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Douglas-Fir Forests in the Cascade Mountains of Oregon and Washington: Is the Abundance of Small Mammals Related to Stand Age and Moisture?¹

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Management of old-growth Douglas-fir (*Pseudotsuga menziesii*) forests west of the Cascade Mountains in the Pacific Northwest is an increasingly controversial topic, arising from a fundamental conflict. These forests are extremely valuable sources of timber; 40 ha of old growth is valued at about \$1.6 million (Meslow et al. 1981). At the same time, conservationists view old growth as a unique ecosystem that is nonrenewable under current management practices (Cutler 1984, Schoen et al. 1981). Old-growth forests are disappearing; during the past 30 years, removal of Douglas-fir saw timber from western Oregon and Washington has exceeded annual growth by a factor of three (Harris 1984). Now, less than 20% of the original old-growth forest in the Pacific Northwest remains (Spies and Franklin in press).

Historically, old-growth forests were viewed as decadent stands of

wasted timber that provided little wildlife habitat. For example, Tevis (1956) stated:

Virgin forest in the Douglas-fir (*Pseudotsuga taxifolia* [menziesii]) region of northwestern California is sterile habitat for wildlife. Dense shade and competition from large old trees prevent the growth of nearly all bushy and herbaceous vegetation except a weak understory of tan oak (*Lithocarpus densiflora*). Food for animals is scarce.

The value of old growth has been rehabilitated. Currently, old-growth Douglas-fir forests are considered excellent wildlife habitats, dominated by large trees, but possessing a complex and varied structure (Franklin et al. 1981, Franklin and Spies 1984), including some of the highest amounts of coarse woody debris (CWD) reported for any forest ecosystem (Spies et al. in press).

Most remaining old growth in the Pacific Northwest is on Federal land managed by the Forest Service and Bureau of Land Management (Harris 1984). The policy of the U.S. Department of Agriculture is to "...maintain viable populations of all existing native vertebrate populations..." (Cutler 1980) but, until recently, the information needed to achieve this goal did not exist. Most lists of species with some degree of dependence on

Abstract.—Red tree voles (*Arborimus longicaudus*) were the only small mammal strongly associated with old-growth forests, whereas vagrant shrews (*Sorex vagrans*) were most abundant in young forests. Pacific marsh shrews (*S. bendirii*) were most abundant in wet old-growth forests, but abundance of this species in young (wet) forests needs further study. Clearcuts had a mammalian fauna distinct from young forest stands. Abundance of several species was correlated to habitat features unique to naturally regenerated forests, indicating an urgent need to study the long-term effects of forest management on nongame wildlife.

or association with old growth are incomplete or inferential (e.g., Harris and Maser 1984, Meslow et al. 1981). Recent research has improved this situation, but little of it is directed toward nongame species. A recent symposium on wildlife and old-growth relations (Meehan et al. 1984) included 27 papers. Two-thirds (17) of the papers concerned game species, and only four papers discussed ecology of nongame wildlife. Remaining papers discussed either characteristics of old-growth forests (three papers) or management objectives (three papers).

In 1981, to provide the information necessary for managing wildlife in the national forests of the Pacific Northwest, the U.S. Forest Service chartered the Old-Growth Wildlife Habitat Program⁵ (OGWHP). Its goals (Ruggiero and Carey 1984) were to: (1) identify old-growth forests were unique components of coniferous forest ecosystems, (2) identify the ecological characteristics of old growth, (3) identify any wildlife species dependent on old growth for survival or optimal habitat, and (4) determine the amount and distribution of old growth necessary to meet the needs of dependent species.

Vegetation and vertebrate community studies were performed on a matrix of forest conditions in naturally regenerated stands. Forest de-

⁵Now the Wildlife Habitat Relationships in Western Oregon and Washington Project.

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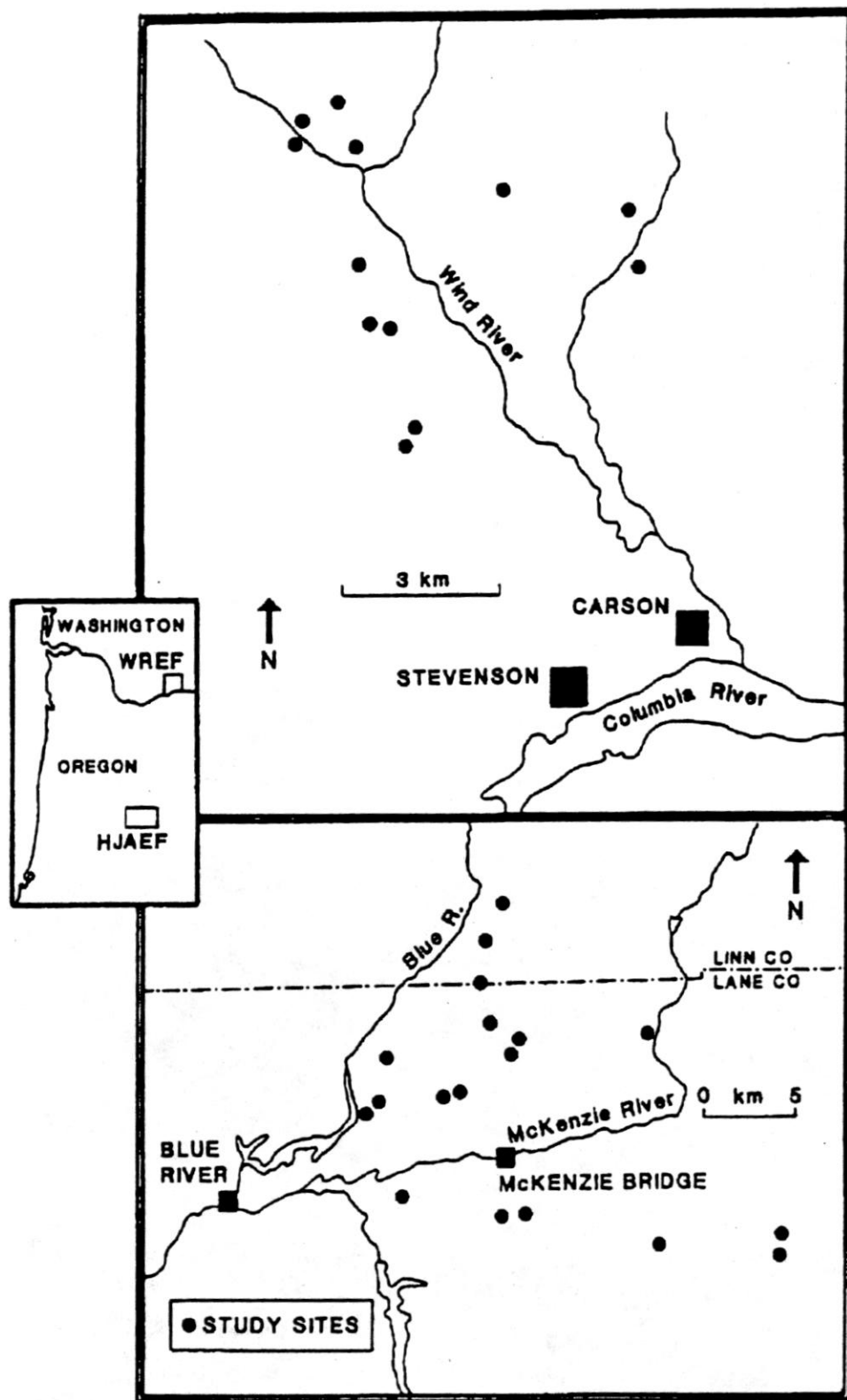


Figure 1.—Maps of study areas where pitfall trapping was conducted in 1983. HJAEF = H. J. Andrews Experimental Forest; WREF = Wind River Experimental Forest. Note that the scale for each map is different.

velopment was examined across a chronosequence, and a moisture gradient was examined for the old-growth stands.

Field work began in 1983 with vegetation and vertebrate community pilot studies at 30 stands spread between two sites in the Oregon and Washington Cascade Mountains. The primary goal of the first year was to evaluate and recommend sampling techniques. The pilot studies were successful in developing and refining sampling methods (e.g., Bury and Corn 1987, Thomas and West 1984, West 1985). In 1984 and 1985, community studies expanded to more than 180 stands in the Washington Cascades, the Oregon Cascades, the Oregon Coast Range, and the Siskiyou and Klamath mountains of southern Oregon and northern California. Since 1985, species-specific studies have been emphasized, largely concerning the ecology and management of the spotted owl (*Strix occidentalis*) and its prey base.

Our paper concerns the community ecology of small mammals as revealed by pitfall trapping in 1983. The data collected in 1983 are useful for other than evaluating techniques, but these data are difficult to integrate into 1984 and 1985 results, because the sampling methods were changed (Bury and Corn 1987). Therefore, we report these results with the caveat that variation between years is not examined.

Our specific objectives are to examine the relations of the abundance of small mammal species to the chronosequence and the moisture gradient and to identify specific habitat features that contribute to abundance. The effects of forest management are also discussed.

METHODS

Study Areas

Forest stands were studied in two areas on the western slopes of the

Cascade Mountains (fig. 1). Twelve stands were in the Wind River Experimental Forest (WREF) or the surrounding Gifford Pinchot National Forest, Skamania County, Washington, and 18 stands were in the H. J. Andrews Experimental Forest (HJAEF) or Willamette National Forest, Lane and Linn counties, Oregon. Appendix A lists ages, elevations, and locations of all stands.

Stand Selection and Classification

Initial stand selections were made by OGWHP investigators studying the structure of old growth (Franklin and Spies 1984, Spies and Franklin in press). Age was the primary criterion for establishing a stand's position on the chronosequence. Topographic position and understory vegetation provided a first approximation of a moisture gradient (south- or west-facing ridges were generally dry, whereas stands on north-facing slopes were usually moist to wet). Most stand boundaries were not highly distinct (e.g., forest islands surrounded by clear cuts) but were determined by several factors, including age, disturbance history, vegetational composition, physiography, and soils. Stands were first chosen from aerial photographs and forest type maps, but an on-site inspection was completed before any of the vertebrate sampling plots were established. Stand sizes varied from about 10 to 20 ha.

Coarse woody debris (CWD), vegetation, and site characteristics were sampled in five nested, circular plots in each stand (Spies et al. in press). Classification of downed CWD (=logs) followed Franklin et al. (1981) and Maser and Trappe (1984): from class 1 logs (essentially undecayed) to class 5 logs (well decayed, appearing as raised hummocks in the forest floor).

The chronosequence consisted of four categories beginning with clearcuts (< 10 years old), closed-can-

opy young stands (30-80 years), mature stands (80-195 years), and old growth (195-450 years). The latter three categories were all composed of naturally regenerated forests. Ages of young and mature stands were estimated by increment coring of at least five dominant Douglas-fir trees per stand (Spies et al. in press). Ages of old-growth stands were estimated from increment cores and by examining stumps in adjacent clearcuts and roadsides.

In an ideal chronosequence analysis, age classes should have similar means and ranges of site characteristics. We were only partly successful in achieving this goal, because the age classes were not equally distributed over the landscape, and other criteria such as stand size, accessibility, and absence of logging activity took precedence over site uniformity. Consequently, young and mature stands spanned a wider range of environments than originally planned and for some variables (such as elevation at the HJAEF), the younger age classes differed from old growth.

We conducted analysis of moisture effects across the old-growth

stands. Adjustments were made to the preliminary field classification of dry (OGD), moderate (OGM), and

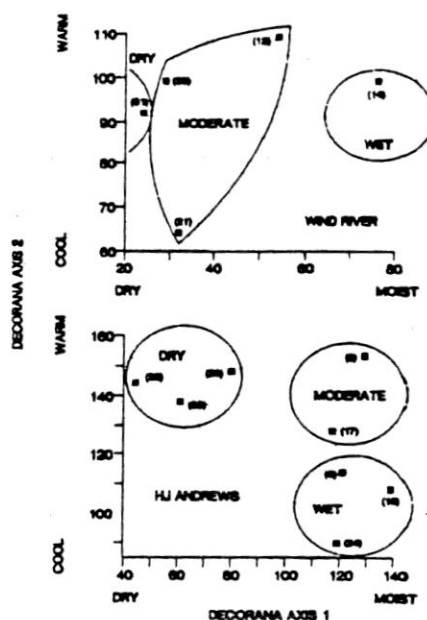


Figure 2.—Detrended correspondence analysis (DECORANA) of percent occurrence of understory plant species in old-growth stands in Oregon and Washington. Stands were placed in moisture categories (wet, moderate, or dry) based on their relative positions on the two gradients.



Figure 3.—A pitfall array in clearcut stand #291 in Oregon. Photo by L. Hanebury.

wet (OGW), after conducting ordinations of old-growth stands using detrended correspondence analysis (DECORANA). DECORANA is a weighted average technique that is computationally related to principal components analysis (Gauch 1982). The percent occurrence of understory plant species in five 1,000-m² plots in each stand was used in separate analyses of each study area (fig. 2). The first axis in both areas separated stands along a moisture gradient correlated with indicators of topographic moisture, such as aspect and slope. The second axis in both analyses separated stands along a complex gradient of temperature and moisture and was correlated with elevation.

Pitfall Trapping

We installed a pitfall trap array (fig. 3) in each stand. An array included two triads, 25 m apart, each consisting of three 5-m long aluminum drift fences with screen wire funnel traps on each side and pitfall traps at each end. Thus, each array had six fences and twelve pitfall and twelve funnel traps. Bury and Corn (1987, this volume) provide more complete descriptions and illustrations.

The traps were opened the last week in May 1983 and were operated continuously for 180 days. No water was put in traps, because this has a deleterious effect on the preservation of amphibians, which were a major target of the traps (Bury and Corn, this volume). In practice, most traps accumulated some water and most mammals drowned. Traps were checked initially every three days, but as trap rate declined over time, the interval between checks increased to about seven days.

Mammals taken from traps were identified, sexed, measured, and preserved as skulls, skeletons, or skins and skulls. All specimens from Oregon and most from Washington were deposited in the National Museum of

Natural History (USNM), where all identifications were verified. Common and scientific names used in this paper follow Banks et al. (1987).

We encountered one problem that significantly affected the data analysis. The high trap success at the WREF stands exceeded the field crew's ability to process specimens, and approximately 25% of the mammals were discarded in the field. When the remaining specimens were examined later at the USNM, about 10% of the field identifications of Trowbridge's shrews (*Sorex trowbridgei*), montane shrews (*S. monticolus*), and vagrant shrews (*S. vagrans*) were inaccurate. Thus, the exact numbers of these shrews captured at WR are in doubt (Bury and Corn 1987), and analyses of overall species richness and individual abundance of these species were only reported for Oregon data.

Statistical Analyses

We analyzed the mean abundance (total number of captures) of each species, mean total abundance, and mean species richness across each gradient with one-way analysis of variance (ANOVA). No traps were missing or damaged during the 180-day trapping period, so it was unnecessary to adjust raw abundance for trap nights. Scavengers may remove animals from traps when there are long intervals between checks (M. G. Raphael, personal communication), and traps with water may be more effective than dry pitfalls at capturing rodents with good leaping ability. Because 70% of all mammals were captured in the first 60 days of trapping (Bury and Corn 1987), when traps were checked frequently, we feel these considerations are minor and we made no adjustments to the data.

Abundances were log transformed before the ANOVAs were run. Clearcuts, OGW and OGD stands were not included in the ANOVA of

the chronosequence. Clearcuts, young, and mature stands were not included in the ANOVA on moisture (Spies et al. in press). A comparison of species' abundances in clearcuts versus young stands is presented separately. Pearson correlation coefficients were calculated between abundance (transformed as $\ln[\text{abundance} + 1]$) and 24 of the habitat variables (appendix B). Percentage variables (e.g., % cover of grasses) were arcsin transformed, other variables were log transformed. We also performed a principal components analysis using the habitat variables, but because the first three factors explained only 52% of the variation among stands, we report only the significant ($P < 0.05$) bivariate correlations between abundance and individual habitat variables. All analyses were performed using the statistical program SYSTAT⁶ (Wilkinson 1988).

RESULTS

The pitfall arrays were highly effective at capturing small mammals, producing 3,877 captures of 27 species. Insectivores and microtine rodents were best caught by pitfalls, while deer mice (*Peromyscus maniculatus*) were under-sampled (Bury and Corn 1987). Captures of each species in each stand are listed in tables 1 (HJAEF) and 2 (WREF).

Mean species richness (number of species) varied from about nine in mature stands to 12 in OGW stands (fig. 4). There was no significant difference across either the chronosequence or the moisture gradient. Total abundance was highest in young and mature stands and lowest in OGM stands, but the difference was not significant. There was no apparent trend in small mammal abundance across the moisture gradient.

⁶Trade names are provided for the benefit of the reader; such use does not constitute an official endorsement by the Fish and Wildlife Service.

Table 1.—Abundance of small mammals captured at the H. J. Andrews Experimental Forest in Oregon. Arrays of pit-fall traps with drift fences were operated continuously for 180 days in 1983.

Species	Stand no.	Old growth									Mature			Young				Clearcut		
		Wet			Moderate			Dry			11	35	42	39	47	48	75	55	291	391
		15	03	24	02	17	33	25	29											
Trowbridge's Shrew		33	48	48	76	35	60	75	70	51	56	78	70	139	71	83	18	39	17	
Montane Shrew		16	15	28	23	13	9	7	19	15	16	15	26	17	14	22	3	8	13	
Vagrant Shrew		13	2	1			2		4	2	7	2	17	3	5	6	1	1	74	
Pacific Marsh Shrew		7	14	8		1	1	1	1	7	9		2	2	4	13			1	
Northern Water Shrew													4							
Pacific Shrew									1							2				
Unidentified shrews			1		1											1				
Shrew Mole		3	5	3		1	1		2	4	2		9	4	2	5			1	
Coast Mole		1		1	4	5	4	6	1	2	2	1		7	1	2	3	2		
Western																				
Red-backed Vole		14	4	1	2	9	6	3	10	6	15	18	52	13	7	4			1	
Creeping Vole			1		1	2	1		1	1			2			3	1	5	28	
Red Tree Vole		1	3	3	4	1				1	2				1			1		
Water Vole					1	2	1						1			1				
Heather Vole									1										5	
Townsend's Vole			1									2						1		
Deer Mouse		3		3	3	1	3	2	1	3	3		3	1	2	5	2	3	24	
Pacific Jumping Mouse			1	1			2				1		3	1		14		1	3	
Western Pocket Gopher											1	2	1						16	
Others ^a			1	2		1		2	2				2		1	1		1	1	

^aTownsend's Chipmunk (8), Northern Flying Squirrel (3), Ermine (2), Spotted Skunk (1), Snowshoe Hare (1).

Table 2.—Abundance of small mammals captured at the Wind River Experimental Forest in Washington. Arrays of pit-fall traps with drift fences were operated continuously for 180 days in 1983.

		Old growth												
		Wet	Moderate			Dry	Mature			Young		Clearcut		
Species	Stand No.	14	12	21	20	31	41	42	50	60	61	70	71	
Pacific Marsh Shrew	10		3	2	3		6	3	3	2	7	3		
Other shrews ^a	86		73	93	46	115	192	127	158	117	97	50	86	
Shrew Mole	6			9	1	2	9	2	6	1	1		3	
Coast Mole			3	3		3	4	1	1	2				
Southern														
Red-backed Vole	15		10	21	20	40	13	16	3	41	31	4	1	
Creeping Vole	2			4	2	3	6	9	2	1	4	9	11	
Townsend's Vole	1					5	2	1	1	1			5	
Other Microtines ^b										3	1		2	
Deer Mouse	8		16	40	11	28	23	11	16	9	7	32	7	
Pacific Jumping Mouse	2			2			2			1		1		
Northern Pocket Gopher							2		1		1		4	
Others ^c			1	1		7					1	1	3	

^aUnidentified (70), Trowbridge's Shrew (696?), Montane Shrew (351?), Vagrant Shrew (120?), Masked Shrew (?), and Northern Water Shrew (3).

^bUnidentified (6), Heather Vole (1).

^cErmine (6), Townsend's Chipmunk (3), Yellow-pine Chipmunk (2), Snowshoe Hare (2), Northern Flying Squirrel (1), Pika (1).

Species-Habitat Associations

Trowbridge's Shrew

These shrews were the most abundant small mammal (about 46% of all captures). At HJAEF, this species was most abundant in young stands (fig. 5), but the variation across the chronosequence was not statistically significant. Most of the high mean abundance in young stands was due to one stand (#47) at HJAEF (table 1). Abundance on the moisture gradient increased from OGW to OGD, but the differences were not significant.

Habitat variables that were positively correlated with abundance of Trowbridge's shrews included the total basal area and mean diameter at breast height (d.b.h.) of live trees, the number of decay class 4 and 5 (most decayed) downed logs, and litter depth (table 3). Variables negatively

correlated were percent cover by herbs and grasses and the biomass of least decayed logs (class 1 and 2).

Montane Shrew

This was the second most abundant species, occurring in similar numbers in stands of different ages (fig. 5). There is a trend on the moisture gradient of decreasing abundance from OGW to OGD, but the differences are not significant. Abundance of montane shrews was positively correlated with tree size (MDBH) and negatively correlated with percent cover by grasses and number of decay class 1 and 2 logs (table 3).

Vagrant Shrew

Vagrant shrews were significantly less abundant in older forest stands (fig. 5, $P = 0.02$), and variation across the moisture gradient was not significant. This species reached its greatest abundance in one clearcut (see below). Abundance of vagrant shrews was negatively correlated with several characters associated with old-growth forests: number of decay class 4 and 5 logs, percent cover by mosses, litter depth, and slope (table 3).

Pacific Marsh Shrew

The Pacific marsh shrew (*Sorex bendirii*) is a large shrew generally associated with small streams and swamps (Maser et al. 1981, Whitaker and Maser 1976). Our results agree. The greatest abundance was in OGW stands (fig. 5), and the difference across the moisture gradient was significant ($P < 0.001$). Marsh shrews were captured (albeit in low numbers) in moderate and dry old-growth stands where the pitfall arrays were some distance from flowing or standing water, but many of the younger stands in which this species occurred (e.g., stands 11, 35, and 75 at the HJAEF) contained streams

or ponds. Variation across the chronosequence was not significant, but this may be misleading given the high abundance in OGW stands. Our study design precluded us from determining whether Pacific marsh shrews would be abundant in younger wet stands.

Several habitat variables were associated with abundance of Pacific marsh shrews. Positive correlations reflected older, wet forests and included litter depth, total density of live trees, mean d.b.h., and biomass of class 4 and 5 logs. The number of decay class 1 and 2 logs and slope were negatively correlated with abundance (table 3).

Shrew Mole

Shrew moles (*Neurotrichus gibbsii*) are small moles but are more like shrews in appearance and habits. Patterns of their abundance were similar to the Pacific marsh shrew (fig. 5). Shrew moles were most abundant in OGW, but there were no significant differences across the moisture gradient or the age gradient. Unlike the marsh shrew, none of the habitat variables were correlated with abundance.

Coast Mole

We captured 59 coast moles (*Scapanus orarius*), a form rarely taken by conventional snap- or live-trapping techniques. This species might be more active on the surface than other moles (Maser et al. 1981), or our drift fences (which were sunk 20-30 cm into the ground) might have interrupted their burrowing (Williams and Braun 1983). There was no significant variation on the chronosequence, but there was on the moisture gradient ($P = 0.05$). Coast moles were most abundant in OGM and OGD stands and were virtually absent from OGW stands (fig. 5).

Coast moles might prefer well-drained soils (Maser et al. 1981). This

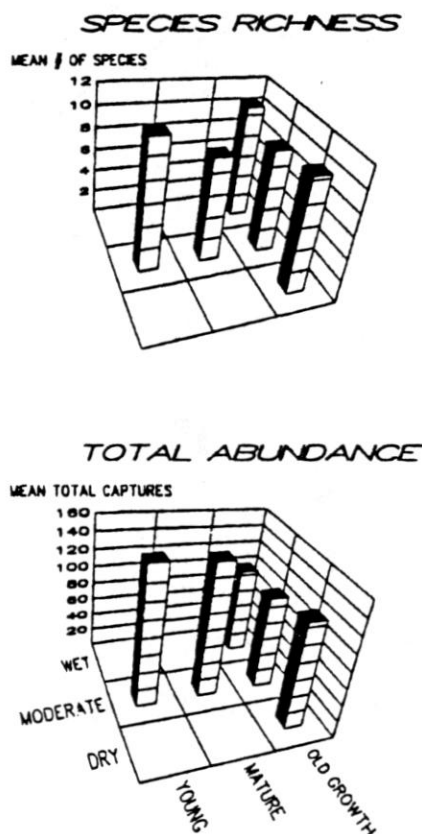


Figure 4.—Mean species richness (HJAEF only) and total abundance (all stands) of small mammals in closed-canopy stands.

is supported by their low abundance in OGW stands where soils are saturated for long periods. Abundance of coast moles was positively correlated with percent cover by deciduous trees. Habitat variables negatively correlated were the number of decay class 3 logs and the number of large-diameter logs.

Red-Backed Voles

We captured two species of red-backed voles: the southern red-backed vole (*Clethrionomys gapperi*) at WREF, and the western red-backed vole (*C. californicus*) at HJAEF. We caught more southern than western red-backed voles (fig. 6), but the patterns of abundance were similar. Both species were combined in the ANOVAs to maximize the sample size. No differences were detected on either the age or moisture gradients.

Habitat variables were tested separately for each species, but the results were similar (table 4). Abundance of western red-backed voles was positively correlated with total basal area of live trees, mean d.b.h., and percent cover by evergreen shrubs (mainly Oregon grape, *Berberis* spp., and salal, *Gaultheria shallon*).

Negative correlations were with grass cover, biomass of decay class 1 and 2 logs, and aspect (abundance was greatest on southern exposures). Southern red-backed voles were positively correlated with density and basal area of live trees, and mean d.b.h., and were negatively correlated with grass cover.

Red Tree Vole

This species has been identified as an old growth associate (Meslow et al. 1981) and is a major food item of the spotted owl (Forsman et al. 1984). We captured only 17 red tree voles (*Arborimus longicaudus*) in the standard arrays, too few to run the

ANOVA. But, 12 voles were captured in the eight old-growth stands at HJAEF, compared to only five voles in the 10 younger stands ($G = 4.73, P < 0.05$). Corn and Bury (1986) provide a more detailed account of these results.

Creeping Vole

Creeping voles (*Microtus oregoni*) were uncommon in closed-canopy stands (fig. 6), and there was no difference in abundance on either gradient. As with vagrant shrews, this species was more abundant in

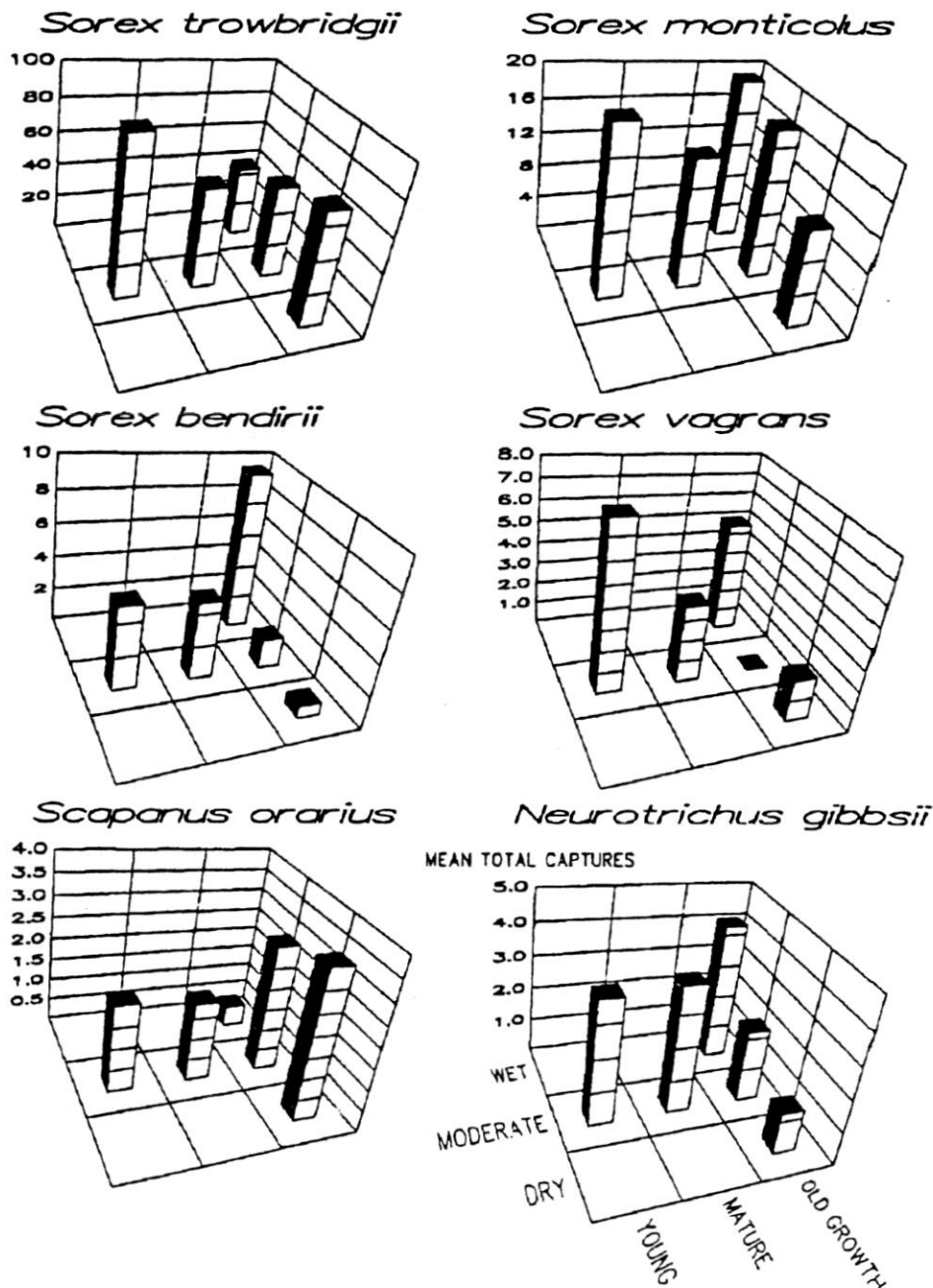


Figure 5.—Mean abundance of insectivores in closed-canopy forest stands. Data for Trowbridge's, montane, and vagrant shrews are from HJAEF only. Pacific marsh shrews, shrew moles, and coast moles use data from all stands.

Table 3.—Significant ($P < 0.05$) Pearson correlations of insectivore abundance and stand structure and vegetation variables. See appendix B for descriptions of the variables.

Species	Positive		Negative	
	Variable	r	Variable	r
Trowbridge's Shrew ($n = 17-18$)	TOTBA	0.59	HERB	-0.75
	LNDC45	0.59	GRASS	-0.70
	MDBH	0.57	LBDC12	-0.53
	LITTER	0.49		
Montane Shrew ($n = 17-18$)	MDBH	0.51	GRASS	-0.52
Vagrant Shrew ($n = 17-18$)			LNDC12	-0.47
			LNDC45	-0.55
			MOSS	-0.50
			SLOPE	-0.51
Pacific Marsh Shrew ($n = 28-30$)	LITTER	0.41	LITTER	-0.50
	TOTDEN	0.41	LNDC12	-0.50
	MDBH	0.44	SLOPE	-0.37
	LBDC45	0.40		
Coast Mole ($n = 28-30$)	DECTR	0.52	LNDC3	-0.43
			LNDC3	-0.43

clearcuts. Reflecting this, creeping vole abundance was positively correlated with percent cover by grasses and negatively correlated with several "forest" variables: number and biomass of decayed logs, density, basal area and d.b.h. of live trees, and litter depth.

Deer Mouse

Although pitfall traps are not as effective for catching deer mice as snap traps (Williams and Braun 1983, Bury and Corn 1987), we caught moderate numbers of this species, particularly at WREF (table 2). Deer mice were most abundant in OGM stands and least abundant in OGW and young stands. Differences were not significant on either the chronosequence or the moisture gradient. Deer mouse abundance was negatively correlated with percent of coarse fragments in the soil.

Clearcuts Versus Forests

Pitfall arrays were installed in five clearcuts, three at HJAEF and two at WREF. We compared the relative abundance of several of the common small mammals in clearcuts and young stands (fig. 7). Trowbridge's, montane, and vagrant shrews were compared only for the three clearcuts and four young stands at HJAEF.

Southern and western red-backed voles were virtually absent from clearcuts, while creeping voles were more than six times more abundant in clearcuts than in young stands. Most insectivores were two to six times more abundant in young stands, but vagrant shrews were most abundant in clearcuts. Much of the difference in the relative abundance of vagrant shrews is due to their great abundance in clearcut #391 at HJAEF (table 1). Only one vagrant shrew was captured at each of the other clearcuts at HJAEF. Although roughly estimated, vagrant

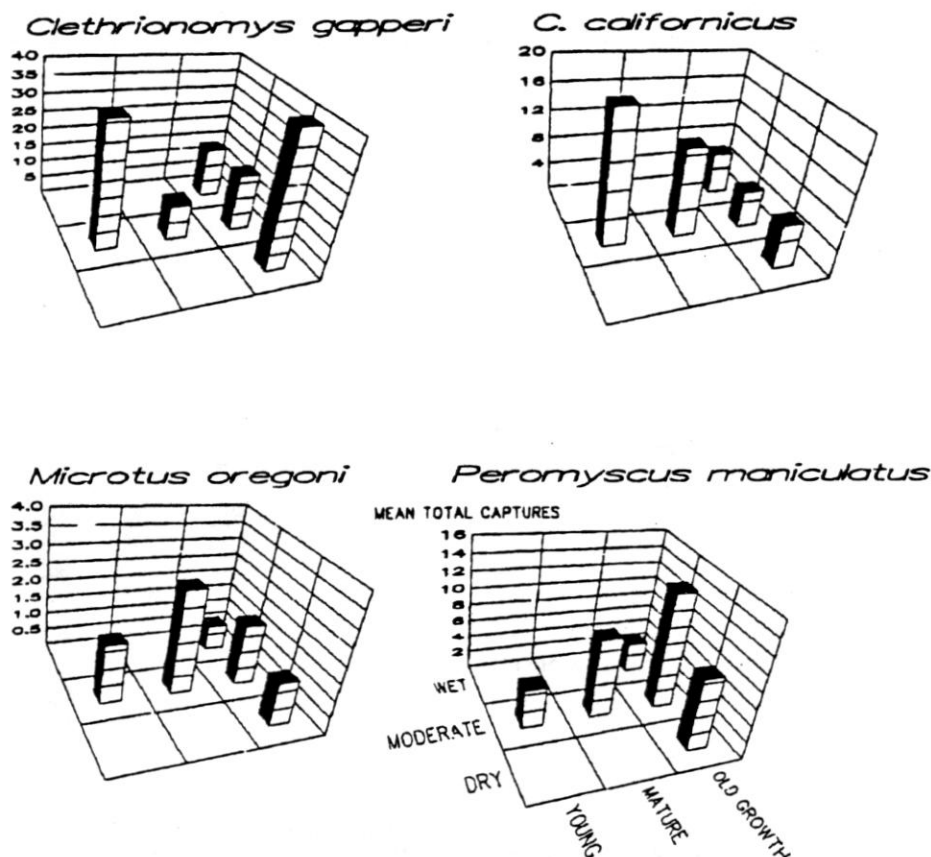


Figure 6.—Mean abundance of rodents in closed-canopy forest stands. Data from all stands were used.

shrews were the most common small mammal at both of the clearcuts at WREF. Deer mice were about three times more abundant in clearcuts than in young stands. A few pocket gophers (*Thomomys mazama* at HJAEF, *T. talpoides* at WREF) were captured and are not depicted in figure 7. Most pocket gophers (20/28) were captured in clearcuts; none were captured in old growth.

DISCUSSION

Old-Growth Species

Answering the question of if a species is dependent on old-growth forest for critical habitat is complex, incorporating several aspects of ecology and needs to account for temporal and random variation (Carey 1984). Also, abundance of individual species within a specific region depend not only on the multidimensional niche, but on the geographic distribution of each species (Brown, 1984). The community ecology studies of the Old-Growth Program were not intended to provide definite answers on old-growth dependencies, but rather the results were to be used as guides for designing species-specific research (Ruggiero and Carey 1984). Our results are based on one season's data and must be interpreted cautiously, but they are useful for comparison with other studies and for suggesting new research.

Only one small mammal, the red tree vole, displayed a significant association with old-growth stands, and the sample size for it was small. Additional captures of this species in the Oregon Coast Range in 1984-1985 were almost exclusively in old-growth forests (Corn and Bury, unpublished data). Recent studies of vertebrates across a similar chronosequence of Douglas-fir forests in northern California (Raphael 1984, this volume, Raphael and Barrett 1984) found significant positive correlations between abundance of sev-

eral species and stand age: Trowbridge's shrews, Pacific shrews (*Sorex pacificus*), coast moles, shrew moles, Allen's chipmunks (*Tamias senex*),

Townsend's chipmunks (*T. townsendii*), Douglas' squirrels (*Tamiasciurus douglasii*), dusky-footed woodrats (*Neotoma fuscipes*), deer

Table 4.—Significant ($P < 0.05$) Pearson correlations of rodent abundance and stand structure and vegetation variables. See appendix B for descriptions of the variables.

Species	Positive		Negative	
	Variable	<i>r</i>	Variable	<i>r</i>
Western Red-backed Vole (<i>n</i> = 17-18)	TOTBA	0.66	GRASS	-0.54
	MDBH	0.56	TRASPECT	-0.51
	EGSHR	0.48	LBDC12	-0.53
Southern red-backed Vole (<i>n</i> = 11-12)	TOTDEN	0.78	GRASS	-0.81
	TOTBA	0.70		
	MDBH	0.71		
Creeping Vole (<i>n</i> = 28-30)	GRASS	0.51	LNDC45	-0.58
			LBDC45	-0.43
			MDBH	-0.52
Deer Mouse (<i>n</i> = 28-30)			TOTDEN	-0.40
			TOTBA	-0.49
			LITTER	-0.62
			TOTCF	-0.36

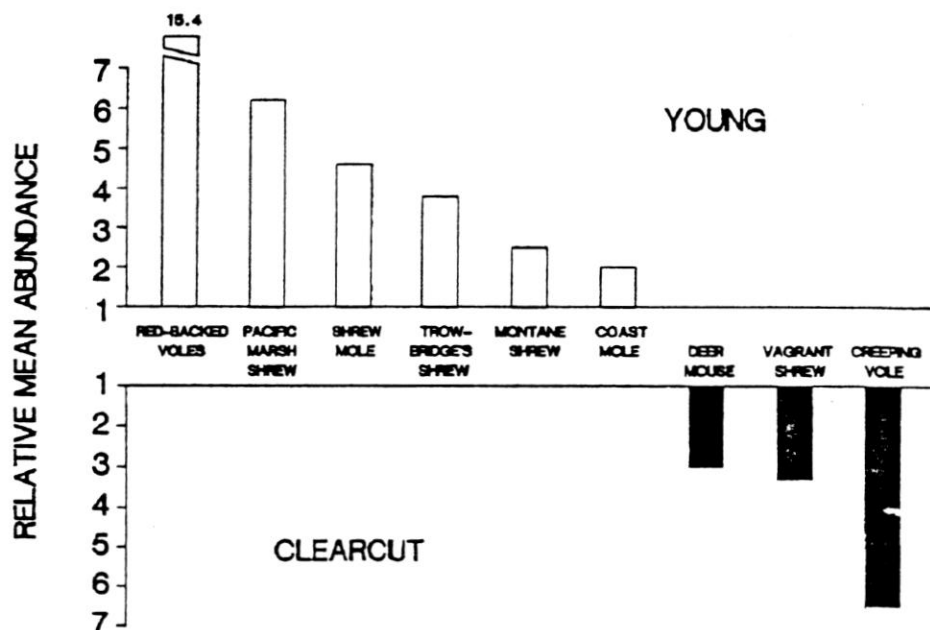


Figure 7.—Relative mean abundance of small mammals in young stands and clearcuts. Species more abundant in young stands are above the horizontal, species more abundant in clearcuts below. Values are the greater mean abundance divided by the lesser, so, for example, red-backed voles were 15.4 times more abundant in young stands than in clearcuts.

mice, western red-backed voles, and fishers (*Martes pennanti*). Many of these correlations were not strong, however, with most species represented in the youngest forest stages. Mean species richness was about 10 in all forest age classes. Analysis of the similarity of species composition showed little difference on the chronosequence (Raphael 1984). This is very similar to our results and suggests that old-growth forests do not harbor unique communities of small mammals.

Anthony et al. (1987) snaptrapped small mammals in riparian zones of old-growth, mature, and young stands at HJAEF in 1983. They found greater abundance of deer mice in old-growth stands, but Pacific shrews (*S. pacificus*) were evenly distributed. They trapped 14 other species, though none in sufficient numbers to analyze. Although both Anthony et al. (1987) and Raphael (1984) found more deer mice in older forests, this species is ubiquitous and reaches its highest densities in the Pacific Northwest in clearcuts (see below).

Small Mammals in Managed Forests

Most studies of habitat relations of small mammals in the Pacific Northwest have compared clearcuts to forested stands. Although there is considerable variation among studies, general trends are similar, likely related to the variety of factors examined (time since logging, burned, unburned, herbicides applied, etc.). Populations of deer mice, creeping voles, and Townsend's chipmunks increase after logging, while red-backed voles and Trowbridge's shrews decline (Anthony and Morrison 1985, Gashwiler 1959 1970, Hooven and Black 1976, Sullivan and Krebs 1980, Raphael, this volume, Tevis 1956). Red-backed voles are probably most affected by clearcutting. Western red-backed voles are

obligate fungivores, and their food supply disappears after clearcutting (Maser et al. 1978, Ure and Maser 1982). Gunther et al. (1983) found southern red-backed voles to be the most common animals on the clearcuts they trapped, but they trapped only three months after logging and probably were sampling a residual population. Also, this species is less dependent on fungi (Ure and Maser 1982) and might be able to persist for a time after logging.

Other studies have not noted the increase of vagrant shrews in clearcuts that we observed. Several factors might be involved, including random variation. Although mean abundance was high, vagrant shrews were rare (one capture each) on two of our five clearcuts. Other studies probably underestimated shrew abundance, because they used either snap or live traps. Also, some investigators might have followed Findley (1955) and considered montane and vagrant shrews to be the same species.

Changes in small mammal communities after logging can be dramatic, but clearcuts per se might not be the main factor influencing species diversity in managed forest landscapes in the Pacific Northwest. In a managed forest with a 90-year rotation, about 30% of the area will be in clearcuts and young plantations lacking canopy closure. The remaining 70% of the landscape will be in stands 30-90 years old that have closed forest canopies. The habitat characteristics of these forest plantations will be a major determinant of biological diversity in managed lands. For example, the extensive logging of low-elevation old-growth forests in Oregon has probably eliminated much of the habitat of red tree voles. The giant Douglas-fir trees, which seem to be preferred as nest sites, will not occur in managed forests. Meanwhile, the heather vole (*Phenacomys intermedius*), a species of alpine meadows, might be benefiting from increased logging of high-

elevation forests (Corn and Bury 1988).

Although we have found few differences between old-growth and younger naturally regenerated forests for small mammals or the herpetofauna (Bury and Corn, this volume), the same probably cannot be said for comparisons of old-growth to managed forests. Our analysis of habitat variables revealed that abundance of several species was correlated with habitat features that would be absent or greatly reduced in managed forests. Aside from large trees, CWD is the primary component of old growth that is eliminated by current forestry practices (Harris et al. 1982, Spies et al. in press). CWD is correlated to abundance of shrews (this study), salamanders (Bury and Corn, this volume, Raphael 1984), and probably is required habitat for red-backed voles (Maser and Trappe 1984). Bury and Corn (this volume) provide further discussion of the role of CWD as wildlife habitat.

Research Needs

These types of community ecology studies provided baseline data on nongame wildlife in naturally regenerated forests of the Pacific Northwest. For example, we can use the data on abundance and the correlations with habitat variables to begin classifying species as to their degree of rarity (Rabinowitz et al. 1986). Species with small geographic distributions, restricted habitat specificity, and small local populations (e.g., red tree voles, Pacific marsh shrews) are likely to be affected by habitat alteration. Species with large populations, broad habitat specificity, and either large (deer mice) or small (Trowbridge's shrews) geographic distributions, are less likely to be affected by forest management.

Our study does not address changes in habitats in managed forests stands or the effects of forest fragmentation as remaining old

growth is harvested. Further studies of small mammals should emphasize managed stands and managed landscapes.

Even with the creation of old-growth habitat areas on National Forests, most of the landscape will probably be in plantations less than 100 years old. Research needs to be focused on the degree of loss of diversity in these managed forests and evaluate silvicultural options for maintaining or enhancing habitat structure.

Thus far, there is little evidence that small mammal populations in Douglas-fir forests are strongly influenced by stand size or amount of insularization (Raphael 1984, Rosenberg and Raphael 1986). As these authors point out, however, forest fragmentation in western coniferous forests might not have advanced far enough or existed long enough for effects to be observed. Conversely, forest fragmentation in the Pacific Northwest is not usually conversion of forest to farmland or urban areas as is the case in other temperate regions (e.g., Wilcove et al. 1986, Askins et al. 1987, Dickman 1987). Rather, it results in the replacement of one forest habitat with another. Patches of old growth in a managed forest are not strict analogs of oceanic islands or isolated mountain tops (Harris 1984), so the ability of forest-floor small mammals to maintain populations in managed forests is dependent on habitat availability after logging.

Our results indicate that some "old-growth species" are found in younger stands, but the proximity of old growth to younger forest might partly explain their occurrence. The effect of stand size, shape, edge, and juxtaposition on small mammal populations needs attention. Where old growth and other habitat areas are set aside to maintain biological diversity in intensively managed landscapes, the long-term viability of these habitats and their vertebrate populations needs to be monitored.

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Table A1.—Ages, elevations, and locations of 18 stands in Oregon. Locations are distances (km) from McKenzie Bridge.

Stand	Type	Age (yr)	Elev. (m)	Location
15	OGW	450	795	Linn Co., 9.2 N, 1.2 W
03	OGW	450	815	Lane Co., 6.4 N, 0.6 E
24	OGW	450	860	Lane Co., 6.0 N, 0.6 E
02	OGM	450	560	Lane Co., 4.6 N, 6.5 W
17	OGM	450	790	Lane Co., 6.6 N, 0.3 W
33	OGD	200	670	Lane Co., 6.0 N, 7.5 E
25	OGD	195	500	Lane Co., 2.4 N, 7.5 W
29	OGD	200	700	Lane Co., 2.6 S
11	Mature	140	670	Lane Co., 5.4 S, 8.8 E
35	Mature	130	900	Linn Co., 10.5 N, 1.0 W
42	Mature	150	1030	Lane Co., 3.1 N, 3.0 W
39	Young	76	1050	Lane Co., 4.4 S, 14.3 E
47	Young	50	1110	Lane Co., 3.3 N, 2.4 W
48	Young	69	1075	Linn Co., 13.2 N, 0.8 E
75	Young	30	560	Lane Co., 1.6 S, 5.2 W
55	Clearcut	9	830	Lane Co., 2.8 N, 6.6 W
291	Clearcut	5	690	Lane Co., 2.6 S, 1.4 E
391	Clearcut	5	1100	Lane Co., 3.8 S, 14.8 E

Table A2.—Ages, elevations, and locations of 12 stands in Washington. Locations are distances (km) from Carson, Skamania Co.

Stand	Type	Age (yr)	Elev. (m)	Location
14	OGW	375	520	17.7 N, 16.9 W
12	OGM	450	485	6.4 N, 11.3 W
21	OGM	375	440	17.2 N, 14.0 W
20	OGM	375	480	11.3 N, 11.9 W
31	OGD	375	670	18.5 N, 16.5 W
41	Mature	105	485	19.3 N, 13.7 W
42	Mature	140	500	13.7 N, 2.4 W
50	Mature	130	610	16.0 N, 2.1 W
60	Young	65	475	13.5 N, 12.1 W
61	Young	65	640	8.1 N, 6.3 W
70	Clearcut	5	535	11.3 N, 13.4 W
71	Clearcut	5	730	16.9 N, 7.2 W

Table B1.—Stand structural and vegetation variables.

Variable name	Description
SLOPE	Percent slope
TRASPECT	Transformed aspect
LNDC12	Number of logs per ha, decay class 1 and 2
LNDC3	Number of logs per ha, decay class 3
LNDC45	Number of logs per ha, decay class 4 and 5
LNDM1	Number of logs per ha, <30cm diameter
LNDM2	Number of logs per ha, >30cm and <60 cm
LNDM3	Number of logs per ha, >60 cm
LBDC12	Biomass (1,000 kg per ha) of logs, class 1 and 2
LBDC3	Biomass (1,000 kg per ha) of logs, class 3
LBDC45	Biomass (1,000 kg per ha) of logs, class 4 and 5
MDBH	Mean d.b.h. (cm) in stand
TOTDEN	Density of live trees (number per ha)
TOTBA	Basal area of live trees (m ² per ha)
LITTER	Litter depth (01 + 02 horizons; cm)
TOTCF	Volume (%) of coarse fragments in soil
MOSS	% cover by mosses
FERN	% cover by ferns
GRASS	% cover by grasses
HERB	% cover by herbaceous vegetation
EGSHR	% cover by evergreen shrubs
DESHR	% cover by deciduous shrubs
EVGTR	% cover by evergreen trees
DECTR	% cover by deciduous trees