanders or other species that use CWD for habitat.

The range of CWD volumes I observed in my project was greater than the range observed by others for unmanaged stands. CWD volume in natural stands in the western Cascades, averaged 248 m^3/ha in young stands (< 80 years old), 148 m^3/ha in mature stands (80-120 years old), and 313 m^3/ha in old-growth stands (400-500 years old) (Spies *et al.* 1988). Moreover, CWD volume in the H.J. Andrews Experimental Forest, in the western Oregon Cascades, ranged from 175 to 320 m^3/ha in old-growth Douglas-fir stands (Mark Harmon, unpubl. data). Historical trends in wood utilization standards substantially influenced the range of CWD volumes in my project. The low volume stands I sampled were originally harvested after the 1960's and intensively salvage logged (R. Gehrman, pers. comm.). The high volume stands I sampled were originally harvested prior to the 1950's, when wood utilization standards were lower. CWD residue following timber harvest was modeled by Harmon *et al.* (1996). They found timber harvesting increases downed CWD residue, even with current wood utilization standards. Therefore, stands that were originally harvested in the early 1900's may have more than adequate CWD for meeting most management objectives, whereas stands originally harvested after the 1960's, and possibly salvaged logged since then, may lack adequate CWD to meet most management objectives. In either case, however, recruitment of future CWD needs to be considered in CWD management plans.

The natural range of variability of CWD in unmanaged forests provides one framework for discussing CWD retention goals in managed forests. However, defining specific objectives for CWD management is another way to develop management plans to meet desired objectives. My project is a good example of describing the relationship between CWD volume and distribution with terrestrial salamanders. It shows that ensatina presence and abundance will likely increase if more CWD is retained in low CWD volume stands. The same response also is likely for clouded salamander abundance. In contrast, other species I observed, like shrew-moles, may not benefit from additional CWD retention. Therefore, higher CWD volumes may be desirable for one objective and not for another. My project provides an example of how we might change the way we think about CWD management, by managing to meet specific objectives (providing habitat for wildlife, facilitating nutrient cycling, or multiple objectives). This makes more practical and biological sense than applying a standard guideline or regulation across a large landscape.

LITERATURE CITED

Aubry, K.B., L.L.C. Jones, and P.A. Hall. 1988. Use of woody debris by plethodontid salamanders in Douglas-fir forests in Washington. *In:* R.C. Szaro, K.E. Severson, and D.R. Patton, tech. coords. Management of amphibians, reptiles, and small mammals in North America-proceedings of the symposium. U.S. For. Serv. Gen. Tech. Rep. RM-166. Pages 32-37.

______ and P.A. Hall. 1991. Terrestrial amphibian communities in the southern Washington Cascade range. *In:* L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, tech coords. Wildlife and vegetation of unmanaged Douglas-fir forests. U.S. For. Serv. Gen Tech. Rep. PNW-285. Pages 326-338.

Blaustein, A.R., J.J. Beatty, D.H. Olson, and R.M. Storm. 1995. The biology of amphibians and reptiles in old-growth forests in the Pacific Northwest. U.S. For. Serv. Gen. Tech. Rep. PNW-337. 98 pp.

Burton, T.M. and G.E. Likens. 1975. Energy flow and nutrient cycling in salamander populations in the Hubbard Brook Experimental Forest, New Hampshire. Ecology. 56:1068-1080.

Bury, R.B. 1994. Vertebrates in the Pacific Northwest: species richness, endemism and dependency on old-growth forests. *In:* S.K. Majumdar, F.J. Brenner, J.E. Lovich, J.F. Schalles, and E.W. Miller, eds. Biological diversity: problems and challenges. The Pennsylvania Academy of Science. Pages 392-404.

______ and P.S. Corn. 1988. Douglas-fir forests in the Oregon and Washington Cascades: relation of the herpetofauna to stand age and moisture. *In:* R.C. Szaro, K.E. Severson, and D.R. Patton, tech. coords. Management of amphibians, reptiles, and small mammals in North America-proceedings of the symposium. U.S. For. Serv. Gen. Tech. Rep. RM-166. Pages 11-22.

Carraway, L.N. 1989. A morphologic and morphometric analysis of the relationships within the “Sorex vagrans species complex” in the Pacific Coast region. Ph.D. Dissertation, Oregon State Univ., Corvallis. 144 pp.

Cook, J.G., T.W. Stutzman, C.W. Bowers, K.A. Brenner, and L.L. Irwin. 1995. Spherical densiometers produce biased estimates of forest canopy cover. Wildl. Soc. Bull. 23(4):711-717.

Corn, P.S., R.B. Bury, and T.A. Spies. 1988. Douglas-fir forest in the Cascade mountains of Oregon and Washington: Is the abundance of small mammals related to stand age and moisture? *In:* R.C. Szaro, K.E. Severson, and D.R. Patton, tech. coords. Management of amphibians, reptiles, and small mammals in North America-proceedings of the symposium. U.S. For. Serv. Gen. Tech. Rep. RM-166. Pages 340-352.

______ and R.B. Bury. 1990. Sampling methods for terrestrial amphibians and reptiles. U.S. For. Serv. Gen. Tech. Rep. PNW-256. 15 pp.

______ and R.B. Bury. 1991*a*. Terrestrial amphibian communities in the Oregon Coast Range. *In:* L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, tech coords. Wildlife and vegetation of unmanaged Douglas-fir forests. U.S. For. Serv. Gen Tech. Rep. PNW-285. Pages 304-317.

______ and R.B. Bury. 1991*b*. Small mammal communities in the Oregon Coast Range. *In:* L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, tech coords. Wildlife and vegetation of unmanaged Douglas-fir forests. U.S. For. Serv. Gen Tech. Rep. PNW-285. Pages 240-253.

Dalquist, W.W. and D.R. Orcutt. 1942. The biology of the least shrew-mole, *Neurotrichus gibbsii* minor. Am. Midl. Nat. 27:387-401.

Daubenmire, R. 1959. A canopy coverage method of vegetation analysis. Northwest Sci. 33:43-64.

deMaynadier, P.G. and M.L. Hunter, Jr. 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. Environmental Reviews, Vol. 3. Pages 230-261.

Franklin, J.F. and C.T. Dyrness. 1973. Natural vegetation of Oregon and Washington. Oregon State University Press, Corvallis. 417 pp.

Gilbert, F.F. and R. Allwine. 1991. Terrestrial amphibian communities in the Oregon Cascade Range. *In:* L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, tech coords. Wildlife and vegetation of unmanaged Douglas-fir forests. U.S. For. Serv. Gen Tech. Rep. PNW-285. Pages 318-324.

Harmon, M.E. and J. Sexton. 1996. Guidelines for measurements of woody detritus in forest ecosystems. Publication No. 20. U.S. LTER Network Office: University of Washington, Seattle, WA, USA. 73 pp.

______, S.L. Garman, and W.K. Ferrell. 1996. Modeling historical patterns of tree utilization in the Pacific Northwest: carbon sequestration implications. Ecological Applications. 6(2):641-652.

Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs. 54:187-211.

Leonard, W.P., H.A. Brown, L.L.C. Jones, K.R. McAllister, and R.M. Storm. 1993. Amphibians of Washington and Oregon. Seattle Audubon Society, Seattle, WA. 168 pp.

Maser, C. and E.F. Hooven. 1974. Notes on the behavior and food habits of captive Pacific shrews, *Sorex pacificus pacificus*. Northwest Sci. 48:81-95.

______, J.M. Trappe, and R.A. Nussbaum. 1978. Fungal-small mammal interrelationships with emphasis on Oregon coniferous forests. Ecology. 59:799-809.

______, B.R. Mate, J.F. Franklin and C.T. Dyrness. 1981. Natural history of Oregon coast mammals. U.S. For. Serv. Gen. Tech. Rep. PNW-133. 496 pp.

______ and J.M. Trappe, tech eds. 1984. The seen and unseen world of the fallen tree. U.S. For. Serv. Gen. Tech. Rep. PNW-164. 56 pp.

McComb, W.C., T.A. Spies, and W.H. Emmingham. 1993. Douglas-fir forests: managing for timber and mature-forest habitat. J. For. 91:31-42.

Muir, P.S. and B. McCune. 1988. Lichens, tree growth, and foliar symptoms of air pollution: are the stories consistent? J. Environmental Qual. 17:361-370.

Nussbaum, R.A., E.D. Brodie, Jr., and R.M. Storm. 1983. Amphibians and reptiles of the Pacific Northwest. University Press of Idaho, Moscow, ID. 332 pp.

Oregon Department of Forestry. 1995. Forestry program for Oregon. Oregon Board of Forestry and Oregon Department of Forestry. Salem, OR. 64 pp.

______. 1996. Oregon Department of Forestry: Oregon Forest Practices Act (May 10, 1996 unofficial version, official publication by the Secretary of State is pending.). Salem, OR. 26 pp.

Ramsey, F.L. and D.W. Schafer. 1997. The statistical sleuth: a course in methods of data analysis. Duxbury Press. 742 pp.

Raphael, M.G. 1988. Long-term trends in abundance of amphibians, reptiles, and mammals in Douglas-fir forests of northwestern California. *In:* R.C. Szaro, K.E. Severson, and D.R. Patton, tech. coords. Management of amphibians, reptiles, and small mammals in North America-proceedings of the symposium. U.S. For. Serv. Gen. Tech. Rep. RM-166. Pages 23-31.

SAS Institute Inc. 1990. SAS/STAT® User's guide, version 6, 4th edition. Cary, North Carolina. Pages 1351-1456.

______. 1997. SAS/STAT® Software: Changes and enhancements through release 6.12, Cary, North Carolina. Pages 247-348.

Sollins, P. 1982. Input and decay of coarse woody debris in coniferous stands in western Oregon and Washington. Can. J. For. Res. 12:18-28.

Spies, T.A. and S.P. Cline. 1988. Coarse woody debris in forests and plantations of coastal Oregon. *In:* C. Maser, R.F. Tarrant, J.M Trappe, and J.F. Franklin, eds. From the forest to the sea: a story of fallen trees. U.S. For. Serv. Gen. Tech. Rep. PNW-229. Pages 5-23.

______, J.F. Franklin and T.B. Thomas. 1988. Coarse woody debris in Douglas-fir forests of western Oregon and Washington. Ecology. 69:1689-1702.

Stebbins, R.C. 1954*a*. Amphibians and reptiles of western North America. New York: McGraw-Hill Book Co. 536 pp.

______. 1954*b*. Natural history of the salamanders of the plethodontid genus Ensatina. Univ. Calif. Publ. Zool. 54:47-124.

Thompson, R.L. 1996. Home range and habitat use of western red-backed voles in mature coniferous forests in the Oregon Cascades. M.S. Thesis, Oregon State Univ., Corvallis. 88 pp.

Trappe, J.M. 1965. Tuberculate mycorrhizae of Douglas-fir. For. Sci. 11:27-32.

United States Department of Agriculture (USDI) Forest Service and United States Department of Interior (USDI) Bureau of Land Management. 1994. Record of Decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Standards and Guidelines for management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. USDA Forest Service, USDI, Bureau of Land Management. 74 pp.

Ure, D.C. and C. Maser. 1982. Mycophagy of red-backed voles in Oregon and Washington. Can. J. Zool. 60:3307-3315.

Van Wagner, C.E. 1968. The line intersect method in forest fuel sampling. Forest Science. 14:20-26.

Wenger, Karl. 1984. Forestry handbook. 2nd edition. John Wiley and Sons, Inc. 1335 pp.

APPENDICES

Appendix A. CWD retention guidelines in the Oregon Forest Practices Act (Oregon Dept. of Forestry 1996) and the Northwest Forest Plan (USDA, Forest Service and USDI, BLM 1994). Guidelines are expressed in the English measurement system with metric system equivalents.

Oregon Forest Practices Act (Oregon Dept. of Forestry (pg. 8) 1996)
According to the Oregon Forest Practices Act, "Forest operators...are required to retain two downed logs per acre in certain harvest units larger than 25 acres. The total basal area (the area of cross section of a tree stem at breast height-4.5 feet-expressed in square feet) per acre of 11 inches DBH and larger remaining after harvest determines if wildlife tree and downed log retention are required. This basal area threshold varies by site productivity as follows: for Cubic Foot Site Class I, II, and III (Douglas-fir 100-year site index 124 and greater): less than 33 square feet of basal area per acre...each downed log must be at least six feet long and contain a gross volume of at least 10 cubic feet. Logs containing 20 cubic feet or more count as two logs".

Simplified, in English measurements
2 downed logs/acres are required in harvest areas >25 acres if the total basal area of trees (>11 inches dbh) is <33 ft^2/acre, in Douglas-fir stands. Logs must be $\geq$6 ft in length and contain a gross volume of $\geq$10 ft^3.

Simplified, in metric measurements
5 downed logs/hectare are required in harvest areas >10 hectares if the total basal area of trees (>28 cm dbh) is <7.6 m^2/hectare, in Douglas-fir stands. Logs must be $\geq$1.8 m in length and contain a gross volume $\geq$0.3 m^3.

Therefore, 5 downed logs/hectare @ 0.3 m^3 = 1.5 m^3/hectare.

Appendix A. Continued.

Northwest Forest Plan (USDA, Forest Service and USDI, BLM (Standards and Guidelines pg. C-40) 1994)
According to the Northwest Forest Plan, "for western Oregon...including...the Eugene BLM District, leave 240 linear feet of logs per acre greater than or equal to 20 inches in diameter".

Simplified, in English measurements
Leave 240 linear feet of logs/acre $\geq$20 in. in diameter.

Simplified, in metric measurements
Leave 181 linear meters of logs/hectare $\geq$51 cm in diameter.

Volume calculated using the formula

$$V = \pi r^2 h = \pi(0.255\ m)^2\ (181\ m) = 37\ m^3/ha$$

where V is the volume (m^3), r is the radius (m), and h is the height (m).

English and Metric Equivalents (Wenger 1984).

1 inch = 2.540005 centimeters
1 foot = 0.30480 meters
1 square foot = 0.092903 square meters
1 cubic foot = 0.028317 cubic meters
1 acre = 0.404687 hectare

Appendix B. Vertebrate species captured in pitfall traps and timed, area-constrained ground searches in 1996 and 1997 in the western Oregon Cascades.

Pitfall trapping.

Season	Spring 1996	Fall 1996	Spring 1997
Total number of trap nights	27,216	13,608	23,256
Species[a]			
Mammals			
Trowbridge's shrew	622	454	187
Fog shrew	70	20	39
Marsh shrew	3	1	-
Vagrant shrew	11	1	-
Pacific shrew	1	-	-
Unidentified shrew	1	-	-
Coast mole	5	11	8
Shrew-mole	19	24	8
Deer mouse	11	9	-
Western red-backed vole	10	11	9
Creeping vole	3	5	4
Long-tailed vole	-	1	-
Douglas squirrel	-	1	-
Total mammals	756	538	255
Amphibians			
Ensatina	32	39	75
Northwestern salamander	7	15	3
Rough-skinned newt	1	11	18
Clouded salamander	-	1	-
Pacific giant salamander	1	2	1
Red-legged frog	1	-	1
Total amphibians	42	68	98
Total (all species)	798	606	353
Number of species	16	16	11

Appendix B. Continued.

Timed, area-constrained ground searches.

Season	Spring 1996	Spring 1997
Species[a]		
Ensatina	102	65
Northwestern salamander	1	4
Rough-skinned newt	3	5
Clouded salamander	1	6
Total amphibians	107	80
Number of species	4	4

[a] common and scientific names are listed in appendix D.

Appendix C. Average species richness among 3 seasons of pitfall trap captures in 1996 and 1997 in the western Oregon Cascades (mammal and amphibian species combined).

Stand Number/Ownership[a]	Average species richness among seasons[b]
1/b	4.3 (0.7)
2/w	6.3 (0.3)
3/w	3.7 (0.7)
4/w	5.7 (1.9)
5/w	5.3 (0.3)
6/w	4.3 (1.3)
7/b	4.7 (0.9)
8/b	5.3 (0.9)
9/b	4.0 (0.0)
10/b	5.0 (1.0)
11/w	4.7 (0.7)
12/w	6.0 (1.0)
13/w	4.7 (0.9)
14/w	5.7 (0.9)
15/w	5.0 (1.2)
16/w	4.3 (0.9)
17/w	5.3 (0.9)
18/w	6.7 (0.7)

Appendix C. Continued. Average amphibian species richness among 2 seasons of timed, area-constrained ground searches in 1996 and 1997 in the western Oregon Cascades.

Stand Number/Ownership[a]	Average species richness among seasons[b]
1/b	1.0 (0.0)
2/w	1.5 (0.5)
3/w	0.5 (0.5)
4/w	1.0 (0.0)
5/w	0.5 (0.5)
6/w	1.5 (0.5)
7/b	1.0 (0.0)
8/b	1.5 (0.5)
9/b	1.0 (0.0)
10/b	1.5 (0.5)
11/w	0.5 (0.5)
12/w	1.0 (0.0)
13/w	0.5 (0.5)
14/w	1.5 (0.5)
15/w	1.5 (0.5)
16/w	1.5 (0.5)
17/w	2.0 (1.0)
18/w	1.5 (0.5)

[a] b = Bureau of Land Management stand, w = Weyerhaeuser Company stand.
[b] average (standard error).

Appendix D. Common and scientific names of vertebrates captured during 1996 and 1997 in the western Oregon Cascades.

Common name	*Scientific name*
Trowbridge's shrew	*Sorex trowbridgii*
Fog shrew	*Sorex sonomae*
Marsh shrew	*Sorex bendirii*
Vagrant shrew	*Sorex vagrans*
Pacific shrew	*Sorex pacificus*
Coast mole	*Scapanus orarius*
Shrew-mole	*Neurotrichus gibbsii*
Deer mouse	*Peromyscus maniculatus*
Western red-backed vole	*Clethrionomys californicus*
Creeping vole	*Microtus oregoni*
Long-tailed vole	*Microtus longicaudus*
Douglas squirrel	*Tamiasciurus douglasi*
Ensatina	*Ensatina eschscholtzii*
Northwestern salamander	*Ambystoma gracile*
Rough-skinned newt	*Taricha granulosa*
Clouded salamander	*Aneides ferreus*
Pacific giant salamander	*Dicamptodon tenebrosus*
Red-legged frog	*Rana aurora*