Larson 1985, Stebbins 1951) or large chunks of down wood (Aubry and others 1988, Bury and Corn 1988a, Whitaker and others 1986).

Plethodontid salamanders—One goal of our surveys of down wood was to provide estimates of the density of salamanders strongly associated with down wood. Estimated numbers of clouded salamanders and western redback salamanders per hectare were strongly correlated to stand age (fig. 6) because of the strong correlation between volume of down wood and stand age (Spies and others 1988). Because numbers of these two species (per cubic meter of down wood) did not vary among forest age-classes, changes in numbers per hectare apparently were solely due to changes in the volume of down wood. Predicted abundance of ensatinas did not increase with the age of the forest (fig. 6) because the number (per cubic meter of down wood) was significantly lower in old-growth stands. The increased volume in down wood in old-growth stands compensated for this, so the estimated numbers of ensatinas did not vary significantly among age-classes.

The estimated abundance of plethodontid salamanders (combined) was also positively correlated with stand age (fig. 6). The mean density (D) was 364 salamanders per ha in young stands, 387 per ha in mature stands, and 744 per ha in old-growth stands. These figures are considerably less than the 2367 redback salamanders per ha that Burton and Likens (1975) estimated for the Hubbard Brook Experimental Forest in New Hampshire, or the 7000 *Plethodon* per ha that Hairston (1987) estimated for forests in the southern Appalachian Mountains. The abundance we estimated, however, includes only salamanders closely associated with down wood. We may be somewhat close to estimating the actual abundance of clouded salamanders, but ensatinas and western redback salamanders use a broader range of habitats. These species were 49 and 56 times more abundant in pitfall traps than clouded salamanders, suggesting that neither species is closely associated with down wood. A recent 3-year study of western redback salamanders on two small plots on Vancouver Island found only about 15 percent of captures associated with down wood (Ovaska and Gregory 1989). Stebbins (1954) estimated 1708 ensatinas per ha at a site in the San Francisco Bay area, and Gnaedinger and Reed (1948) estimated 2833 ensatinas per ha in a ravine on the campus of Reed College in Portland. Ovaska and Gregory (1989) recorded surface activity of up to 1.16 western redback salamanders per square meter. Relative abundances of ensatinas and western redback salamanders were equivalent in our pitfall traps, so the true density of plethodontid salamanders in Douglas-fir forests in western Oregon may be several thousand per ha, similar to salamander densities in eastern forests.

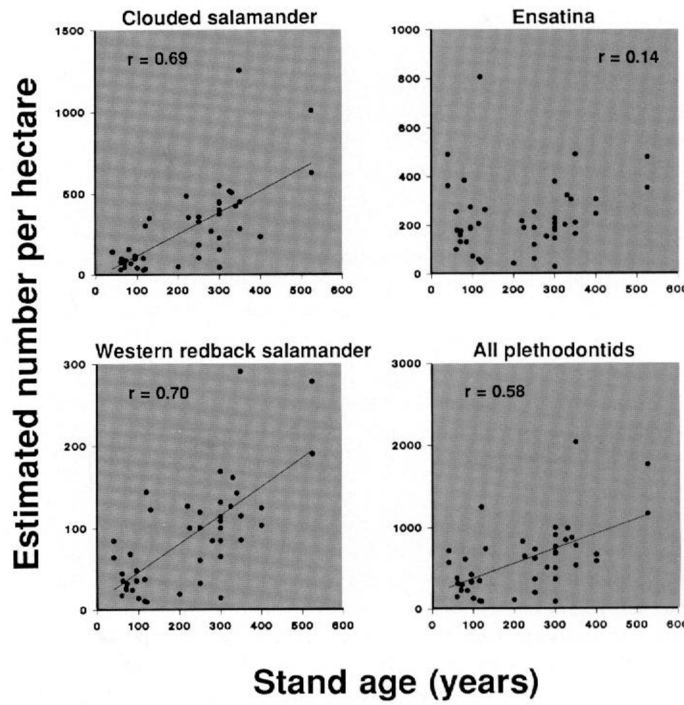


Figure 6—Predicted abundance in the Oregon Coast Range of plethodontid salamanders associated with down wood.

Microhabitat Features

We found few strong associations between amphibians and habitat features unique to old-growth forests. Upland habitats used by tailed frogs tended to be dense, moist forests, which is not unexpected for a species with low tolerance to high temperature and desiccation (Claussen 1973a, 1973b). These conditions may be supplied by young forests as well as old growth, however.

Three general microhabitats are available to terrestrial salamanders: rocky substrates, down wood, and leaf litter. The four plethodontid salamanders in the Coast Range segregate among these habitat types with various degrees of overlap. Dunn's salamander is most abundant in rock rubble in seeps and along small streams (Bury 1988, Bury and Corn 1988b, Corn and Bury 1989, Dumas 1956, Nussbaum and others 1983). Western redback salamanders are most abundant on rocky slopes (Dumas 1956, Nussbaum and others 1983, Ovaska and Gregory 1989), as are most western *Plethodon* (Herrington 1988, Herrington and Larson 1985, Nussbaum and others 1983, Ramotnik and Scott 1988, Stebbins 1951). Western redback salamanders apparently select drier habitats than Dunn's salamanders and are more tolerant of desiccation (Dumas 1956). Clouded salamanders are the dominant species associated with down wood, and prefer large, intact logs with loose bark (Bury and Corn 1988a; Bury and Martin 1973;

Welsh and Lind 1988, this volume: Whitaker and others 1986). Ensatina is the most primitive western plethodontid (Wake 1966) and has the most general habitat use (Gnaedinger and Reed 1948, Stebbins 1954). Ensatinas were common on rocky slopes and in older decay-classes of down wood; their abundance was positively correlated with litter depth.

Considerable evidence has been found that differences in habitat use by terrestrial amphibians are driven by competition (see Hairston 1987), and western plethodontids with similar adult body size have large overlap in diets (Altig and Brodie 1971, Lynch 1985). Our study was unable to determine whether competition is occurring in terrestrial salamanders in the Coast Range or whether current habitat preferences reflect past selective pressures.

The abundance of ensatinas in pitfalls was negatively correlated with percentage cover by decay-class 4 and 5 down wood, which initially seems paradoxical in view of the data from the log surveys, where ensatina preferred well-decayed wood. Salamanders that are closely tied to down wood, however, such as clouded salamanders or Oregon slender salamanders in the Cascades (Bury and Corn 1988a; Gilbert and Allwine, this volume c), are rarely captured in pitfalls. Surface activity of ensatinas should decline in stands with large amounts of well-decayed wood.

Managed Forests

Clearcutting may significantly affect terrestrial herpetofauna. Several studies have documented declining abundance, changes in the species composition of amphibians, or both (Buhlman and others 1988, Bury 1983, Bury and Corn 1988a, Pough and others 1987, Raphael 1988c). Meanwhile, populations of reptiles, particularly lizards, increase and exploit new openings in the forest canopy (Bury and Corn 1988a, Raphael 1988c). The three clearcuts we studied in the Coast Range did not display significant changes in amphibian populations. Abundance was slightly lower, and two species found in adjacent old-growth stands were absent, but the pattern of amphibian abundance was similar in old growth and clearcuts.

Three stands are inadequate to assess the effects of clear-cutting in the Coast Range, but even in an intensively managed forest, a minority of the landscape will be in the open canopy stage (Bury and Corn 1988b, Harris 1984). The problem for most amphibian species will be how to exist in short-rotation second-growth forest that is structurally dissimilar from naturally regenerated forest. Harris and others (1982) predict a loss of about 25 percent of vertebrate species in managed forests, primarily because snags and down wood are eliminated. Raphael (1988c) predicted that the abundance of three plethodontid salamanders in northern California could decrease by 29 to 75 percent if logging of old-growth forest continues. Few actual studies have been made of the long-term effects of logging on amphibian populations, however. Terrestrial amphibians were reduced in some second-growth forests in the Eastern United States (Bennett and others 1980, Pough and others 1987), and density and biomass of stream amphibians in the Coast Range were greatly reduced in streams flowing through stands logged 14 to 40 years before (Corn and Bury 1989). Stream amphibians are particularly vulnerable in a managed landscape, because headwater streams are not protected and they are less than 0.4 percent of the landscape in Coast Range forests (Bury 1988).

Logging may have negative impacts on amphibians associated with talus (Herrington 1988, Herrington and Larson 1985), which is an important consideration for species with limited distributions (Bury and others, this volume a). Assuming that the talus slope is not destroyed by such activities as rock removal for road building (Herrington 1988, Scharpf and Dobler 1985), however, the habitat should persist. The main talus-dwelling salamander in the Coast Range is the western redback salamander, which is widely distributed, abundant, and unlikely to be seriously threatened by logging.

Managed forests have reduced amounts of coarse woody debris (Bartels and others 1985, Harmon and others 1986), which is exacerbated in each rotation as residual down wood decays and little new down wood enters the system (Spies and Franklin 1988, Spies and others 1988). Species associated with down wood, such as clouded salamanders and Oregon slender salamanders (Bury and Corn 1988a; Gilbert and Allwine, this volume c), are likely to decline in managed landscapes. Previous studies have found clouded salamanders to be common in clearcuts but always in association with large woody debris (Bury 1983, Bury and Corn 1988a, Whitaker and others 1986). Although we have said that this species does not appear to be associated with old-growth conditions (Bury and Corn 1988b), we believe that survival of clouded salamanders in managed forests over a few rotations is open to question.

Generalist species such as ensatinas are likely to persist in managed forests, although populations may be reduced. Female ensatinas use large, well-decayed down wood for nest sites (Aubry and others 1988), but considering the high abundance of this species in nearly all stands sampled in Washington, Oregon, and California (Bury and others, this volume a), down wood seems unlikely to be an absolute requirement.

Recommendations

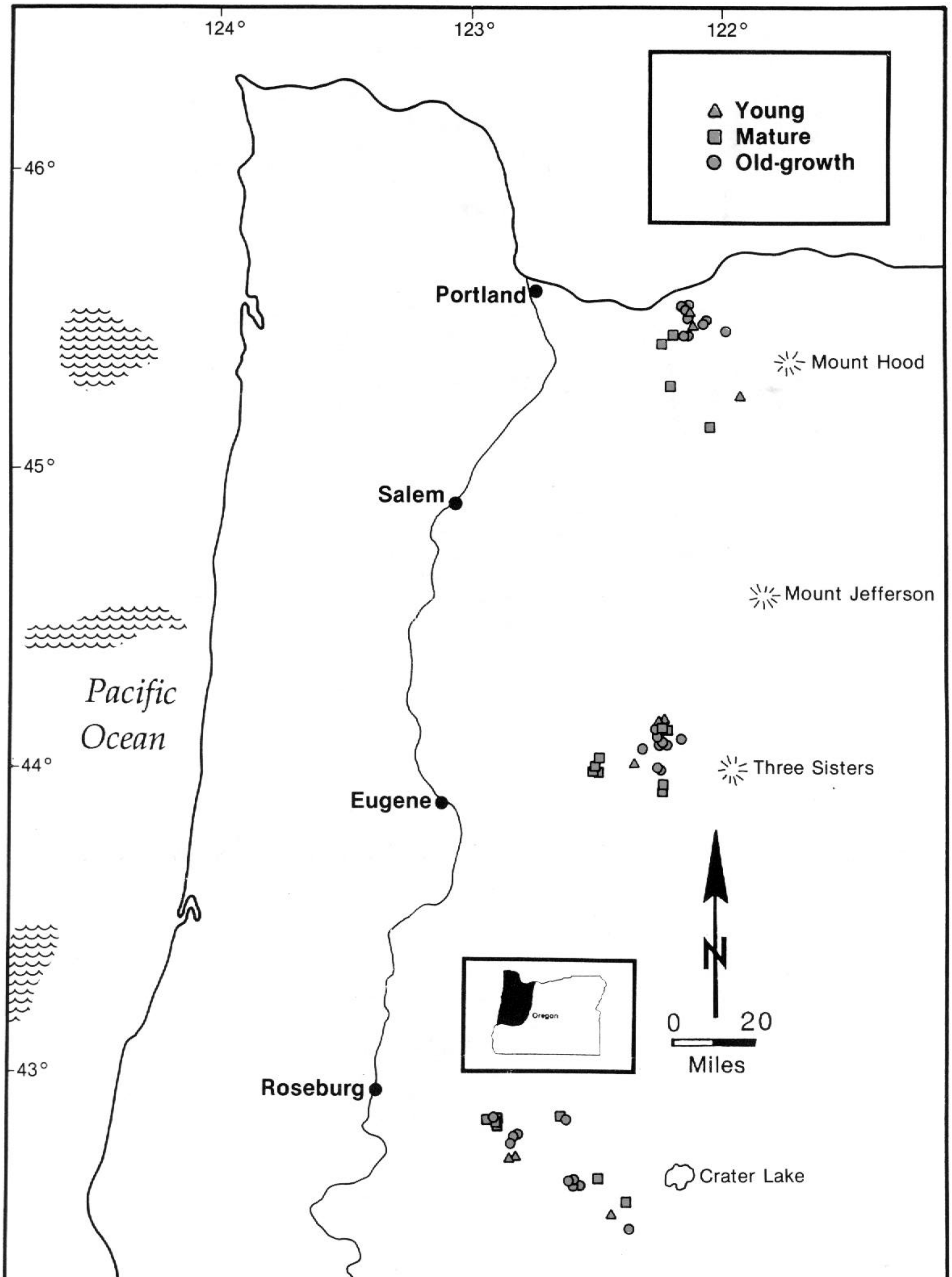
Forests in the Coast Range of Oregon are among the most heavily impacted by logging in the Pacific Northwest (Harris 1984, Monthey 1984). Much of the second growth, however, results from past logging practices that left considerably more woody debris than current practices, and harvesting of second growth on Federal lands is **just** beginning. For this reason, we believe that none of the terrestrial amphibians in the Coast Range of Oregon are in immediate danger of extinction or severe reduction from logging, but we make the following suggestions for further research:

- Investigate amphibian populations in managed forests. Research to date has focused on naturally regenerated forests, and only a few clearcuts have been sampled:
- Determine ways to increase amounts of down wood in managed forests. Logging plans could be modified to increase the amount of cull timber left after cutting, but a more difficult problem is how to increase recruitment of new down wood before the next rotation;
- Determine the effects of forest fragmentation on amphibians. Amphibians may not be particularly sensitive to fragmentation (Rosenburg and Raphael 1986), but this needs more attention in the Coast Range;
- Increase our knowledge of the basic natural history of amphibian species. Much basic information, including population sizes and reproductive characteristics, is lacking; and
- Initiate long-term monitoring of amphibian populations in natural and managed forests immediately. Long-term studies of communities are critical for understanding the processes that are shaping them, but are rarely done (Scott and Campbell 1982).

Acknowledgments

Funding was supplied by the U.S. Department of the Interior, Bureau of Land Management, and the U.S. Department of Agriculture, Forest Service, through cooperative agreements between the Forest Service and Fish and Wildlife Service. We thank L. Benson, J. Corn, B. Fiero, A. Gillesberg, L. Jones, R. Kuntz, P. Morrison, R. Newton, L. Rottman, D. Smith, W. Stolzenburg, P. Sullivan, and K. Wetzel for assistance in the field. G. Mires allowed us to turn his kitchen into a laboratory. We acknowledge the valuable contributions of BLM Roseburg and Salem Districts, Siuslaw National Forest, and the Pacifc Northwest Research Station for logistical support. K. Aubry, A. Carey, R. Storm, and two anonymous reviewers commented on the manuscript.

This paper is contribution 110 of the Wildlife Habitat Relationships in Western Washington and Oregon Research Project, Pacific Northwest Research Station, USDA Forest Service. 0



Location of study sites.

Terrestrial Amphibian Communities in the Oregon Cascade Range

Frederick F. Gilbert and Rochelle Allwine

Authors

FREDERICK F. GILBERT is a professor and wildlife biologist, and ROCHELLE ALLWINE is an agriculture research technician, Department of Natural Resource Sciences, Washington State University, Pullman, Washington 99164-6410.

Abstract

Ensatina was the most common terrestrial amphibian in the Oregon Cascade Range, representing over 50 percent of all captures. The tailed frog was the second most abundant species but was the dominant species of the northernmost study location (Mount Hood). The roughskin newt was the only other species captured in the pitfall traps with 25 percent of the total captures. Species richness did not differ between locations or between years.

No species was significantly associated with old-growth stands, although time-constrained searches indicated the clouded salamander and the Oregon slender salamander were found primarily in logs of the older decay classes. The northwestern salamander was associated with old growth at Mount Hood. Most amphibians seemed to select the mesic to wet portion of the moisture gradient, but the Pacific giant salamander was the only species with captures significantly associated with wet sites. Ensatina was overrepresented in dry stands and was captured at sites with a high percentage of exposed rock and bare soil. Relation to ground cover was generally consistent between years, but the vegetative associations had little predictive value between years. The Oregon Cascades amphibians apparently can be retained as viable populations wherever crown closure has occurred and breeding streams remain cool and unsilted. Forest management practices for these species should include protecting riparian zones, maintaining topography favoring ephemeral ponds as breeding sites, and considering cutting practices that would provide stand structure and coarse woody debris like those in naturally regenerated stands.

Introduction

Amphibians are an often-neglected component of the vertebrate fauna, despite their relative abundance and contribution to the faunal biomass in most locations. Studies at the Hubbard Brook Experimental Forest, New Hampshire, indicate that amphibians contribute about twice the biomass of breeding birds and about the same biomass as small mammals (Burton and Likens 1975). Many forest amphibian species are aquatic in part or all of their life cycle, and much of the amphibian literature is devoted to them (for example, Bury and Corn 1988b, Hawkins and others 1983, Murphy and Hall 1981, Murphy and others 1981).

Aubry and Hall (this volume), Corn and Bury (this volume b) and Raphael (1988c) have used pitfall traps (with and without drift fences) and time-constrained sampling to identify amphibian communities in Douglas-fir forests from California to Washington. Our study was intended to provide information on these vertebrates in the Oregon Cascade Range and, where possible, to relate their presence and abundance to the age, moisture conditions, and vegetative structure of the Douglas-fin- stands where they were found.

Materials and Methods

Amphibian populations were sampled at three sites on the west side of the Oregon Cascades during 1984 (Mount Hood, Hood; H.J. Andrews, the Andrews; and Rogue River-Umpqua, Rogue-Umpqua). Only the Andrews was studied in 1985. Pitfall trapping was done in September and October both years. Grids (6 x 6) with stations 15 m apart were used in each of 56 stands in 1984 and 15 stands in 1985. An additional eight pitfall grids were placed in the Andrews stands in 1985 to determine effects on amphibian populations of the previous year's trapping (Gilbert and Allwine, this volume b: see appendix table 15). Time-constrained searches were conducted in the spring of 1984. Each stand was searched intensively for 4 person-hours. Ephemeral (melt-water) ponds, located in all the study stands when time-constrained searches were conducted, were examined at least twice during the spring of 1984 for amphibians and egg masses. Egg masses found were collected and allowed to hatch so species could be identifed. Water temperature, surface area, and water depth were measured at each visit.

The abundance and diversity of species related to the chronosequence (young, 30-80 years; mature, 80-200 years; and old-growth, >200 years), the moisture gradient (wet, mesic, and dry old-growth stands), and vegetational structure were analyzed. Vegetation was described by measurements within a 5.6-m radius (100 m^2) and a 15-m radius (707 m^2) centered on nine pitfall traps (Gilbert and Allwine, this volume a: see appendix table 12). Individual amphibian species were compared between the 1985 old and new grids in eight stands to determine if differences in abundance were significant.

Animals were weighed, measured (snout-vent length, total length), and either released at the capture location or preserved for food habits studies or as specimens for the Conner Museum at Washington State University.

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

We used nonparametric analysis of variance (ANOVA) to test the hypotheses that neither abundance of animals nor species richness differed among the age- or moisture-classes in each location. We used detrended correspondence analysis (DCA) (Hill 1979a) to explore the relation between animal abundance and habitat-classes as environmental variables. Detrended correspondence analysis is an ordination technique that arranges a matrix of species' abundances (communities) by samples (stands) in low-dimensional space so that the communities occurring in each stand are represented in space along several axes. Thus, many components are reduced to a few important ones and variability is reduced. Communities with similar species composition and relative abundances occupy positions near each other within the space described by the first and second DCA axes. The axes that explain (by the ranking of their eigenvalues) the largest variability with the original matrix are determined as being important in exploring distribution with the data set. To determine whether stands were grouped according to a physiographic gradient, a plot of the DCA axes scores was examined to detect clustering.

To classify sites into community phases, two-way indicator species analysis (TWINSPAN) (Hill 1979b) was used. This method, based on a multilevel, two-way partitioning of the correspondence analysis scores, was used to classify species into categories related to location and age- or moisture-classes.

Species found to be associated with old-growth forests from TWINSPAN analysis or from Spearman rank correlations of animal. abundance with stand age were then correlated with individual environmental and vegetative variables to examine the relation between animal species and individual habitat features.

The log-likelihood ratio was used to test for significance in the use of logs by salamanders collected during time-constrained searches. Three decay-class categories (see Fogel and others 1973) were used: category 1 includes decay-classes 1 and 2; category 2 includes decay-class 3; and category 3 includes decay-classes 4 and 5. A G test (likelihood ratio chi-square) was performed after comparison of use to availability.

Statistical significance was at the $P < 0.05$ level (Zar 1974). Means are presented with standard errors.

Results

1984

A total of 951 amphibians were collected in pitfall traps in 1984. With the exception of ensatina, the amphibian species were most abundant at the Hood location (table 1). Hood produced significantly more specimens than either of the

Table 1—Amphibians captured in pitfall traps by subprovince in the Oregon Cascades, 1984

Species	Rogue-Umpqua (N=20)	Andrews (N=20)	Mt. Hood (N=16)	Totals
Northwestern salamander	6	1	31*	38
Clouded salamander	0	2	4	6
+Tailed frog	4	38	196*	238
Oregon slender salamander	0	4	2	6
Western toad	0	2	0	2
+Pacific giant salamander	4	8	31*	43
+Ensatina	185*	101	52	338
Pacific treefrog	1	1	0	2
+Dunn's salamander	0	29	46	75
+Roughskin newt	8	35	110*	153
Red-legged frog	12	0	11	23
+Frog[a]	12*	0	0	12
Olympic salamander	0	0	3	3
+Western redback salamander	12*	0	0	12
Totals:	244	221	486	951

* Significant ANOVA value for location.
\+ Significant Spearman rank correlation with latitude.
[a] Twelve frogs could not be identified because of their condition; they may have been foothill yellow-legged or Cascade frogs, as well as red-legged frogs.

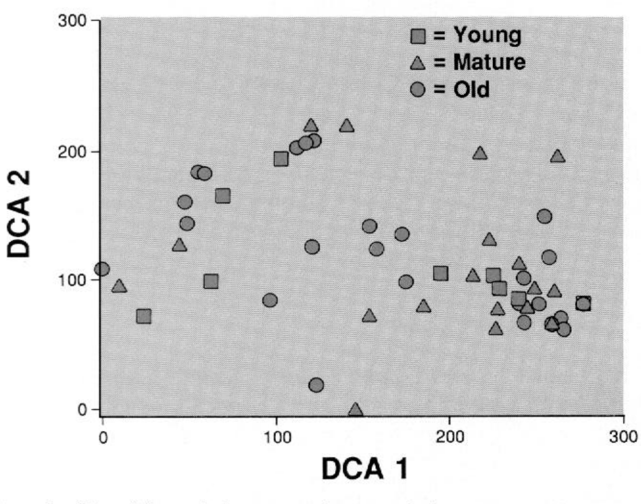


Figure 1—Plot of detrended correspondence analysis axes scores for amphibians caught in pitfall traps related to age of stand, Oregon Cascades, 1984.

others (31.3 ± 6.8 vs. 12.4 ± 1.4 at Rogue-Umpqua and 11.2 ± 2.0 at Andrews). Ensatina was the most common amphibian at Andrews (45 percent of captures) and at Rogue-Umpqua (78 percent of captures). At Hood, the tailed frog (40 percent of captures) was the most common amphibian. The average number of amphibians caught compared to the age of the stand was not significantly different (old-growth 14.0 ± 2.7, mature 15.8 ± 2.1, young 29.7 ± 10.7 (ANOVA F value 2.87, $P < 0.07$).

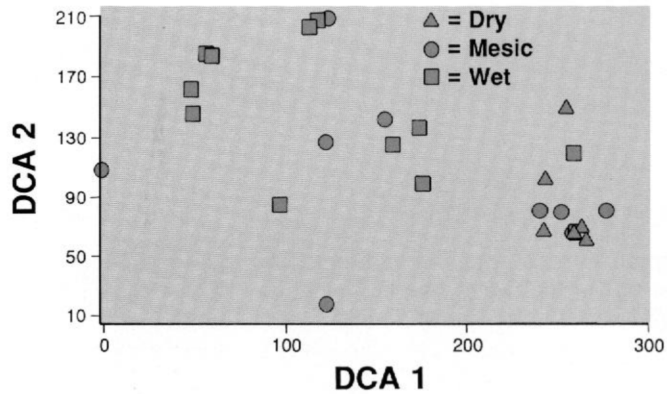


Figure 2—Plot of detrended correspondence analysis axes scores for amphibians caught in pitfall traps related to moisture condition of old-growth stands, Oregon Cascades, 1984.

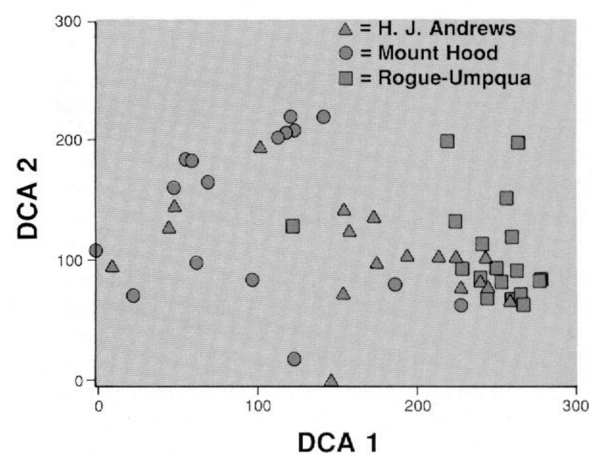


Figure 3—Plot of detrended correspondence analysis axes scores for amphibians caught in pitfall traps related to location, Oregon Cascades, 1984.

DECORANA analysis showed no influence of stand age on the amphibians captured (fig. 1). Some separation appeared between wet and dry stands, indicating some selection was occurring (fig. 2), and a definite location effect was found as Rogue-Umpqua separated from Hood with the Andrews interfacing with both (fig. 3).

No species were significantly associated with old-growth stands, although the frogs were found only in mature and old-growth stands and the Olympic salamander was found only in old-growth stands. The tailed frog (ANOVA F value 2.71, $P < 0.08$) and the roughskin newt (ANOVA F value 4.99, $P < 0.01$) captures were associated with young stands.

Although the most amphibians were collected in mesic stands (average 19.6 ± 5.8; wet 12.0 ± 3.3; dry 11.1 ± 3.5), no significant differences were found along the moisture gradient. Ensatina was the only species significantly associated with

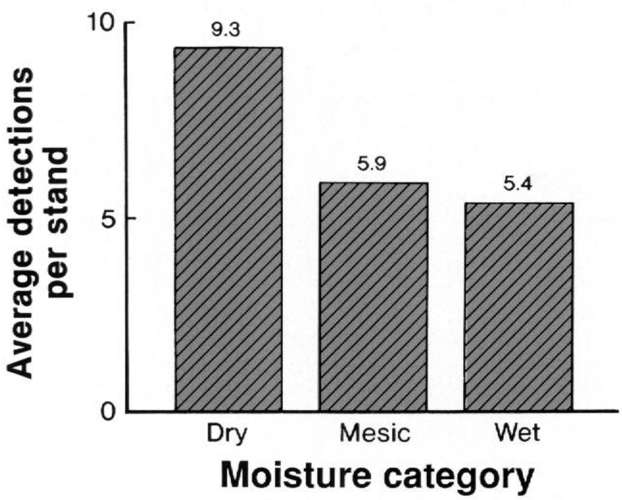


Figure 4—Relative pitfall capture rates for ensatina across the moisture gradient, Oregon Cascades, 1984.

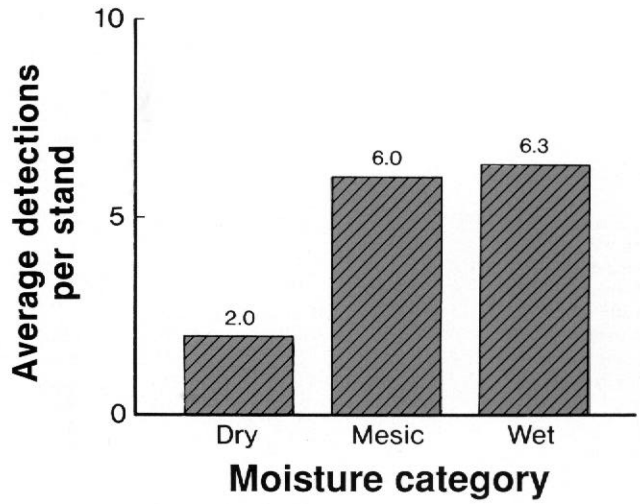


Figure 5—Relative pitfall capture rates for the Pacific giant salamander across the moisture gradient, Oregon Cascades, 1984.

dry sites (ANOVA F value 4.81, $P = 0.02$) and the Pacific giant salamander, the only species significantly associated with wet stands (ANOVA F value 3.88, $P = 0.03$) (figs. 4-5).

Fifteen different species were captured, and species richness was identical (10) at all three sites. The northwestern salamander was significantly associated with old-growth at Hood. Although Dunn's salamander generally was found in younger stands in the Oregon Cascades, it was found primarily in mature stands at the Andrews. The tailed frog was associated with young stands at Hood, mature stands at the Andrews, and found only in old-growth stands at Rogue-Umpqua.

The presence of water near the pitfall site was not related to capture for any species, with the possible exception of the unidentified frogs (ANOVA $P = 0.06$).

Ensatina was found where forest-floor conditions had a high percentage of bare soil (Spearman rank correlation $R = 0.32$, $P = 0.02$), and this species was negatively associated with moss ground cover (Spearman rank correlation $R = -0.44$, $P = 0.0001$). The tailed frog and the Pacific giant salamander by contrast, were captured at locations with moss cover ($R = 0.40, 0.30$; $P = 0.002, 0.02$, respectively). The tailed frog was negatively associated with areas of bare soil and fine litter, another characteristic selected by ensatina. Areas with high coverage by grass were negatively correlated with the roughskin newt ($R = -0.39$, $P < 0.003$), Dunn's salamander ($R = -0.31$, $P < 0.02$), and the Oregon slender salamander ($R = -0.31$, $P < 0.02$). The Pacific giant salamander was captured at sites with fern cover (0-0.5 m high $R = 0.42$, $P = 0.001$; 0.5-2.0 m high $R = 0.37$, $P = 0.005$), as were the clouded salamander (0-0.5 m $R = 0.36$, $P = 0.006$; 0.5-2.0 m $R = 0.37$, $P < 0.005$) and Dunn's salamander (0-0.5 m $R = 0.30$, $P = 0.02$; 0.5-2.0 m $R = 0.40$, $P = 0.002$).

Time-constrained searches produced 375 amphibians representing nine species (table 2). Eight species were captured at Hood and six each at the Andrews and Hood ($P > 0.05$). Ensatina was the most abundant amphibian (50.7 percent of captures), followed by the Oregon slender salamander (25.3 percent of captures) and clouded salamander (13.3 percent of captures). The tailed frog, the Pacific treefrog, the Olympic salamander, Dunn's salamander, the western redback salamander, and the roughskin newt were the only other species represented.

The Oregon slender salamander and the western redback salamander were associated with the wet portion of the moisture gradient and ensatina with the dry. No species was significantly associated with the chronosequence, although the only specimens of the tailed frog (2) and the Olympic salamander (1) were taken in old-growth stands. Use of logs by decay-classes (1+2, 3, 4+5) by ensatina, the clouded salamander, and the Oregon slender salamander was tested to see if it varied by species. The G test was highly significant ($P = 0.001$). Of these common species, the Oregon slender salamander ($G = 2.25$, $P < 0.001$) and ensatina ($G = 6.32$, $P = 0.04$) deviated from availability for decay-class 4 and 5 logs, but the clouded salamander showed no significant differences from expected values ($P = 0.88$).

Surveys showed that at least four species—the red-legged frog, the Pacific treefrog, the northwestern salamander, and the roughskin newt—used meltwater ponds as breeding sites.

Table 2-Amphibians collected during time-constrained searches in the Oregon Cascades, spring 1984, related to stand age (values in brackets are mean captures/stand)

Species	Old-growth	Mature	Young	Total
Ensatina	92 (3.41)	69 (3.45)	29 (3.22)	190 (3.39)
Oregon slender salamander	34 (1.26)	42 (2.10)	19 (2.11)	95 (1.70)
Clouded salamander	26 (0.96)	20 (1.00)	4 (0.44)	50 (0.89)
Western redback salamander	8 (0.30)	5 (0.25)	1 (0.11)	14 (0.25)
Dunn's salamander	9 (0.33)	3 (0.15)	0 (0.00)	12 (0.21)
Roughskin newt	4 (0.15)	1 (0.05)	3 (0.33)	8 (0.14)
Pacific treefrog	0 (0.00)	1 (0.05)	2 (0.22)	3 (0.05)
Tailed frog		0 (0.00)	0 (0.00)	2 (0.04)
Olympic salamander	1 (0.04)	0 (0.00)	0 (0.00)	1 (0.02)
Totals	176 (6.52)	141 (7.05)	58 (6.44)	375 (6.69)

Red-legged frog adults and egg masses were found in all but one of the 35 ponds surveyed. Pond depth, temperature, and surface area were all unrelated to presence or absence of amphibians. Ponds were only studied in old-growth or mature stands because none of the young stands studied had melt-water ponds.

Studies in 1985

Of the 462 amphibians captured in pitfall traps in 1985, ensatina contributed 267 and the roughskin newt 98 specimens (79.1 percent of all captures). The tailed frog was the only one of the other seven species to have more than 3 percent of the captures (table 3). The roughskin newt was significantly associated with young stands (ANOVA F value 4.86, P c 0.03). Young stands had more amphibians caught (average 52.7 $\pm$ 15.8) than either mature (34.0 $\pm$ 10.1) or old-growth stands (22.7 $\pm$ 3.8) (F value 3.92, $P < 0.05$). Wet stands produced more amphibians (average 27.5 $\pm$ 6.3) than did mesic (25.5 $\pm$ 10.5) or dry stands (14.3 $\pm$ 2.4), but the differences were not significant.

Although some forest-floor characteristics differed significantly between 1984 and 1985, general patterns were similar. For example, Dunn's salamander continued to be captured at sites with high percentages of bare rock and bare soil (1984 values $R = 0.44$, $P = 0.10$; $R = 0.43$, $P < 0.11$ and 1985 values $R = 0.62$, $P = 0.01$; $R = 0.75$, $P = 0.001$), and the Pacific giant salamander was caught at sites with a high percentage of moss (1984 $R = 0.55$, $P = 0.03$; 1985 $R = 0.43$, $P < 0.11$) based on Spearman rank correlations. Ensatina was found associated with logs of decay-class 1+2 (1984 $R = 0.52, P < 0.05$; 1985 $R = 0.47, P < 0.08$).

Table 3-Herpetofauna captured in pitfall traps at the H.J. Andrews, fall 1985 (values in brackets represent percentages)

Species	original grids (15)	New grids (8)	Total
Ensatina	174 (66.4)	93 (46.5)	267 (57.9)
Roughskin newt	38 (14.5)	60 (30.0)	98 (21.2)
Tailed frog	29 (11.1)	25 (12.5)	54 (11.7)
Dunn's salamander	8 (3.1)	4 (2.0)	12 (2.6)
Pacific treefrog	2 (0.8)	7 (3.5)	9 (1.9)
Pacific giant salamander	6 (2.3)	2 (1.0)	8 (1.7)
Oregon slender salamander	2 (0.8)	4 (2.0)	6 (1.3)
Red-legged frog	3 (1.1)	2 (1.0)	5 (1.1)
Northwestern salamander	0 (0.0)	3 (1.5)	3 (0.6)
Total	262	200	462

Comparison between years showed that only the tailed frog had a difference in its relation to the chronosequence, moisture gradient, or both. More captures were made in the dry portion of the moisture gradient in 1985 (chi-square = 5.669, 2 df, $P = 0.06$).

Although no significant difference was found in the amphibian species captured in the old and new grids of the same stands, the number of amphibians captured was different (chi-square = 20.164, 8 df, $P < 0.01$). The roughskin newt, the Pacific treefrog and the tailed frog were more abundant in the new grids.

Discussion

Porter (1972) suggested that amphibians tend to be restricted by dry conditions. Our findings support this generalization because Rogue-Umpqua, the subprovince with the least average annual precipitation, had the lowest number of amphibians, and many species selected mesic-wet stands over dry stands. Some species though, such as ensatina, may prefer drier sites. In general, we found similar relations between the amphibians and habitat conditions to those described in Nussbaum and others (1983) and Stebbins (1985).

Clouded salamanders and Oregon slender salamanders were seldom taken in pitfall traps. Both species live under the bark on logs, or within the logs, so time-constrained searches were the only effective way of sampling their presence and abundance (Bury and Corn 1988a). They were the second and third most abundant amphibians taken in me searches, and the Oregon slender salamander used more-decayed logs than did the clouded salamander. The decay-class use by these two species was similar to Bury and Corn's (1988a) observation that the clouded salamander used logs of decay-class 2 and 3 and the Oregon slender salamander used the older decay classes. Raphael (1988c) considered the clouded salamander to be associated with old growth because of its dependence on logs.

Tailed frogs seemed dependent on ambient temperature. They used stands of different ages at the three sites. At the warmest location (Rogue-Umpqua), old growth seemed to be selected; at the intermediate location (Andrews), mature stands had the most captures; and at the coolest location (Hood), the species was most abundant in young stands. This species breeds and the larvae develop in cool flowing streams, so the temperature in the streams may be what restricts distribution (Bury and Corn 1988b, Gilbert 1985). At Rogue-Umpqua, most of the streams were in old-growth stands; streams in the younger stands may be mostly intermittent and thus incapable of supporting tailed frogs. The Olympic salamander is more restricted to the vicinity of cool streams and seeps. It, too, is likely to be temperature dependent, but the major threat to these aquatic forms may be stream siltation, which destroys their prey base (Corn and Bury 1989).

The roughskin newt and northwestern salamander, like the red-legged frog, used meltwater ponds as breeding sites. Unlike the frog, the other two species were more ubiquitously distributed along the chronosequence and perhaps not as restricted in their movements. In partial contradiction, however, the roughskin newt may have been partially trapped out in 1984 because the old pitfall grids produced fewer of this species than the new grids in the same stands.

None of the amphibians we found was restricted to old growth, although some, such as the Olympic salamander, selected habitat conditions that may be most abundant in old growth, which may also be true for the Oregon slender salamander. This species used logs of the older decay-classes, a feature usually associated with old-growth forests (Franklin and others 1981). Logs in all age-classes were abundant in the natural stands we studied, however.

Because all the common (>6 observations) species were found in young as well as older stands, closed canopy conditions are apparently sufficient to sustain these species in the Oregon Cascades. Nonetheless, Bury (1983) and Bury and Corn (1988b) may well be correct that logging, especially clearcutting, can be disruptive to amphibian populations.

Clearcuts are unlikely to have the coarse woody debris or stand structure characteristic of the natural conditions in our study stands. If these characteristics could be maintained in managed forests, all the amphibian species we found in the Oregon Cascades should also be present in such forests.

Vegetative structure was not predictably related to species captures between years, probably because of the time of year of the pitfall trapping and the high percentage of juveniles in the populations. “Pulses” of high capture rates corresponded with periods of precipitation, a finding similar to other studies (Bury and Corn 1987, Bury and Corn 1988b). These pulses consisted of dispersing juveniles, so the capture sites may not represent actual habitat requirements.

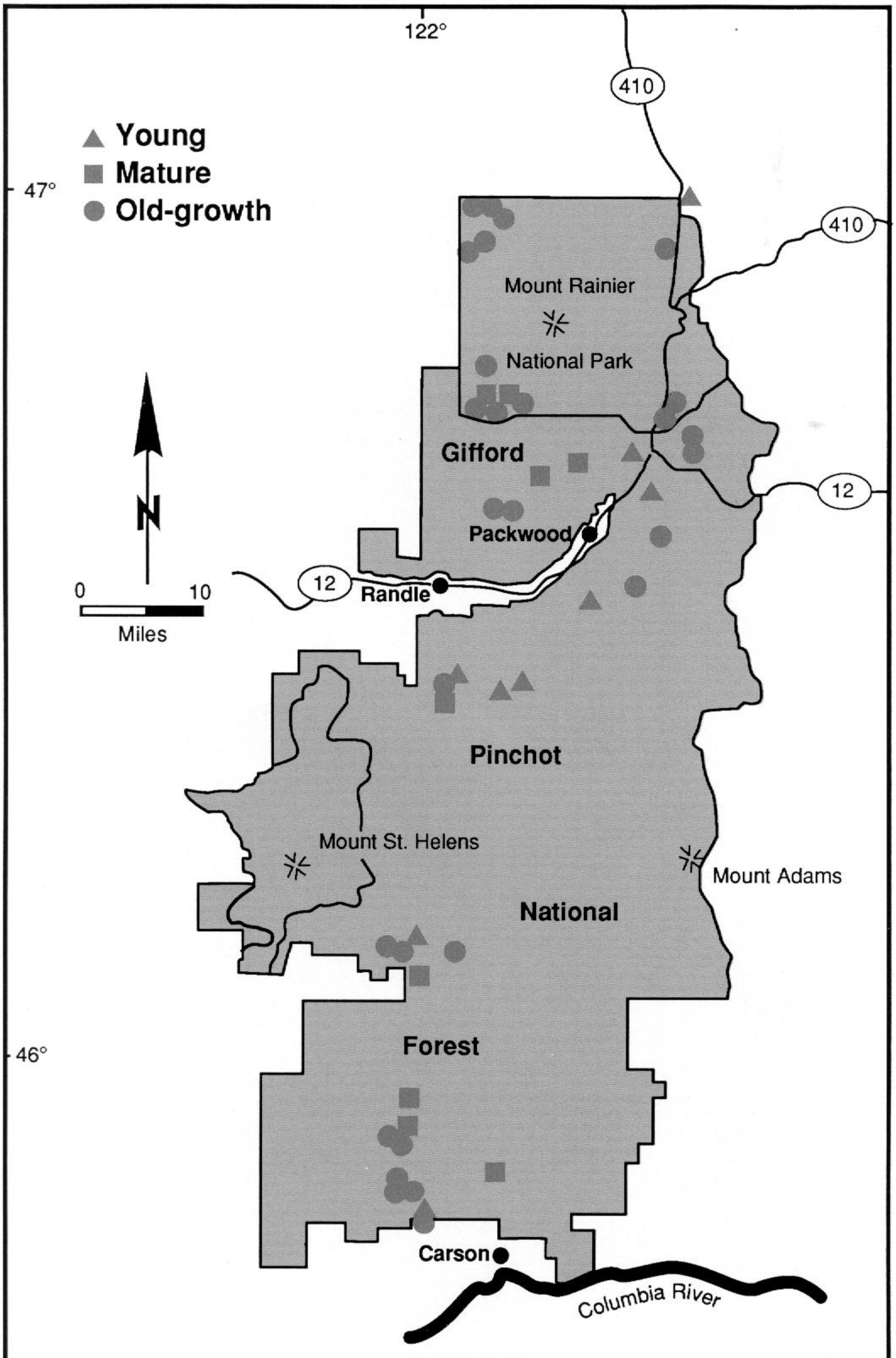
When amphibian communities are studied, recognizing that shifts occur in resource use is important, as exemplified by differences between breeding and nonbreeding communities. Such factors as spatial or temporal partitioning of available breeding sites like meltwater ponds or of male calling sites generally organize the community (Bogert 1960, Collins 1975, Dixon and Heyer 1968, Wiest 1982). In essence, the community structure shifts; our studies in the Oregon Cascades have not fully analyzed any single structural entity. As Crump (1982) stated, “There has been little integration of reproductive ecology and community dynamics.” We have some tantalizing hints of these relations but often little beyond life histories. Scott and Campbell (1982) stress the need for long-term studies of herpetological communities if we are to understand the roles of competition and intra-population social behavior. Our understanding is sketchy and our findings, particularly from this study, hardly predictive-except for the obvious need for adequate breeding conditions, whether that means clear, cool streams or sufficient ephemeral ponds, and for adequate substrate, such as logs for certain salamanders. None ,of these factors requires old-growth forests if forest planning and management succeed in ensuring uneven-aged structure, maintaining coarse woody debris, and protecting riparian zones.

Acknowledgments

The Oregon Cascades study was made possible by the contributions of many people, including U.S. Forest Service personnel. Effective field supervision was given by Wynn Cudmore, and crew leaders Jim Reichel and Troy Cline at Rogue River-Umpqua, Kathleen Fulmer at H.J. Andrews, and Jeff Picton at Mount Hood in 1984. The 1985 crew leader was Tony Fuchs. John Teburg, Dick Gilbert, Rich Alldredge, and Betsy Piersone all assisted in data entry and analysis. The hard-working field crews, primarily made up of Washington State University wildlife students, were essential to successful completion of the work.

This paper is contribution 113 of the Wildlife Habitat Relationships in Western Washington and Oregon Research Project, Pacific Northwest Research Station, USDA Forest Service. 0

This page was intentionally left blank



Location of study sites.

Terrestrial Amphibian Communities in the Southern Washington Cascade Range

Keith B. Aubry and Patricia A. Hall

Authors

KEITH B. AUBRY is a research wildlife biologist and PATRICIA A. HALL[1] is a wildlife biologist, USDA Forest Service, Pacific Northwest Research Station, Olympia, Washington 98502.

Abstract

We surveyed terrestrial amphibian communities with pitfall traps in 46 forest stands of various ages and moisture conditions in the southern Washington Cascade Range in 1984 and 1985. We captured a total of 1516 individuals of 13 species. Data were sufficient to examine community- and species-habitat relationships for seven species: ensatina, western redback salamander, northwestern salamander, roughskin newt, tailed frog, red-legged frog, and Cascades frog. We found no significant differences among stand age-classes for either species richness or diversity. Species richness, however, decreased significantly with both increasing elevation and increasing stand moisture. Detrended correspondence analysis (DCA) of amphibian communities revealed non-overlapping clusters of stands with distinct community composition; DCA axes were associated with gradients of slope, stand age, temperature, elevation, and moisture. In general, older stands with cooler temperatures and relatively flat slopes had the highest amphibian species richness.

The tailed frog was significantly more abundant in mature stands than in young stands. Although differences across the age gradient for other species were not significant, patterns of abundance for these species were evident. The ensatina and western redback salamander were most abundant in young stands, the red-legged frog in mature stands, and the north-western salamander, roughskin newt, and Cascades frog in old growth. Only abundances for the roughskin newt varied significantly among old-growth moisture-classes; abundance of this species was low in wet old-growth stands compared to either moderate or dry stands. The ensatina and north-western salamander also were least abundant in wet stands. The northwestern salamander and roughskin newt are associated with old-growth Douglas-fir forests in the southern Washington Cascades during the fall, whereas the ensatina, western redback salamander, and possibly the red-legged frog are associated with coarse woody debris that is characteristic of old-growth forests and unmanaged young forests.

Introduction

In recent years, harvest of old-growth Douglas-fir forests in the Pacific Northwest and its potentially detrimental effects on biological diversity have become a political and economic issue of national significance (see Lumen and Neitro 1980,

[1] Now wildlife biologist, School of Forestry, Northern Arizona University, Flagstaff, Arizona 86011.

Meslow and others 1981, Norse 1990, Norse and others 1986, Wilcove 1988). Most research on the habitat relationships of species associated with old-growth forests has been directed primarily at larger birds and mammals (for example, Meehan and others 1984), especially the spotted owl (GmZrrez and Carey 1985), which has become the social and political focus of concern over the loss of old-growth Douglas-fir forests.

Little work had been done on the habitat relationships of other birds, small mammals, amphibians, or reptiles in old-growth Douglas-fir forests, with the exception of vertebrate community studies conducted in the early 1980s in northern California (Raphael 1984, Raphael and Barrett 1984). In 1983, a comprehensive program of research was initiated throughout the Pacific Northwest to identify wildlife species that are associated with old-growth Douglas-fir forests and to investigate the ecological basis of observed patterns of association (this volume; Ruggiero and Carey 1984).

As part of this program of research, amphibian communities in different-aged Douglas-fir forests in the southern Washington Cascade Range were sampled with time-constrained searches, stream surveys, and pitfall trapping. Results of time-constrained searches were reported previously (Aubry and others 1988), and results of stream surveys are reported here by Bury and others (this volume b). In this paper, we report the results of pitfall trapping conducted in the fall of 1984 and 1985. Our objectives are to:

- Characterize the structure and composition of terrestrial amphibian communities in Douglas-fir forests of southern Washington and relate community patterns to features of the environment;
- Describe the habitat relationships of terrestrial amphibians in these forests;
- Identify terrestrial amphibian species that are associated with old-growth Douglas-fir forests; and,
- Make recommendations for further research.

Methods

Study Areas

We studied terrestrial amphibian communities in 46 closed-canopy forest stands on the western slope of the Cascade Range in southern Washington from Mount Rainier south to the Columbia River Gorge (see frontispiece). Stands were 55 to 730 years old, at least 20 ha in extent, and at elevations ranging from 404 to 1218 m. All had resulted from natural regeneration after catastrophic wildfires; none had undergone silvicultural manipulations.

All stands were in the Western Hemlock Zone and lower elevations of the Pacific Silver Fir Zone (Franklin and Dyrness 1973), which are characterized by a wet and mild maritime climate. Old-growth stands typically contained high proportions of both Douglas-fir and western hemlock. Old growth stands in wet sites also contained a high proportion of western redcedar. Mature and young stands consisted predominantly of Douglas-fir. In all age-classes, other species such as red alder, vine maple, bigleaf maple, Pacific silver fir, and western hemlock occurred in lesser amounts . See Spies and Franklin (this volume) and Spies (this volume) for more detailed descriptions of the vegetative and structural characteristics of the study stands.

Stands were selected for study in accordance with a "T-matrix" design consisting of an age gradient of stands of comparable moisture condition ranging from young to old growth, and an old-growth moisture gradient that consisted of old-growth stands ranging from wet to dry. See Carey and Spies (this volume) for a detailed description of the experimental design.

At least nine stands were selected in each of five age- and moisture-classes: wet old growth (210-730 years old), moderate old growth, and dry old growth; moderate mature (80-190 years old); and moderate young (55-75 years old). The average age of each stand was determined by growth-ring counts from increment coring or examination of cut stumps in nearby stands (Spies and others 1988). Stands were selected and tentatively classified into moisture-classes during initial field reconnaissance based on vegetation, physiography, and soils. Subsequent analyses of vegetation data collected in each stand resulted in refinements to the original classifications (Spies and Franklin, this volume). These analyses indicate that the young and mature stands we sampled encompass a broader range of environmental conditions than originally intended. Some of the wet and dry old-growth stands, for example, were comparable in moisture condition to the 'moderate' mature and young stands. Several old-growth stands were therefore reclassified as moderate for inclusion in age-gradient analyses. As a result, the age gradient of stands of comparable moisture condition for the southern Washington Cascade Range consisted of 37 stands: 19 old growth, 9 mature, and 9 young.

To compare moisture-classes of old-growth stands, Spies and Franklin (this volume) used ordination analyses of the species composition of old-growth stands to reevaluate the relative moisture condition of each stand. The resulting classification consisted of 9 wet, 12 moderate, and 7 dry old-growth stands. Because this classification is independent of the age-gradient classification, data from these two gradients were analyzed separately. Variation related to age was

Continue