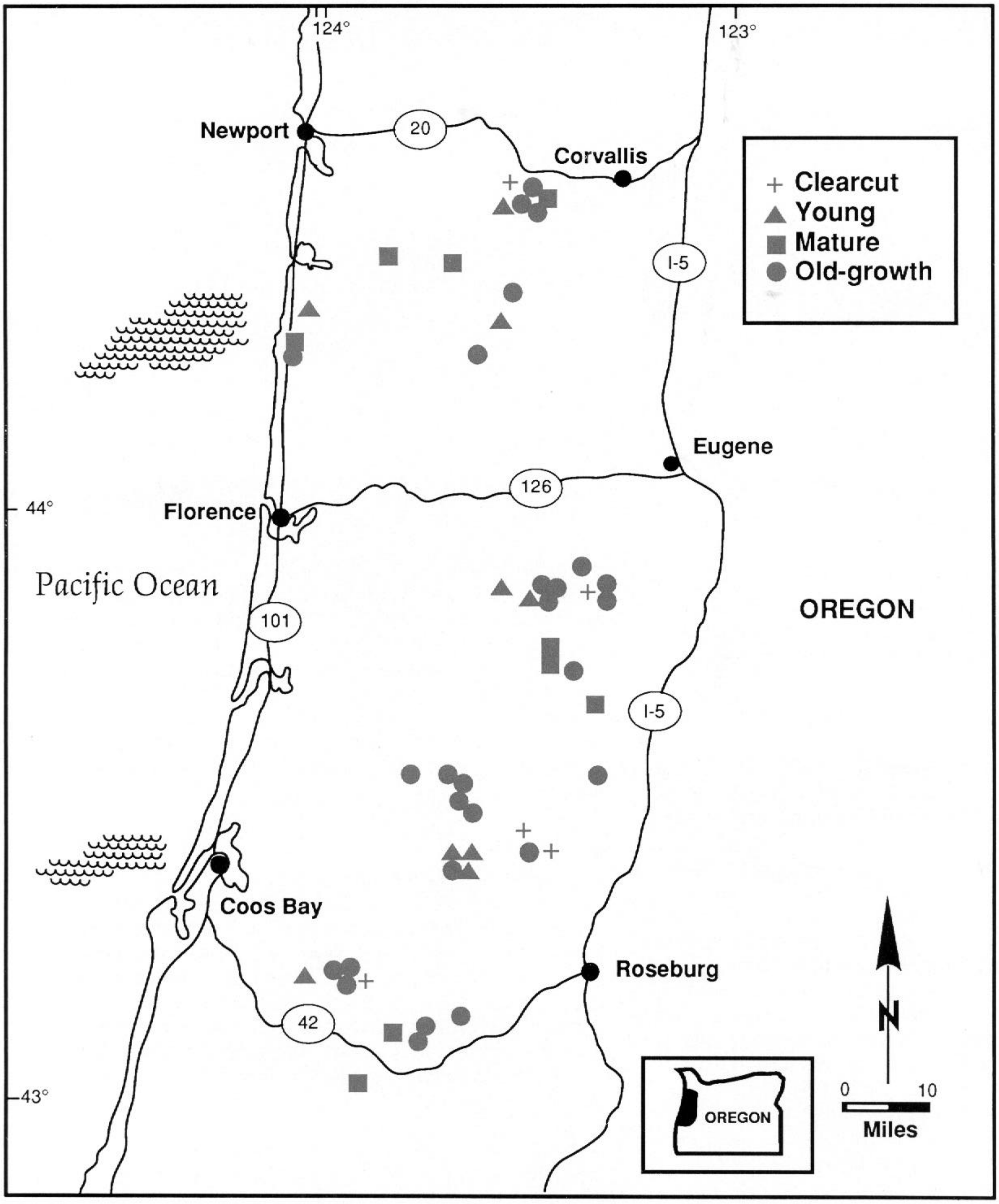
Part 6

Amphibians of Oregon and Washington



Location of study sites.

Terrestrial Amphibian Communities in the Oregon Coast Range

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Authors

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Abstract

We used pitfall trapping and surveys of down wood to sample amphibian populations on clearcuts, young, mature, and old-growth forests on Forest Service or Bureau of Land Management land in the Coast Range of Oregon in 1984 and 1985. We attempted to identify species or unique groups of species associated with old-growth forests and structural components of the habitat associated with abundance of amphibians. Pitfall traps captured 10 species and 1878 individual amphibians in 45 forested stands and three clearcuts in 80 nights in 1984 and 1985. Western redback salamanders, ensatinas, and roughskin newts were the species most commonly captured by pitfall traps in both forested stands and clearcuts. Significantly more Olympic salamanders were captured in old-growth compared to mature and young forest stands. On a moisture gradient in old growth, tailed frogs were more abundant in wet stands. Western redback salamanders were most abundant on steep, rocky slopes, but few strong correlations were found between amphibian abundance and habitat features characteristic of old-growth forests. We also sampled 536 logs in 18 stands and captured 328 amphibians (seven species). Clouded salamanders (166 individuals, compared to only 13 caught in pitfalls), and ensatinas (111 captures) were the most common salamanders found associated with down wood. Habitat preferences differed markedly. Clouded salamanders preferred large Douglas-fir logs with bark still attached, but ensatinas were found more often in well-decayed logs. Based on amounts of down wood available in Douglas-fir forests, we predict densities of clouded salamanders to be highly correlated with stand age, and we expect this species to be rare in intensively managed forests where down wood is reduced.

Introduction

Amphibians and reptiles are the subjects of less than 10 percent of recent studies in ecology and wildlife ecology (Gibbons 1988), yet they are numerically dominant in many habitats and supply an important component of the energy present in terrestrial and aquatic ecosystems. Hairston (1987) estimated that energy present in salamanders in southern Appalachian forests exceeds that of all other vertebrate predators combined. Terrestrial salamanders typically have stable populations that are suitable for assessing impacts of disturbance (Hairston 1987).

Although the number of species of amphibians and reptiles in Douglas-fir forests of the Pacific Northwest is low relative to mammals and birds (Harris and Maser 1984), the herpetofauna are a distinctive and important component of the vertebrate fauna (Bury 1988). Several species of amphibians that occur in the Coast Range in Oregon, including the tailed frog, Olympic salamander, Pacific giant salamander, clouded salamander, Dunn's salamander, western redback salamander, and roughskin newt, are endemic to the Pacific Northwest (Nussbaum and others 1983). Species adapted to a specific habitat (Douglas-fir forests) might be expected to be sensitive to major disturbance of that habitat (logging). Studies in northern California found differences among seral stages of Douglas-fir and redwood forests in composition and abundance of the herpetofauna (Bury 1983; Raphael 1984, 1988c; Raphael and Barrett 1984).

The Old-Growth Program was designed, in part, to gather information on abundance of forest. amphibians and their habitat preferences in Oregon, Washington, and California (Ruggiero and Carey 1984). Pilot studies were conducted in the Cascade Range in 1983 (Bury and Corn 1988a), and in 1984, vertebrate community studies were extended to the Coast Range in Oregon. We used pitfall traps and hand collecting (Bury and Corn 1987, Bury and Raphael 1983, Campbell and Christman 1982) to sample the terrestrial herpetofauna.

Pitfall trapping provides good estimates of relative abundance of many amphibian species, but it severely undersamples salamanders that are closely associated with down wood (Bury and Corn 1988a). Time-constrained collecting is effective for capturing individuals of these species, but the technique produces potentially biased estimates of relative abundance (Bury and Corn 1988a; Corn and Bury 1990). To estimate the relative abundance of salamanders associated with down wood, we searched uniform numbers of down logs.

In this paper, we report the results of sampling amphibians over a large area of the Coast Range in 1984 and 1985. Our objectives were to:

- Identify amphibians associated with old growth by determining the relative abundance of amphibians in young, mature, and old-growth forests and across a moisture gradient in old growth;
- Compare the abundance of amphibians to major physiographic and vegetation gradients, and to identify important habitat features that could be incorporated into managed forests to maintain the diversity of amphibians;
- Contrast changes in abundance of amphibians between old-growth forests and clearcuts as a first step in comparing managed and natural forests; and
- Estimate abundance of salamanders associated with down wood, and describe differences among species in the use of this microhabitat.

Methods

Study Areas

We studied 45 closed-canopy forest stands and 5 recently clearcut stands in the Coast Range of Oregon (see frontispiece). Most stands were in the interior or on the eastern flank (valley margin) of the Coast Range. Most of the stands south of Eugene were on land managed by the Bureau of Land Management (BLM) Eugene, Roseburg, and Coos Bay Districts. Stands north of Eugene were on BLM (Salem District) land, the Siuslaw National Forest (including Cape Perpetua and Drift Creek Wilderness Areas), or land managed by the city of Corvallis (Marys Peak).

Stand Selection and Classification

Stands initially were selected to conform to a chronosequence of four categories beginning with five clearcuts (<10 years old), eight closed-canopy young stands (40 to 75 years), 10 mature stands (80 to 120 years), and 27 old-growth stands (150 to 525 years). Most forest stands were composed of naturally regenerated forests. Ages of stands were estimated a *posteriori* by increment coring or by examining stumps in adjacent clearcuts and roadsides (Spies and others 1988).

A moisture gradient (wet, moderate, and dry) was examined for old-growth stands. The moisture classification was based on a multivariate ordination of understory vegetation (Spies and Franklin, this volume).

Pitfall Trapping

We installed 36 pitfall traps (6.41 volume, 15 m apart in a 6 x 6 grid) in each forest stand and three clearcuts in summer 1984. Details of trap construction and installation are in Bury and Corn (1987) and Corn and Bury (1990, this volume a). Before and after each trapping season, traps were closed with a tight-fitting plastic lid. Each grid was placed at least 100 m from the edge of the stand. This distance was a compromise between the need to avoid edge effects and the need for a field crew to be able to check the grids in five to seven stands in one day.

We opened traps during the first week in October and trapped continuously for 50 days in 1984 and for 30 days in 1985. The same grids were used in both years. No water was put in the traps because amphibians that drowned did not preserve well. In practice, most traps accumulated some water and some amphibians drowned. Traps were checked about once a week; nine times in 1984 and five times in 1985. Any water that had accumulated was bailed out.

Amphibians taken from traps were killed in dilute chloretone (a saturated solution of hydrous chlorobutanol in 95-percent ethanol, diluted to about a 5-percent solution in water). After identifications were verified, we determined the sex and measured snout-vent length (SVL), total length, and mass. Amphibians were fixed at least 24 hours in 10 percent formalin and then rinsed in water and preserved permanently in 50 percent isopropyl alcohol. Amphibians that had drowned were identified. sexed, and measured, and stomachs and eggs (if any) were dissected and preserved. Specimens were deposited in the National Museum of Natural History, Washington, DC.

Vegetation Sampling

We sampled vegetation at nine points within the pitfall grid, with the center of each sampling plot equidistant from four pitfall traps (Corn and Bury, this volume a). We estimated physiographic, coarse woody debris, live tree, and ground cover variables (see appendix in Corn and Bury this volume a) in two nested circles of 5.6-m radius (100 m) and 15-m radius (707 m^2). Percentage cover was estimated by eye. Count variables were converted to density (number per hectare).

Surveys of Down Wood

We conducted surveys of down wood in 18 stands (nine old-growth, three mature, three young, and three clearcuts) between 19 March and 10 April 1985. We searched 30 logs in each stand (26 in one stand) with minimum diameter of 10 cm and minimum length of 1 m. Down wood was classified on a five-point scale (Franklin and others 1981, Maser and others 1979): (1) intact, recently downed trees; (2) intact wood with loose bark; (3) bark beginning to slough off and decayed sapwood; (4) loss of most bark and decayed heartwood; and (5) hummocks of wood chunks and organic material. In each stand, we sampled equal numbers of logs in three broader categories: 10 class 1 and 2 logs, 10 class 3 logs, and 10 class 4 and 5 logs. We recorded the slope, aspect (to the nearest 459, tree species, length, diameter, and decay-class of each log sampled. We then searched for amphibians under the bark, in the wood, under the log, and under bark on the ground adjacent to the log for a maximum of 20 staff minutes (a staff minute is one person searching for 1 minute). We recorded the length and diameter of the portion of the log that was searched. For every amphibian encountered, we determined the sex, measured SVL, and recorded where found (such as under bark or in log) and the depth inside the log. A series of voucher specimens was preserved from each stand, but most amphibians were released at the site of capture.

Logs were sampled as the crew traced an irregular path through a portion of the stand away from the pitfall grid. Logs were generally sampled as encountered, except that we attempted to maintain about equal numbers in each decay category as the survey progressed. Therefore, logs in abundant decay categories were occasionally passed in the search for the next log in a less abundant category.

Statistical Analyses

Captures in pitfall traps-All statistical analyses were done on a microcomputer using SYSTAT (Wilkinson 1988). Analysis of the chronosequence was originally intended to compare young, mature, and old-growth stands with similar moisture conditions, and so was to exclude wet and dry old-growth stands (Carey and Spies, this volume). Because mature and young stands had much greater variation on the moisture gradient than expected (Spies and Franklin, this volume), however, only those old-growth stands that were outliers on the moisture gradient were excluded. In the Coast Range, all but two old-growth stands were retained in the chronosequence analyses. Analysis of the moisture gradient was restricted to old-growth stands.

We measured abundance as the number captured per 100 trap-nights. Pitfall traps may capture large numbers of young-of-the-year amphibians that are dispersing from breeding ponds or streams (Bury and Corn 1987). To reduce the bias introduced by the proximity of breeding habitats to grids, the analyses of abundance used only adult tailed frogs ($\geq$ 35 mm SVL), red-legged frogs (235 mm SVL), northwestern salamanders (270 mm SVL), and roughskin newts ($\geq$ 40 mm SVL). Analysis of the abundance of individual species depended on numbers captured. “Common” species were species with more than 50 total captures, and differences on the age and moisture gradients were analyzed by analysis of variance (ANOVA) of ($\log_e$ abundance + 1). “Rare” species had fewer than 50 and greater than 10 total captures. Because of the low sample sizes, we used all captures of these species in both years. We put “common” and “rare” in quotes, because captures in pitfalls may not reflect the actual abundance of these species. For example, clouded salamanders are rarely captured by pitfalls but commonly are taken in time-constrained surveys (Bury and Corn 1988a). Differences in numbers captured among age- and moisture-classes were tested using the G-test (log likelihood ratio) for goodness of fit (Sokal and Rohlf 1981).

Physiographic and vegetation variables-variables measuring percentage cover were arcsin-transformed (Sokal and Rohlf 1981) before analysis. Count variables had large variances which were log-transformed. We computed Pearson product-moment correlation coefficients between continuous physiographic and vegetation variables and abundance of common species. Associations between abundance and categorical physiographic variables were tested with ANOVA. For rare species, we compared mean values of physiographic and vegetation variables between stands where each species was present or absent, or we computed log likelihood ratios based on the presence or absence of amphibians and categorical physiographic variables.

We performed a principal components analysis using a subset of eight vegetation variables (Corn and Bury, this volume a) representing habitat features that have been used in ecological definitions of old-growth Douglas-fir forests (Franklin and Spies 1984, Morrison 1988, Spies and Franklin 1988). Three factors accounted **for** 67.6 percent of the variance. Factor 1 (33.1 percent of variance) describes an age gradient, factor 2 (19.3 percent) was associated with down wood, and factor 3 (15.2 percent) was associated with shrub cover (Corn and Bury, this volume a). We tested the abundance of common species against these three factors using multiple regression, and we tested the three factors against the presence or absence of rare species using multivariate analysis of variance.

Salamanders in down wood-The density in down wood of each species of salamander (number per cubic meter) was calculated as the number caught in each log divided by the volume of wood sampled in each log. Mean densities in down wood in each stand were calculated for each of the three decay-categories (decay-classes 1 and 2, class 3, classes 4 and 5). We used a nested ANOVA (stands within forest age-classes) to test whether density (log transformed) in down wood of any species varied among decay-categories or age-classes (old-growth, mature, and young).

We **compared** slope and log dimensions for sites where each species was captured versus sites where each species was absent with one-way ANOVA. For the categorical variables aspect (four categories; N and NE, E and SE, S and SW, W and NW), tree species (Douglas-fir versus other), decay-category, and position (under bark, in log, or on ground; either under log or under bark), we compared total captures of each species among categories using log likelihood ratios.

We calculated predicted densities of plethodontid salamanders in 45 forest stands from the following formula:

$$D = \sum_{i=1}^{3} (d_i * V_i)$$

where D = number of salamanders per hectare, d_i = density in down wood in decay-category i, and V_i = m^3 of down wood per hectare in category *i* (data provided by T. Spies). If d varied among age-classes, then D was calculated using the mean density in down wood for each age-class. Predicted densities are minimum estimates, because we did not investigate salamander populations in other microhabitats.

Results

Pitfall Trapping

Abundance of amphibians--In 1984 and 1985 combined, we captured 1797 individuals and 10 species of amphibians in 45 forest stands (table l), and an additional 81 individuals in three clearcuts. Only a few young-of-the-year northwestern salamanders, roughskin newts, and red-legged frogs were captured, but 28 juvenile tailed frogs (30 percent of captures) were excluded from further analyses. Combined abundance of amphibians was higher in 1985 (1.767 per 100 trap-nights) than in 1984 (1.158 per 100 trap-nights; Wilcoxon signed-ranks test, $P < 0.00l$), but among individual species, only ensatina was captured significantly more often in 1985 (0.728 per 100 trap-nights) than in 1984 (0.348 per 100 trap-nights; $P < 0.001$). The patterns of combined abundance and abundance of ensatina across the age and moisture gradients were similar in both years, and because abundance did not differ between years for any other species, all further analyses used the combined abundance (captures in 1984 + 1985 with 80 nights of trapping [2880 trap-nights] per grid).

Five species (Pacific giant salamanders, ensatinas, western redback salamanders, roughskin newts, and tailed frogs) were considered common, with 61 to 737 captures. Four other species, including northwestern salamanders, Olympic salamanders, clouded salamanders, and Dunn's salamanders had 13 to 45 captures and were considered rare. Fewer than 10 adult red-legged frogs were captured, and the abundance of this species was not analyzed.

Table l-Total numbers of amphibians captured by pitfall grids in **45 forest stands in the Oregon Coast Range in 1984 and 1985 (grids were open for 50 days in 1984 and 30 days in 1985)**

Species	1984	1985	Total
Salamanders"			
Northwestern salamander	12 (15)	6 (7)	18 (22)
Pacific giant salamander	42	19	
Olympic salamander	22	8	30
Clouded salamander	6	7	13
Ensatina	282	354	636
Dunn's salamander	21	24	45
Western redback salamander	412	325	737
Unidentified			
Roughskin newt	93 (97)	52 (61)	14: (158)
Frogs			
Tailed frog	25 (44)	40 (49)	65 (93)
Red-legged frog	3 (4)	5 (6)	8 (10)
Total	911 (938)	839 (859)	1750 (1797)

[a] Only adults of northwestern salamanders (snout-vent length 270 mm), roughskin newts (snout-vent length 540 mm), tailed frogs (snout-vent length ≥ 35 mm), and red-legged frogs (snout-vent length 235 mm) were used in analyses of abundance. Total captures of these species am in parentheses.

Table 2—Mean abundance, mean relative abundance,[a] and percentage occurrence of common amphibians (>50 total captures) in different forest types in the Oregon Coast Range

Species	Measure	Stand type (N) Old-growth (25)	Mature (10)	Young (8)
All amphibians	Number/100 TN[b]	1.303	1.330	1.636
Pacific giant salamander	Number/100 TN	0.050	0.042	0.043
	Relative abundance	4.6	6.2	3.0
	Percentage of stands	64.0	70.0	62.5
Ensatina	Number/100 TN	0.454	0.542	0.569
	Relative abundance	38.6	40.3	52.7
	Percentage of stands	100	90.0	100
Western redback salamander	Number/100 TN	0.532	0.490	0.812
	Relative abundance	39.1	26.6	29.1
	Percentage of stands	88.0	80.0	50.0
Roughskin newt	Number/100 TN	0.111	0.076	0.026
	Relative abundance	7.7	5.2	3.3
	Percentage of stands	68.0	60.0	62.5
Tailed frog	Number/100 TN	0.033	0.101	0.035
	Relative abundance	2.1	16.8	2.1
	Percentage of stands	28.0	60.0	12.5

[a] Relative abundance = the percent of total captures contributed by each species.
[b] TN = trap-nights.

One northern alligator lizard not listed in table 1 was captured in a clearcut in 1984. This contrasts with 120 reptiles captured by pitfall arrays (pitfall traps with drift fences) at 30 sites in the Cascade Mountains of Oregon and Washington in 1983 (Bury and Corn 1988a). The lack of reptiles in 1984 and 1985 reflects both the absence of drift fences (Corn and Bury 1990) and the trapping season (reptiles are less active in the fall after the rains begin).

Variation on the chronosequence—Neither combined abundance nor abundance of any of the five common amphibian species were significantly different among age-classes of forest stands (table 2), but the patterns of relative abundance appeared to differ somewhat. The ensatina was the most common species captured in young and mature stands, while the western redback salamander was the most common species in old growth. Roughskin newts were a higher proportion of captures in old-growth stands than in mature and young stands. Abundance of western redback salamanders was highly variable and not well correlated to frequency of occurrence. Mean abundance of this species was 0.812 per 100 trap-nights in young stands and 0.532 per 100 trap-nights in old-growth stands, but western redback salamanders occurred in only 50 percent (4 of 8) of young stands compared to 88 percent (22 of 25) of old-growth stands. The high mean abundance in young stands was due to two stands with extraordinarily high abundance (3.056 and 2.014 per 100 trap-nights).

Captures of two rare species varied among age-classes. Olympic salamanders (fig. 1) were captured more often in old-growth stands than in mature or young stands ($G = 9.30$, 2 df, $P = 0.01$). Pitfall traps captured 11 clouded salamanders in old-growth stands versus two clouded salamanders in young and mature stands combined ($G = 4.25$, 1 df, $P = 0.039$). Numbers of northwestern salamanders ($P = 0.97$) and Dunn's salamanders ($P = 0.43$) did not differ among old-growth, mature, and young stands (fig. 1).

Variation on the moisture gradient—Tailed frogs (table 3) were absent from dry stands in old growth and much more abundant in wet stands than moderate stands ($F = 10.5$; 2, 24 df; $P = 0.001$). Ensatinas composed a higher proportion of captures in dry stands compared to wet stands, but this was probably a result of the lower number of species captured in dry stands because abundance did not vary significantly across the moisture gradient. Too few clouded salamanders were captured by pitfall traps for analysis, but none were captured in dry stands. Captures of the other rare species did not vary significantly across moisture-classes (fig. 2).

Table 3—Mean abundance, mean relative abundance,[a] and percentage occurrence of common amphibians (>50 total captures) on the moisture gradient in old-growth stands in the Oregon Coast Range

		Stand type (N)		
Species	Measure	Wet (5)	Moderate (14)	Dry (8)
All amphibians	Number/100 TN[b]	1.604	1.270	1.276
Pacific giant salamander	Number/100 TN	0.049	0.062	0.031
	Relative abundance	3.3	5.9	2.7
	Percentage of stands	80.0	71.4	50.0
Ensatina	Number/100 TN	0.451	0.419	0.500
	Relative abundance	31.1	34.9	46.2
	Percentage of stands	100	100	100
Western redback salamander	Number/100 TN	0.563	0.556	0.452
	Relative abundance	35.0	42.7	32.4
	Percentage of stands	100	92.8	75.0
Roughskin newt	Number/100 TN	0.215	0.079	0.192
	Relative abundance	10.8	5.4	13.4
	Percentage of stands	60.0	50.0	100
Tailed frog	Number/100 TN	0.153	0.032	0
	Relative abundance	10.1	2.2	0
	Percentage of stands	80.0	35.7	0

[a] Relative abundance = the percentage of total captures contributed by each species.
[b] TN = trap-nights.

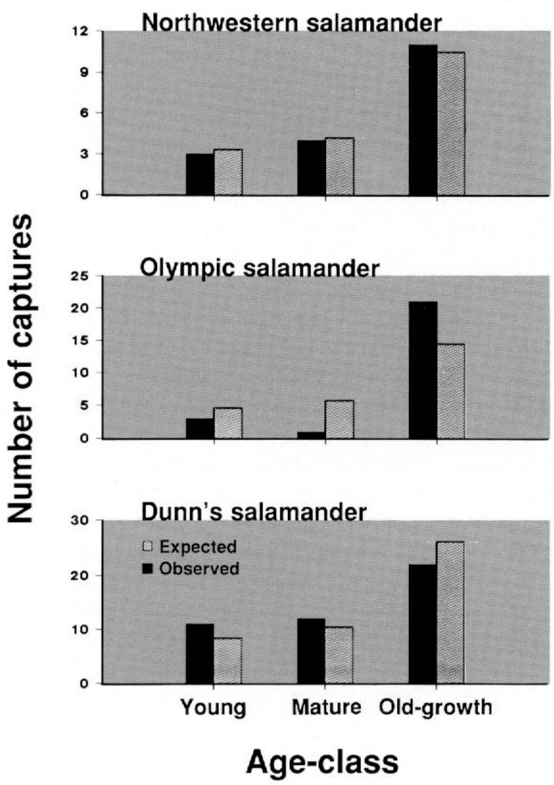

Figure 1—Observed and expected numbers of rare salamanders captured in young, mature, and old-growth stands in the Oregon Coast Range. Rare species had fewer than 50 and greater then 10 total captures.

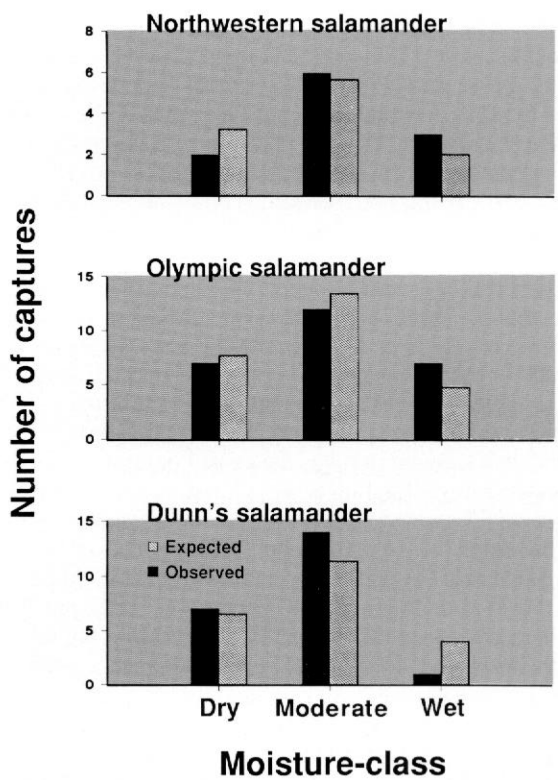

Figure 2—Observed and expected numbers of rare salamanders captured in dry, moderate, and wet old-growth stands in the Oregon Coast Range. Rare species had fewer than 50 and greater then 10 total captures.

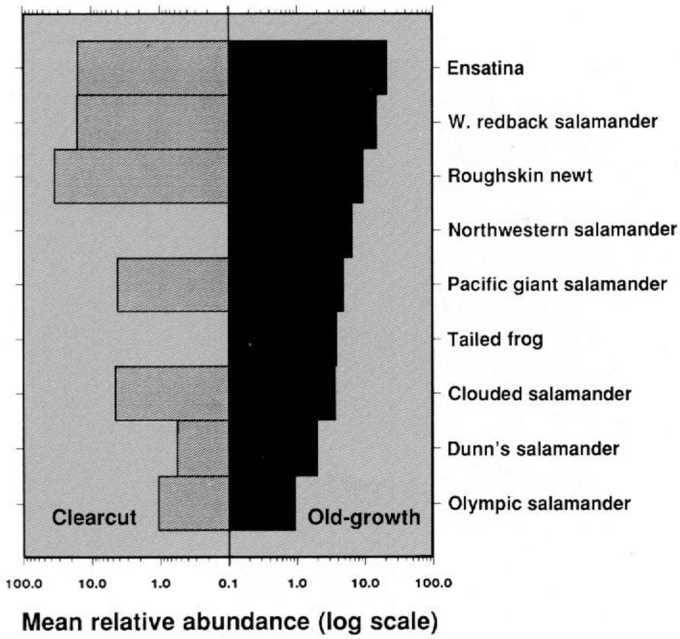

Figure 3—Mean relative abundance of amphibians in three paired clearcuts and old-growth stands.

Old growth versus clearcuts—We captured seven species in three clearcuts ($\bar{x}$ = 4.3 per stand) and nine species in three adjacent old-growth stands ($\bar{x}$ = 4.7 per stand). Two species, northwestern salamanders and tailed frogs, were captured in old growth and not in clearcuts. No species captured in the clearcuts were absent from old-growth stands. Total abundance in old growth (1.25 per 100 trap-nights) was not significantly greater than total abundance in clearcuts (0.76 per 100 trap-nights, P = 0.40). Aside from the two missing species, the pattern of relative abundance was not very different in clearcuts compared to old growth (fig. 3). The ensatina, western redback salamander, and roughskin newt were the most abundant species in both old-growth stands and clearcuts. Newts had the highest mean relative abundance in clearcuts because they were the only amphibians captured in one clearcut (relative abundance = 100 percent).

Microhabitat associations—We compared abundance or occurrence of amphibians with physiographic variables measured at the pitfall grids plus stand age, latitude, and longitude. The strongest associations were with plethodontid salamanders. Dunn's salamander occurred more often on steep slopes (F = 16.7; 1, 43 df; $P < 0.001$), where exposed talus was present (G = 10.5, 1 df; P = 0.001), and in stands at higher latitudes (F = 8.23; 1, 43 df; P = 0.006). Western redback salamanders were more abundant on steep slopes (r = 0.603, $P < 0.01$) and in stands with talus present (F = 18.0; 1, 43 df; $P < 0.001$). Stands where Olympic salamanders were present were older than stands where they were absent (F = 4.23; 1, 43 df; P = 0.046). Roughskin newts were more abundant in stands at higher latitudes (r = 0.463, $P < 0.01$), but they were less abundant in stands with surface water present in the pitfall grid (F = 4.69; 1, 43 df; P = 0.036). Tailed frogs were more abundant in western stands (r = 0.505, $P < 0.01$), and northwestern salamanders occurred more often in eastern stands (F= 4.56; 1, 43 df; P = 0.038). Ensatinas were less abundant on warmer (south-facing) slopes (r = -0.376, $P < 0.05$).

Twenty of 32 vegetation variables were significantly associated with abundance or occurrence of one or more amphibian species (table 4). Few of the significant correlations were very large; most were between 0.3 and 0.5. One exception was the positive correlation between abundance of western redback salamanders and amount of ground cover by rocks (r = 0.566, $P < 0.01$), but this reflected the presence of talus. Mean rock cover was 1.12 percent where talus was present and 0.11 percent where talus was absent (F= 14.2; 1, 43 df; $P < 0.001$). Abundance of tailed frogs was correlated to nine vegetation variables, most of which were negative correlations to understory hardwood trees and shrub cover (table 4). This pattern probably reflects the absence of tailed frogs from dry old-growth stands, where the understory was more dense than in moderate or wet stands (Spies and Franklin, this volume).

The tailed frog was the only species significantly associated with the three habitat variables generated from the principal components analysis (multiple r^2 = 0.323; F = 6.53; 3, 41 df; P = 0.001). Abundance was negatively associated with factor 3 (shrub cover, P = 0.001) and positively associated with factor 2 (down wood, P = 0.016), but abundance was unrelated to factor 1 (age, P = 0.365).

Salamanders in Down Wood

We searched 536 logs ($\bar{x}$ = 18 staff minutes per log), and the amphibians comprised seven species dominated by clouded salamanders (166 captures), ensatinas (111), and western redback salamanders (40). We also captured six Dunn's salamanders, three roughskin newts, one Pacific giant salamander, and one Olympic salamander. Reptiles were encountered in the three clearcuts. We captured six northern alligator lizards, two western fence lizards, one western skink, and one northwestern garter snake. All analyses involve the three commonly captured salamanders.

Clouded salamanders were found in 110 logs, and the density was 1.48 per cubic meter of down wood (table 5). Significant differences in density were found among decay-categories (table 6); density was highest in class 1 and 2 logs and lowest in class 4 and 5 logs. Density of clouded salamanders in down wood did not vary significantly among age-classes. We found ensatinas in 82 logs, and the mean density was 1.30 per cubic meter of down wood. Density varied significantly

Table 4—Significant associations between abundance[a] of common amphibians or occurrence of rare amphibians and vegetation variables measured at pitfall grids (table 1) in the Oregon Coast Range

Variable	Northwestern salamander	Pacific giant salamander	Olympic salamander	Ensatina	Dunn's salamander	Western redback salamander	Roughskin newt	Tailed frog
DLOGSC (Percentage cover)				(-)				
STUMP (Number/ha)				(-)				
MSNAG (Number/ha)			(- -)					
CTREEM (Number/ha)							(- -)	
BTREES (Number/ha)	+							(- -)
BTREEM (Number/ha)						++		(-)
MDTREE (Percentage cover)						++	++	(-)
MCTREE (Percentage cover)		+						
CDTREE (Percentage cover)					+		+	
CBTREE (Percentage cover)								(-)
CCTREE (Percentage cover)								+
LITDEPTH (cm)				++				
SOIL (Percentage cover)				+		+		
ROCK (Percentage cover)					++	++		
FORB (Percentage cover)								++
GRASS (Percentage cover)				+				
FERN (Percentage cover)			+					
ESHRUB (Percentage cover)								(- -)
DSHRUB (Percentage cover)							+	(-)
MSHRUB (Percentage cover)							+	(-)

[a] Abundance and count variables were log transformed, percent variables were arcsin transformed. Negative associations are in parentheses. + (or –) = $P < 0.05$, and ++ (or - -) = $P < 0.01$.

Table 5—Density (number/m^3 of down wood) of clouded salamanders, ensatinas, and western redback salamanders by age- and decay-class

Species	Decay-class	Old-growth[a] (266)	Mature (90)	Young (90)	Clearcut (90)	All (536)
Clouded salamander	1 & 2	2.14	1.07	1.80	0.83	1.69
	3	1.03	3.90	3.48	1.34	1.98
	4 & 5	0.76	0.57	0.45	1.52	0.80
	All	1.31	1.80	1.91	1.23	1.48
Ensatina	1 & 2	0.61	1.98	1.43	0	0.87
	3	0.77	2.40	2.17	0.09	1.16
	4 & 5	1.26	3.19	2.40	1.60	1.84
	All	0.88	2.55	2.00	0.56	1.30
Western redback salamander	1 & 2	0.16	0	0.32	0.41	0.20
	3	0.19	3.22	0.06	0	0.64
	4 & 5	0.51	0.81	0.13	0	0.41
	All	0.29	1.33	1.09	0.14	0.42

[a] The number of logs searched in each age-class are in parentheses.

Table 6-Nested analysis of variance (stands within age-classes) of mean density (number/m^3 of down wood, log-transformed) of clouded salamanders, ensatinas, and western redback salamanders acre old-growth, mature, and young forest age-classes and 3 decay-classes of down wood (1 & 2; 3; 4 & 5)

Species	Factor	df	MSS	*F*	*P*
Clouded salamander	Stands	12	1.110	1.85	0.039
	Age-class	2	0.059	0.10	0.908
	Decay-class	2	3.081	5.13	0.006
	Error	429	0.600		
Ensatina	Stands	12	1.530	2.64	0.002
	Age-class	2	2.318	4.11	0.017
	Decay-class	2	1.844	3.19	0.042
	Error	429	0.579		
Western redback salamander	Stands	12	0.6%	3.43	<0.001
	Age-class	2	0.434	2.14	0.119
	Decay-class	2	0.475	2.35	0.097
	Error	429	0.203		

both across age-classes and decay-categories (table 6). Density was highest in mature and young stands and class 4 and 5 logs, and it was lowest in clearcuts and old growth and class 1 and 2 logs (table 5). Western redback salamanders were found **in 34 logs, and density** did not vary significantly among either age-classes or decay-categories (table 6). Mean density of this species was 0.42 per cubic meter of down Wood.

Habitat characteristics-logs where we found clouded salamanders were larger (both diameter and length) than logs where we did not find this species (table 7). Clouded salamanders were found in Douglas-fir logs more often than in logs **of other tree species (table 8). Logs with ensatinas** present were on flatter slopes than logs without ensatinas, but the size of logs with and without this species did not differ (table 7). Logs with western redback salamanders were on steeper slopes than logs without redback salamanders (table 7), but redback salamanders were also captured more often where the aspect was to the west or northwest (table 8) and logs were on flatter slopes (19 percent) compared to the other three aspect categories (21-23 percent).

The strongest variation among species in use of microhabitats involved the decay-class of down wood and the locations occupied by salamanders in logs. Clouded salamanders were captured most often in class 1 and 2 logs and least often in class 4 and 5 logs (fig. 4, G = 33.6,2 df, P < 0.01). Captures of ensatinas were opposite; they were most common in class 4 and 5 logs and least often in class 1 and 2 logs (fig. 4, G = 13.8,2 df, P < **0.01). Western redback salamanders appeared** to occur less frequently in class 1 and 2 logs (fig. 4), but the differences among decay-categories were not statistically significant (G = 5.16, 2 df, P = 0.08). Sites at each log where

Table 7--Characteristics of logs where salamanders were captured (differences between capture sites with and without each species were tested with one-way ANOVA[a]

Category		Slope (percentage)	Log diameter (cm)	Log length (m)
All logs (n = 536)	$\bar{x}$	20.6	45.1	9.8
	SE	0.50	0.86	0.42
Logs with clouded salamanders (n = 110)	$\bar{x}$	21.3	52.4**	11.2**
	SE	1.10	2.12	1.07
Logs with ensatinas (n = 82)	$\bar{x}$	17.7*	44.7	9.1
	SE	1.17	0.94	0.45
Logs with redback salamanders (n = 34)	$\bar{x}$	26.1**	51.2	10.2
	SE	1.70	4.00	1.74

[a] * *P < 0.05,* *+ *P* < 0.01.

Table Number of captures of clouded salamanders, ensatinas, and western redback salamanders by aspect and tree species

Variable	Category	All logs	cloded salamander	Ensatina	Western redback salamander
Aspect	N and NE	120	29	19	9
	W and NW	131	53	22	18
	E and SE	132	36	34	4
	S and SW	144	45	32	9
	G		6.02	4.16	10.31
	P		0.11	0.24	0.02
Trees	Douglas-fir	454	148	95	35
	Other[a]	78	15	16	5
	G		4.38	0.01	0.16
	P		0.04	0.92	0.69

[a] Western hemlock (30). western redcedar (21), grand fir (10). hardwoods (17).

salamanders were captured were characterized as inside the log, under bark on the surface of the log, or in contact with the ground. All three species showed distinct preferences for specific sites in down wood (fig. 5, G = 71.2,4 df, P < 0.001). Clouded salamanders were found inside the log or under bark, but rarely in contact with the ground. Ensatinas were captured most often inside the log, and they were captured in contact with the ground more often than were clouded salamanders. Western redback salamanders were captured most often in contact with the ground. The mean depth **inside** the wood of 88 clouded salamanders found inside logs was 6.5 cm, and the mean depth of 64 ensatinas **was 7.9 cm, but** the difference was not significant (Student's t = 1.30, P = 0.19).

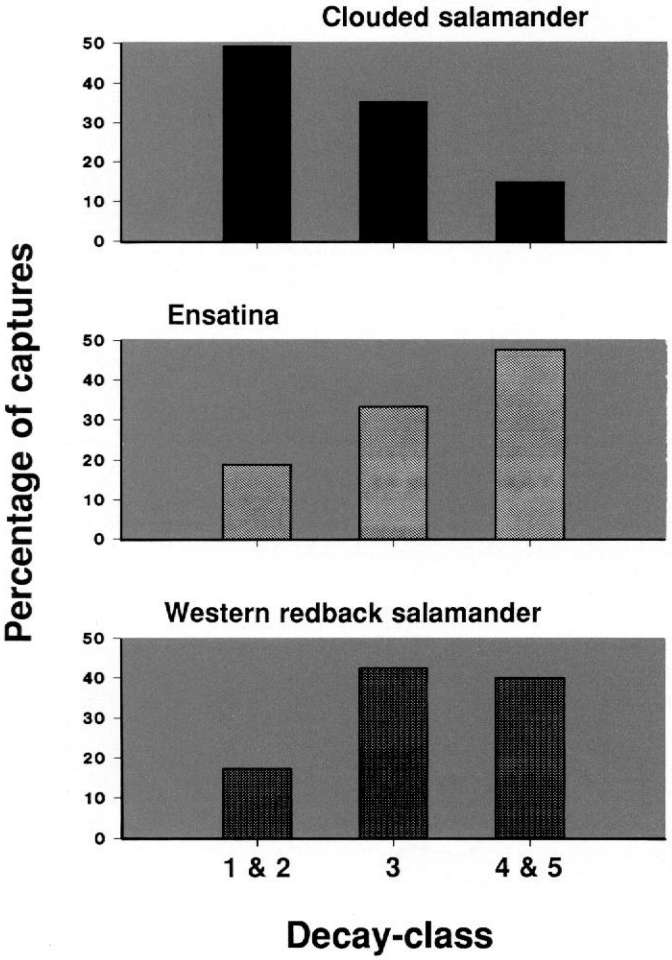

Figure 4—Captures of clouded salamanders, ensatinas, and western redback salamanders by decay-category of down wood.

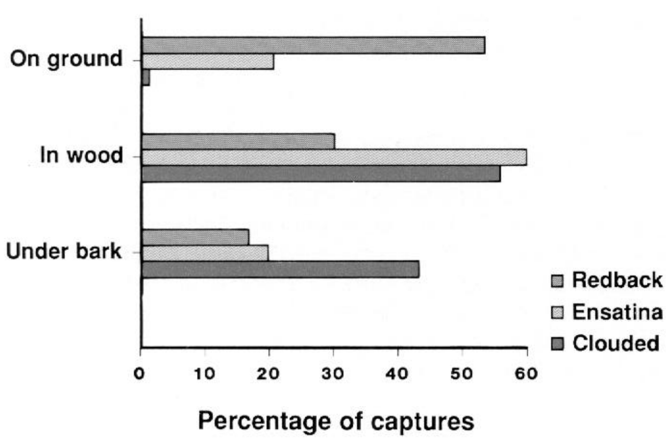

Figure 5—Locations of clouded salamanders, ensatinas, and western redback salamanders captured during surveys of down wood.

Discussion

Species Associated With Old-Growth Forests

Olympic salamanders were captured by pitfall traps more often in old-growth stands, and stands where this species was present were older than in stands where it was absent. Welsh and Lind (1988, this volume) obtained similar results in Douglas-fir forests in northern California. Olympic salamanders are closely tied to headwater streams and seeps (Bury 1988, Nussbaum and Tait 1977), however, and they are not often captured by pitfall traps in upland settings (Aubry and Hall, this volume; Bury and Corn 1987, 1988a; Gilbert and Allwine, this volume c; Raphael 1988c). The best evidence that Olympic salamanders are associated with old-growth forests comes from the stream surveys of aquatic amphibians (Bury and others, this volume b). Density was four times greater in streams in old-growth forests than in streams in young stands. Abundance of Olympic salamanders was greatly reduced in streams in the Coast Range that flowed through logged stands (Corn and Bury 1989), possibly resulting from increased siltation. Olympic salamanders may be very slow to recolonize areas from which they have been extirpated (Bury and Corn 1988b).

Other Coast Range amphibians that were sampled more effectively by pitfall traps showed little preference for old growth. This is in general agreement with data from the Cascades in Oregon and Washington (Aubry and Hall, this volume; Bury and Corn 1988a; Gilbert and Allwine, this volume c), although Aubry and Hall (this volume) found a greater abundance of northwestern salamanders in old-growth stands in the Southern Washington Cascades. Ensatinas (Raphael and Barrett 1984, Welsh and Lind 1988), Del Norte salamanders (Raphael 1988c, Welsh and Lind 1988) and black salamanders (Raphael 1988c) were more abundant in older Douglas-fir forests in northern California.

One major factor may be interfering with our ability to determine the habitat preferences of amphibians: terrestrial pitfall trapping largely ignores breeding habitats. A majority of the amphibian species we captured breed in water, either in cascading headwater streams (tailed frogs, Pacific giant salamanders, Olympic salamanders), or in ponds or backwaters of streams (red-legged frogs, northwestern salamanders, Pacific giant salamanders, roughskin newts). Most amphibians have poor dispersal abilities (relative to birds and mammals), so upland habitat use by aquatic-breeding species may be influenced heavily by proximity to water. Most pitfall grids were within a few hundred meters of a perennial stream, but we have little information about the distribution of ponds relative to our grids. Plethodontid salamanders lay their eggs on land where the embryos hatch into small replicas of the adults. These species do not require surface water but may be tied to other habitat features such as talus slopes (Dumas 1956, Herrington 1988, Herrington and