Pacific
Wildlife
Research PO Box 1069 • Corvallis, OR 97339 • (541) 745-5025

Habitat Selection by Oregon Slender Salamanders (*Batracoseps wrighti*) in the Western Oregon Cascades

Prepared for:

Oregon Department of Fish and Wildlife
(ODFW Contract no. 63506138)

by

David G. Vesely
Pacific Wildlife Research

Final Report
April 9, 1999

www.pwri.com

INTRODUCTION

Oregon slender salamanders (*Batrachoseps wrighti*) are endemic to the west slope of the Cascade Range in Oregon (Nussbaum et al. 1983). The species is most common in mature and old-growth Douglas-fir (*Pseudotsuga menziesii*) forests, but also has been detected in second growth stands, clearcut harvest units, and lava fields (Nussbaum et al. 1983, Bury and Corn 1988, Gilbert and Allwine 1991). Some investigators have reported that the occurrence or abundance of Oregon slender salamanders is associated with logs or other woody detritus (Bury and Corn 1988, Gilbert and Allwine 1991). However none of these studies tested microhabitat selection by Oregon slender salamanders based on the availability of logs or other site characteristics. Oregon slender salamanders are poorly detected by conventional pitfall trapping (Bury and Corn 1983) and habitat studies typically have been hampered by insufficient captures to distinguish patterns of occupancy among different forest conditions or response to management practices. Oregon slender salamanders are classified as “Sensitive-Undetermined” in the state of Oregon (ODFW 1997); it is suspected that forestry practices may reduce habitat suitability for the species but there is insufficient information to assess whether populations are declining (Marshall et al. 1992).

In spring of 1997, we performed reconnaissance surveys for Oregon slender salamanders in 12 unlogged Douglas-fir stands. Our objectives in this pilot study were to determine salamander detection rates using visual encounter surveys (modified after Crump and Scott 1994) and to acquire baseline estimates of abundance in forest conditions that we hypothesized to be highly suitable for this species. We also collected ancillary vegetation and topographic data on plots centered on Oregon slender salamander positions and random locations to examine microhabitat selection by the species.

In 1998, we conducted more intensive amphibian and habitat sampling. Our objectives were twofold. First, we proposed to identify microhabitat features associated with the abundance of Oregon slender salamanders, particularly characteristics of woody detritus. Second, we intended to compare relative densities of salamanders in naturally regenerated forests to that in two types of managed stands.

STUDY AREA

The 1997 reconnaissance survey was conducted in portions of Clackamas, Marion, and Linn counties lying in the Western Cascades physiographic province (Figure 1). The topography is generally rugged, and main ridge crests average 1,500 m (Franklin and Dyrness 1988). Study sites ranged in elevation from 580 m to 1,182 m. All but the highest elevation study sites occurred in the *Tsuga heterophylla* Vegetation Zone (Franklin and Dyrness 1988). Mean temperatures within this region range from approximately 2.5 C° in January to 19 C° in July, with an annual average of 10.5 C°. Precipitation averages approximately 200 cm annually (Oregon Climate Service 1999).

For the 1997 survey, biologists from the Mt. Hood and Willamette National Forests assisted us in selecting 12 late-successional, Douglas-fir stands regenerated after natural disturbance. For the purposes of this study, we defined late-successional stands as having dominant and co-dominant Douglas-firs ≥51-cm dbh. Portions of some stands had individual trees cut and removed but were not substantially different in composition or structure than unlogged areas. Western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*) were common conifer associates of Douglas-fir in these stands. Pacific silver fir (*Abies amabilis*) and noble fir (*Abies procera*) occasionally occurred at some higher elevation sites. Bigleaf maple (*Acer macrophyllum*) and red alder (*Alnus rubra*) were the most frequently observed broadleaf species.

The 1998 study was conducted in the Breitenbush and Detroit Tributaries Watershed Units of the Detroit Ranger District, Willamette National Forest. We selected 56 stands that were in one of three forest conditions: Old-growth (OG), Harvest Clearcut / Reserved (HCR), or Second Growth (SG). Old-growth stands (n=23) were identified from watershed unit maps representing northern spotted owl (*Strix occidentalis caurina*) nesting habitat. Stands in OG condition are characterized by multi-storied canopies dominated by large-diameter (≥51-cm dbh) Douglas-firs. Most stands appeared to have been naturally regenerated and were structurally similar to the 1997 study sites. Second Growth (n=23) and HCR stands (n=10) were identified using district stand structure and year-of-harvest maps. Stands in the SG condition had been regenerated by clearcut during the period of 1950-1969 (29-48 years prior to our study) and replanted with Douglas-fir seedlings. Stands of this age range managed for timber production on the Willamette National Forest typically may receive one or two pre-commercial and commercial thinning treatments. Harvest Clearcut / Reserved stands were logged during the period of 1990-1996 (2-7 years prior to our study).

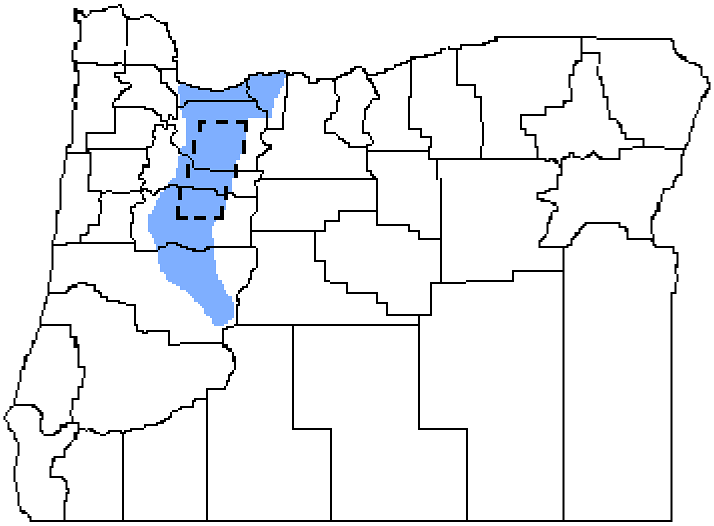

Figure 1. Map of the study area in the western Oregon Cascade Range. The dashed lines enclose 1997 and 1998 study sites. The shaded area indicates the approximate known range of the Oregon slender salamander.

METHODS

Amphibian Sampling

We conducted the reconnaissance survey from April 26 to June 15, 1997, soon after snow melt at the study sites. In typical years, sampling during this season can be expected to yield the greatest number of Oregon slender salamander detections (Nussbaum et al. 1983). We sampled terrestrial amphibians using Visual Encounter Surveys (VES) and standardized the search effort among study sites by a time constraint of 10 surveyor hours. Prior to each survey, the field crew leader verified that the stand met the criteria for the study and delineated the site boundaries based on structural and compositional homogeneity of the dominant and co-dominant tree layers. Surveys were performed by a crew of 2-3 persons trained in VES protocol and supervised by an expert in identifying Pacific

Northwest amphibian species. The crew traversed each stand in a systematic pattern to distribute search effort across the study site. However, only a minor fraction of all potential hiding cover could typically be searched within the 10-hr period at each site. Although prior accounts reported that Oregon slender salamanders are most often found in decayed logs (Nussbaum et al. 1983, Bury and Corn 1988), we instructed surveyors to also search a variety of other cover objects (e.g., rocks, bark piles, scattered debris) so that we could examine this assumption. Stopwatches were used to keep track of elapsed time during the search. Time spent handling animals, recording data, or traversing extremely rough terrain were not included as search effort. Captured amphibians were replaced in their original positions and covered after data were recorded. Amphibian locations were marked with plastic flagging and other surveyors did not search within several meters of a known location. We assumed that replaced amphibians would not move more than 2-3 meters during the course of a survey.

For each stand, we recorded a site identification code, start time, end time, air temperature (C°) 1-m above ground, soil temperature (C°) approximately 5-cm below ground surface, a weather code, and names of surveyors. Data recorded for each amphibian detection included species, snout-vent length, hiding cover and substrate.

The 1998 study was conducted from April 24 to June 13, 1998. The sequence in which stands were sampled was determined by stratified random assignment to avoid a seasonal bias on the treatment effect we intended to test (i.e., forest condition). We sampled terrestrial amphibians on three 2 X 50 m belt transects in each stand instead of using time-constrained searches because we wished to estimate relative densities of salamanders among the three forest conditions. The beginning of each belt transect was fixed at the point where a surveyor stopped after performing a prescribed walk in the stand. Each walk was determined by a randomly selected azimuth (0-360°) and randomly selected distances (between 10-100 paces, 10 pace increments). The orientation of each belt transect also was determined by selecting a random azimuth. Surveyors were instructed to examine all potential salamander hiding cover on the belt transect that could be moved. Bark piles and logs were searched thoroughly and then fragments were reassembled into the approximate original positions to minimize destruction of salamander habitat.

Habitat Sampling

In 1997, we measured or estimated amounts of different types of woody detritus, canopy closure, and topographic characteristics on 5-m radius plots centered on salamander locations to determine microhabitat use. We recorded slope (%), aspect (degrees azimuth), and topographic position (i.e., stream channel, bank, terrace, lower 1/3 slope, middle 1/3 slope, or upper 1/3 slope) at the center of each plot. We recorded the total length (m) of logs within the plot in five diameter classes and three decay classes (modified after Maser et al. 1979). Numbers of snags standing in each plot were tallied in five diameter classes and three decay classes (modified after Cline et al. 1980). We also estimated the percentage of plot covered by leaf litter, fine woody detritus (diameter <10-cm), and bark fragments not attached to logs. In each stand, we sampled additional 5-m radius habitat plots at randomly selected locations to estimate the availability of microhabitats. The number of random plots typically was equal to the number of detection plots in a stand.

In 1998, we divided each belt transect into five 2 X 10 m sub-plots for the purpose of habitat sampling. We recorded microhabitat characteristics on subplot occupied by at least one Oregon slender salamander and one randomly selected plot on each transect. We measured the same microhabitat features in 1998 as in 1997, however we estimated log abundance using a line-intercept method (Bonham 1989) rather than measurements within circular plots. We also estimated two additional topographic descriptors in 1998: approximate average elevation of each stand by comparing stand boundary maps to 1:24,000 USGS topographic maps and we estimated Universal Transverse Mercator coordinates at the center of each transect using a handheld geographic information system receiver.

Data Analysis

In the 1997 study, we used stepwise logistic regression (Hosmer and Lemeshow 1989) to distinguish microhabitat features on plots inhabited by Oregon slender salamanders from those on random plots that we used to characterize microhabitat generally available. We assessed 19 independent variables: topographic position, slope, %cover of three types of fine woody detritus, and downed log abundance (length in meters) in 15 classes of decay and diameter (i.e., three levels of decay X five levels of diameter). We assessed the contribution of individual independent variables using a sequential sum of squared deviance analysis (i.e., Type I Analysis; SAS Institute 1993) and compared reduced models to the saturated model using Drop in Deviance Tests (Ramsey and Shafer 1997). We initially entered independent variables that met a criterion for significance $P \leq 0.05$ and retained variables that continued to meet the criterion after additional variables were included.

In the 1998 study, we compared abundance of Oregon slender salamanders among three forest conditions: OG, HCR, and SG. Stand-level abundance was measured as the sum of salamander counts from all three belt transects. After an initial examination of the data, we used goodness-of-fit tests to determine that the salamander counts conform to Poisson (Krebs 1989: 76-78) or negative binomial (Krebs 1989: 85-90) probability distributions. We also calculated a relative density index (individuals / ha) by dividing stand-level counts by total area searched (300 m^2 per stand) and multiplying by 10,000 to provide a standardized estimate that could be compared to other studies. When we had inadequate detections in a single treatment class (i.e., Forest Condition) to make comparisons, we used an *a postori* sequential sampling procedure (Krebs 1989: 248-253) to test whether we collected adequate data to accept one of the two following alternate hypotheses:

$$H_0 : \textit{mean salamander count / stand} \leq 0.1$$

$$H_1 : \textit{mean salamander count / stand} \geq 0.5$$

To analyze relationships between mean salamander counts, forest condition, and potential explanatory variables, we evaluated a series of descriptive models using maximum likelihood estimation procedures (McCullagh and Nelder 1989). We examined trial models for goodness of fit by summing squared deviance residuals and comparing this statistic to a chi-square distribution with n-p degrees of freedom, where n is the sample size and p is the number of parameters in the model. When overdispersion was indicated in Poisson response models, we included a multiplicative scale parameter, ϕ, estimated by the total model deviance divided by n-p to allow for more variability than expected in the Poisson distribution (McCullagh and Nelder 1989).

For the 1998 study, we pooled the original 15 downed log types into eight broader classes to reduce the number of null observations among the woody detritus data. To examine whether levels of woody detritus and other site characteristics differed among the three forest conditions, we summed sub-plot estimates of logs and snags and used median estimates of canopy, and elevation within a stand and tested for differences among conditions with Wilcoxon Rank-Sum Tests (Steel and Torrie 1980).

To test for an association between salamander abundance and forest condition, we evaluated the following log-linear model for Poisson counts:

$$log(\mu) = \beta_0 + \beta_1 cond_1$$

where μ is a mean count with Poisson distribution, β_0 is the intercept coefficient, β_1 is the slope coefficient, and *cond* = forest condition (two level indicator variable).The significance of the forest condition term was evaluated with a Type III likelihood ratio test (SAS Institute 1993). To examine associations between site characteristics and salamander abundance, we screened a series of log-linear models for Poisson counts.

The potential explanatory variables we examined included: %slope, transformed aspect (Beers et al. 1966), %canopy closure, elevation (m), air temperature (°C) during the survey, log lengths (m) in three decay classes (decay 1, decay2-3, decay4-5) and five diameter (cm) classes (dia10-25, dia25-50, dia50-75, dia75-100, dia>100). When pairs of explanatory variables were highly correlated (Spearman Rank Correlation Coefficient >0.50, $P<0.1$) we retained the variable that we believed would best lead to an easily interpretable model and excluded the alternate variable. We initially fit a model that included only the intercept term and recorded total deviance. We then separately fit all possible two variable models that included the intercept term and each of the potential explanatory variables. Each of these models were compared to the intercept-only model using Drop in Deviance Tests with a significance criterion for a single parameter of $P \geq 0.05$. The explanatory variable that provided the greatest drop in deviance was retained in the model. We continued to test higher order models in a similar manner until no additional variables led to a significant drop in deviance.

RESULTS

We encountered 142 Oregon slender salamanders during the 1997 reconnaissance survey. Nine out of 12 (75%) late-successional stands were occupied by the species. On average, we detected Oregon slender salamanders at a rate of 1.18 individuals / hour during VES. This is a higher rate than any other species of terrestrial salamander we encountered (Figure 2). Our 1997 logistic regression analysis identified four characteristics that distinguished plots selected by Oregon slender salamanders from random plots (Table 1).

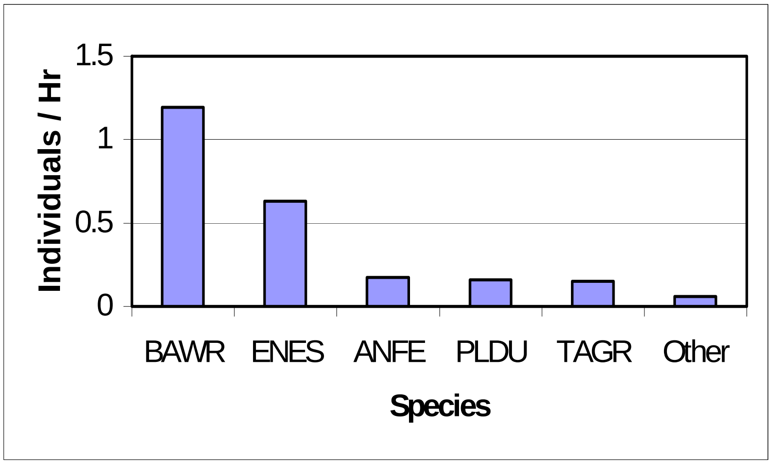

Figure 2. Detection rates (individuals / hr) during visual encounter searches of late-successional stands. BAWR = *Batrachoseps wrighti*, Enes = *Ensatina eschscholtzii*, ANFE = *Aneides ferreus*, PLDU = *Plethodon dunni*, TAGR = *Taricha granulosa*, Other includes *Dicamptodon tenebrosus*, *Hyla regilla*, and *Ambystoma gracile.*

Table 1. Significant variables in the stepwise logistic regression model to predict plot occupancy by Oregon slender salamanders. Data were from the 1997 reconnaissance survey only.

Variable	Slope (β_1)	SE	Wald's χ^2	P	Odds Ratio
Bark (%cover)	0.0639	0.0150	18.1636	0.0001	1.066
Logs, 10-25cmXdecay1	0.1720	0.0832	4.2803	0.0386	1.188
Logs, 26-50cmXdecay 2-3	0.1547	0.0652	5.6286	0.0177	1.167
Logs, 51-75cmXdecay4-5	0.3284	0.0844	15.1234	0.0001	1.389

Of the variables selected with the stepwise logistic regression procedure, the total length (m) of logs that were 51-75 cm in diameter and were decay class 4-5 had the highest odds ratio. This model predicts that a one-meter increase in abundance of this type of log is associated with a 1.4-fold increase in the occupancy rate of a plot when all other factors are held constant.

In the 1998 study, we detected 72 Oregon slender salamanders among the 56 stands surveyed. Our analysis revealed moderate evidence ($F = 2.886$, $P>F = 0.0964$) to reject the null hypothesis that mean counts of the species did not differ between the SG forest condition and OG forests (Table 2). We were unable to make a direct comparison of mean salamander density in HCR stands to other forest conditions because we failed to detect a single Oregon slender salamander after sampling 10 consecutive study sites. However, we estimated that mean counts in HCR stands were no greater than 0.10 / stand by using the *a postori* sequential sampling procedure. Our comparisons of site characteristics among the three forest conditions revealed evidence that abundance of most classes of woody detritus were significantly lower among stands in SG condition than OG condition (Table 3).

Table 2. Comparison of Oregon slender salamander counts and density indices (individuals / ha) in three forest conditions.

Condition	*n*	Mean Count	SE	Density Index
OG	23	2.0870	0.6157	69.5666
SG	23	1.0435	0.3046	34.7833
HCR	10	≤0.10	-	≤3.3333

Table 3. Comparison of microhabitat characteristics among three forest conditions.

	OG		SG		HCR	
Variable	Median	Range	Median	Range	Median	Range
Canopy (%)	93	24	92	34	0	0
Elev (m)	3050	1360	2800	1680	3300	1940
Logs, decay 1	8	125	$0^{\dagger\dagger}$	85	0	8
Logs, decay 2-3	19	175	$4^{\dagger\dagger}$	37	5.75	36.5
Logs, decay 4-5	38	133.5	$17^{\dagger\dagger}$	61.5	11	69
Logs, dia10-25 cm	10.5	52	$15^{\dagger}$	28	4.75	59
Logs, dia 25-50 cm	26	204	$7^{\dagger\dagger}$	77	9.5	32
Logs, dia 50-75 cm	30	133	$0^{\dagger\dagger}$	25	3.5	20
Logs, dia 75-100 cm	0	120	0	23	0	3
Logs, dia >100 cm	0	50	$0^{\dagger}$	14	0	0
Snags, dbh ≥10 cm	1	4	$0^{\dagger}$	2	0	3

Wilcoxon-Rank Sum Test for H_0:median$_{OG}$ = median$_{SG}$ † $0.1 > P > 0.05$, †† $P > 0.05$

We identified six characteristics of our 1998 study sites having a significant association with the number of Oregon slender salamanders we counted in a stand (Table 4). Of all single-term models we examined, canopy closure provided the greatest drop in deviance. When canopy closure was retained, aspect led to the most improved fit among all possible two-term models. The cosine transformation we applied to aspect data for the regression analysis is not easily interpretable. However, when salamander counts are summed by compass quadrants, an orientation to east and west aspects is apparent (Table 5). Additional woody detritus variables continued to result in significant drops in deviance, until the final model included six explanatory variables.

Table 4. Significant variables in the log-linear Poisson regression model to predict counts of Oregon slender salamanders. Data were from the 1998 study only.

Variable	Order Entered	Slope (β_1)	SE	Likelihood ratio χ^2	P
Intercept		-4.0915	1.8081	5.1206	0.0236
Canopy	1	0.0443	0.0198	5.0249	0.0250
Aspect (transformed)	2	0.6488	0.2580	6.3265	0.0119
Logs, dia 10-25	3	-0.0288	0.0193	2.2299	0.1354
Logs, dia 50-75	4	0.0163	0.0049	11.1792	0.0008
Snags	5	0.5979	0.2129	7.8846	0.0050
Logs, decay 2-3	6	-0.0198	0.0101	3.8395	0.0501

Table 5. Total Oregon slender salamander counts summarized by quadrant at 56 study sites.

Compass quadrant	Azimuth range	Salamander count
North	315-45°	8
East	45-135°	26
South	135-225°	14
West	225-315°	24

DISCUSSION

Oregon slender salamanders are the most common terrestrial amphibian in the late-successional forests we sampled. In contrast, Gilbert and Allwine (1991) reported that ensatinas (*Ensatina eshscholtzii*) were almost three times as abundant as slender salamanders in old-growth stands. Bury and Corn (1988) also found ensatinas and clouded salamanders (*Aneides ferreus*) to be more common than slender salamanders. However, data summarized from these previous studies included sampling sites that were near the margin of the known geographic range of Oregon slender salamanders. Our study area included fewer peripheral locations.

We found that unlogged, late-successional forests support relative densities of Oregon slender salamanders approximately twice as great as young Douglas-fir plantations. Visual encounter surveys conducted by Bury and Corn (1988) show a similar relationship between slender salamander abundance and forest seral stage. These investigators detected 33 slender salamanders in eight old-growth stands (4.1 detections / stand) and 10 salamanders in four young (30-76 year old), naturally regenerated stands (2.5 detections / stand) using standardized effort. However, Gilbert and Allwine (1991) found slender salamanders to be more abundant in young (30-80 years), naturally regenerated stands than old-growth forests. Oregon slender salamanders were undetectable in recently harvested stands in our study. The only other report of slender salamander abundance in clearcuts (Bury and Corn 1988) also indicates the species to be distributed sparsely (1 detection / 24 search hours).

Our 1998 analysis of Oregon slender salamander habitat selection indicates that canopy closure and average stand aspect were the two best predictors of relative density among the logged and unlogged forests we surveyed. Slender salamander density was positively correlated with canopy closure, but we found evidence of a bimodal response to aspect. The species occurred at higher densities on east and west facing slopes than north or south aspects. Although previous studies have not reported direct evidence of a similar relationship between slender salamander abundance and these variables, the distribution of terrestrial salamanders is widely believed to be influenced by the forest floor microenvironment (Dupuis et al. 1995, Heatwole 1962, Jaeger 1971). Perhaps the distribution of slender salamanders we observed indicates selection of sites with moderate thermal regimes: southern aspects may be too hot or dry during summer months and northern slopes may retain snowcover late in the spring.

The 1998 analysis also demonstrated that slender salamander density was positively associated with relatively large diameter (50-75 cm diameter) logs, and density of snags at the sites we surveyed. Relative density of salamanders was negatively associated with small diameter (10-25 cm) logs and moderately decayed logs (classes 2 and 3). Analysis of the 1997 data revealed evidence that slender salamanders select microsites in late-successional forests with the high concentrations of woody detritus. Previous investigators (Bury and Corn 1988, Gilbert and Allwine 1991) also have found a similar association between Oregon slender salamander abundance and levels of coarse, woody debris, particularly with very decayed logs (classes 4-5). We excluded class 4-5 logs as a potential explanatory variable in favor of retaining a different parameter (logs, 50-75 cm diameter) with which they were highly correlated (Spearman Rank Correlation Coefficient = 0.51, $P<0.0001$).

Our study provides evidence that relative density of Oregon slender salamanders is most closely associated with two characteristics of forest stands in our study area: canopy closure and average aspect. We hypothesize that slender salamanders may actually be responding to microclimatic gradients on the forest floor. Within stands, slender salamanders select microsites having greater abundance of large logs and snags than are generally available. Observations by our surveyors indicate that Oregon slender salamanders probably do not often use portions of snags >1-m above ground, but deep piles of bark and wood at the base of snags are important refugia for the species.

We found Oregon slender salamanders to be extremely rare in recent clearcuts and attribute this to the combined affects of canopy removal and the low abundance of woody detritus. Young, naturally disturbed stands typically have greater amounts of snags and logs than plantations (Spies and Cline 1988) and slender salamanders may attain abundance greater than in old-growth (Gilbert and Allwine 1991). We found that slender salamander density in Douglas-fir plantations begins to approach that of unlogged, late-successional forests 30-50 after clearcutting. However, surveyor observations during our study indicate that slender salamanders tended to hide under smaller pieces of wood and fine detritus in managed stands. Our surveys of coarse, woody debris demonstrate that large, decayed logs used by slender salamanders for nesting are rare in clearcuts and plantations. Thus, we believe that forests intensively managed on short harvest rotations may represent population “sinks”. Recent changes in forestry practices on federal Matrix Lands (USDA / USDI 1994) provide for greater recruitment and retention of woody detritus and may improve habitat suitability for Oregon slender salamanders at the scale of a home range or small populations. However, the spatial configuration of federal late-successional reserves was designed primarily for Northern spotted owls and to protect remaining tracts of old-growth. It remains untested whether population viability for Oregon slender salamanders will be maintained with the present arrangement of reserves. We recommend that future research examine the interactions between dispersal capability of Oregon slender salamanders, population connectivity, and patterns of forest distribution at a landscape-scale.

ACKNOWLEGEMENTS

This research was made possible by grants and in-kind support from US Fish and Wildlife Service, The Mount Hood and Willamette National Forests, Oregon Department of Fish and Wildlife Northwest Regional Office and the ODFW Wildlife Diversity Program. Char Corkran, Northwest Ecological Research Institute; Joan Hagar, Oregon State University; and Rebecca Goggans, ODFW made very significant contributions to this project. We also wish to thank Lori Turner, Detroit Ranger District; Robert Penson, Clackamas Ranger District, and the other Forest Service biologists that assisted us in selecting study sites.

LITERATURE CITED

Beers, T. W., P. E. Dress, and L. C. Wentzel. 1966. Aspect transformation in site productivity research. Journal of Forestry. 64:691-692.

Bonham, C.D. 1989. Measurements for Terrestrial Vegetation. John Wiley and Sons, New York. 338 pp.

Bury, R. B., and P. S. Corn. 1988. Response of aquatic and streamside amphibians to timber harvest: a review, p. 165-181. In: Streamside Management: Riparian Wildlife and Forestry Interactions. Vol. Contribution no. 59. K.J. Raedeke (ed.). University of Washington, Seattle.

Cline, S. P., A.B. Berg, and H. M. Wight. 1980. Snag characteristics and dynamics in Douglas-fir forests, Western Oregon. Journal of Wildlife Management. 44:773-786.

Crump, M. L., and N. J. Scott, Jr. 1994. Visual Encounter Surveys, p. 84-92. In: Measuring and Monitoring Biological Diversity. W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L.-A. C. Hayek, and M. S. Foster (eds.). Smithsonian Institute Press, Washington. 364 pp.

Dupuis, L.A., J.N.M. Smith, and F. Bunnell. 1995. Relation of terrestrial-breeding amphibian abundance to tree-stand age. Conservation Biology 9:645-653.

Franklin, J. F., and C. T. Dyrness. 1988. The Natural Vegetation of Oregon and Washington. Oregon State University Press, Corvallis. 452 pp.

Gilbert, F. F., and R. Allwine. 1991. Terrestrial amphibian communities in the Oregon Cascade Range, p. 319-324. USDA Forest Service, Portland. of 319-324.

Heatwole, H. 1962. Environmental factors influencing local distribution and activity of the salamander, *Plethodon cinereus*. Ecology 43:460-472.

Hosmer, D. W., Jr., and S. Lemeshow. 1989. Applied Logistic Regression. John Wiley and Sons, New York.

Jaeger, R.G. 1971. Moisture as a factor influencing the distributions of two species of terrestrial salamanders. Oecologia 6:191-207.

Krebs, C. J. 1989. Ecological Methodology. Harper Collins Publishers, New York, NY. 654 pp.

Marshall, D. B., M. Chilcote, and H. Weeks. 1992. Sensitive Vertebrates of Oregon, Oregon Department of Fish and Wildlife. [irregular pagination].

Maser, C., R.G. Anderson, K. Cromack, J.T. Williams, and R.E. Martin. 1979. Dead and down woody material, p. 78-95. In, J. W. Thomas (eds). Wildlife Habitats in Managed Forests: The Blue Mountains of Oregon and Washington. USDA Forest Service Agricultural Handbook No. 553. Portland. 512 pp.

McCullagh, P., and J. A. Nelder. 1989. Generalized Linear Models. Chapman and Hall. 511 pp.

Nussbaum, R. A., E. D. Brodie, Jr., and R. M. Storm. 1983. Amphibians and Reptiles of the Pacific Northwest. Univ. of Idaho Press, Moscow, Idaho.

Oregon Climate Service. 1999. Data Archives. March. 1999. Chris Hannan. http://www.ocs.orst.edu/allzone/allzone4.html.

Oregon Department of Fish and Wildlife (ODFW). 1997. Oregon Department of Fish and Wildlife Sensitive Species. Report number unknown [dated December, 1997]. 12 pp.

Ramsey, F. L., and D. W. Schafer. 1997. The Statistical Sleuth : A Course in Methods of Data Analysis. Duxbury Press, Belmont, CA. 742 pp.

Spies, T.A. and S.P. Cline. 1988. Coarse woody debris in forests and plantations of coastal Oregon. Pp. 5-24. In, C. Maser, R.F. Tarrant, J.M. Trappe, and J.F. Franklin (Tech Edit.) From the Forest to the Sea: A Story of Fallen Trees. USDI Forest Service, Pacific Northwest Research Station General Technical Report PNW-GTR-229. 153 pp.

SAS Institute Inc. 1993. SAS Technical Report P-243, SAS/STAT Software: The GENMOD Procedure, Release 6.09, Cary, NC. 88 pp.

Steel, R. G. D., and J. H. Torrie. 1980. Principles and Procedures of Statistics : A Biometrical Approach. McGraw-Hill, Inc., New York. 633 pp.