AN ABSTRACT OF THE THESIS OF

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Abstract approved: ______________________________

William C. McComb

I examined the abundance and habitat associations of terrestrial amphibian species and the species richness of terrestrial amphibian communities in riparian buffer strips, clearcuts, and unmanaged riparian forests. The study was conducted in the western hemlock (*Tsuga heterophylla*) vegetation zone of the northern and central Oregon Coast Range. Data were collected on amphibians, vegetation characteristics, and topography at 29 study sites. The abundance of torrent salamanders (*Rhyacotriton* spp.), ensatinas (*Ensatina eschscholtzii*), western red-backed salamanders (*Plethodon vehiculum*), and Dunn's salamander (*Plethodon dunni*) was greater in unmanaged forests than in recently harvested clearcuts, but the abundance of each species was similar between unmanaged forests and buffer strips. Amphibian species richness was positively correlated with buffer strip width, however even wide buffers (> 40 m) had fewer species than unmanaged forests. The abundance of each amphibian species was only weakly associated ($R^2 \leq 0.42$) with habitat characteristics that I measured or estimated. I hypothesize that buffer strips 30-40m should adequately protect most amphibian species closely associated with stream-side habitats from effects of timber harvest. Amphibian species that are associated with upslope habitats (e.g., ensatinas) may not benefit from buffer strips.

Terrestrial Amphibian Abundance and Species Richness in Headwater Riparian Buffer Strips, Oregon Coast Range

by

David G. Vesely

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APPROVED:

Major Professor, representing Forest Science

Chair of Department of Forest Science

Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

David G. Vesely, Author

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Lastly, I would like to offer my greatest appreciation for my wife, Joan, who introduced me to the beauty of a peregrine's flight over 10 years ago and has enriched my life ever since.

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INTRODUCTION

For more than two decades, riparian buffer strips have been an important component of stream protection strategies on private and public forests in the Pacific Northwest. Buffer strips, or riparian management areas (RMA's) are designated zones on managed forests where the primary objective is to reduce the impact of forestry operations on the riparian environment. The silvicultural practices and allowable harvests permitted in buffer strips differ among state and federal jurisdictions, and rules are usually tailored to the size of the stream, and the occurrence of fish (Belt and O'Laughlin 1994).

Much of the early research on riparian protection in managed forests focused on maintaining water quality and spawning habitat of salmonids (Hall and Lantz 1969, Meehan et al. 1969, Brown and Krygier 1970, Brazier and Brown 1973). Management recommendations from studies of this era generally attempted to maximize allowable harvest in riparian areas by retaining only trees considered necessary to protect habitats of sport fish species (Brown and Krygier 1970, Streeby 1971, Brazier and Brown 1973). More recently, ecologists have recognized that streams and riparian forests perform a suite of ecosystem processes (Vannote et al. 1980, Gregory et al. 1991), provide a complex of landforms and special habitats (Power et al. 1988, Agee 1988), support wildlife populations that differ from upslope forests (Doyle 1990, Gomez 1992, McComb et al. 1993), and contribute to regional biodiversity (Naiman et al. 1993). Forest managers in the Pacific Northwest have begun to incorporate these broader ecosystem and wildlife issues into riparian protection strategies (Oregon Department of Forestry 1994, BLM / USFS 1994).

Twelve of the 16 amphibian species that inhabit Oregon's forests require riparian habitats (McGarigal and McComb 1993). Amphibians are generally restricted to aquatic or cool, moist terrestrial habitats by physiological (e.g., high body surface to volume ratio and a thin, highly-vascularized skin) and embyological (anamniotic embryo) characteristics. Several species pass through a larval stage in streams, disperse into terrestrial habitats as adults, and return to streams to breed. Some current forest management practices may alter important structural components of amphibian habitats or lead to a less favorable microclimate on the forest floor. Stand conditions that result from clear-cut harvesting can lead to increased annual maximum soil and air temperatures (Hungerford 1979, Fowler et al. 1988), and in riparian areas can lead to higher average stream temperatures (Levno and Rothacher 1967, Brown and Krygier 1970) until a forest canopy is re-established. Most studies that have compared amphibian abundance among seral stages have found relatively depauperate terrestrial amphibian populations in early seral stages (Bury 1983, Pough et al. 1987, Petranka et al. 1993) or less abundant aquatic amphibians in streams that traverse clearcuts (Hawkins et al. 1983, Corn and Bury 1989, Kelsey 1995). Harvesting operations and road constuction may promote soil erosion on some steep sites and lead to increased suspended sediments in streams (Brown and Krygier 1971, Beschta 1978) and greater amounts of fine sediment in stream beds (Meehan et al. 1969, Moring and Lantz 1974). Pacific giant salamanders (*Dicamptodon tenebrosus*) and tailed frogs (*Ascaphus truei*) deposit their eggs among the interstitial spaces between cobbles and coarse substrates in streambeds. Hawkins et al. (1983) found a negative correlation between numbers of larval Pacific giant salamanders and percent of fine sediments in stream substrate. Logs, decayed stumps, and bark piles are the primary microhabitat of several Pacific Northwest amphibians (Aubry et al. 1988). Coarse woody debris may be removed from management units prior to tree planting by mechanical means or prescribed burning (Garrison and Smith 1974). Management practices that are performed in riparian areas are likely to exert the strongest affect on amphibian habitats because of the relatively large numbers of species that can occur near streams.

Riparian buffer strips are, by definition, linear landscape features. In Oregon, buffer strips on headwater streams (average annual flow 2 to 10 cubic feet / second (0.06-0.30 cms)) in state and private forests are generally required to be 70 feet wide (21.3 m)(one side of stream) if there are fish present in the stream reach, and 50 feet wide

(15.2 m) if fish do not occur (Oregon Department of Forestry 1994). Chen et al. (1995) found that microclimatic edge effects extend 30 to >240 m from clearcuts into interior forest, depending on the site and the specific microclimate parameter examined. It is likely that the microclimate in headwater buffer strips is different than in large blocks of unmanaged forest and may influence the capability of amphibians to persist in managed riparian areas.

Buffer strips or riparian reserves have been recommended as a management technique that may benefit amphibians and other riparian-dependent species (Bury and Corn 1988, Corn and Bury 1989, Sedell and Reeves 1993). Kelsey (1995) found greater post-harvest abundance of larval Pacific giant salamanders and tailed frogs in streams with buffer strips than streams without buffers. No similar study has been performed on habitats of terrestrial amphibians.

Prior to beginning the study, I wished to test two hypotheses. First, I hypothesized that species richness of terrestrial amphibian assemblages and abundance of most species would be greater in buffer strips than in clear-cut harvested riparian areas. Second, amphibian species richness and abundance in buffer strips would tend to become increasingly similar to unmanaged riparian areas as buffer width increases because of the greater distance between the buffer edge and stream-side habitats. My specific objectives were:

1) determine if there are differences in amphibian abundance and species richness in managed stands among buffer strips of different widths

2) determine if there are differences in amphibian abundance and species richness between clearcut and buffered riparian areas in managed stands

3) compare vegetation structure among unmanaged riparian forests, buffer strips, and clearcut riparian areas

4) identify the combination of habitat characteristics that are associated with amphibian species richness and the abundance of each species.

STUDY AREA

My study area lies entirely within the Oregon Coast Range physiographic province between 45°20' and 44°12' latitude. Study sites were 60 - 480 m above sea level in elevation. Annual temperatures within the study area averages 8°- 9°C (Franklin and Dyrness 1973) and normal annual precipitation ranges from 1250 to 2500 mm (Taylor 1993), occurring mostly in winter. The study area is within the western hemlock (*Tsuga heterophylla*) vegetation zone (Franklin and Dyrness 1973). Study sites were generally dominated by Douglas-fir (*Pseudotsuga menziesii*), western hemlock, and western red-cedar (*Thuja plicata*), except those portions of study sites that were recently harvested and dominated by shrub communities. Other common overstory trees included red alder (*Alnus rubra*), bigleaf maple (*Acer macrophyllum*), and occasionally Sitka spruce (*Picea sitchensis*) at sites near the coast. Dominant conifers at unmanaged stands averaged between 110 and 150 years old. Common shrubs included salmonberry (*Rubus spectabilis*) and other species of *Rubus*, vine maple (*Acer circinatum*), salal (*Gaultheria shallon*), and red huckleberry (*Vaccinium parvifolium*). Sword fern (*Polystichum munitum*) also was a common understory component at many sites.

The forest landscape pattern in the study area is dominated by clearcuts, Douglas-fir plantations, and young (< 40 yrs), even-aged forests managed by private, state, and federal landowners. Mixed-age stands are relatively common in some areas of the Oregon Coast Range and late-successional stands (avg. conifer diameter > 21 inches (53 cm)) comprise approximately one-fourth of the federal forests in the province (Forest Ecosystem Management Assessment Team, 1993).

METHODS

Site Selection and Sampling Design

I selected 30 riparian study sites in the central and northern regions of the Oregon Coast Range (one site was later dropped because it had been modified by burning prior to sampling). Most of these sites were found by examining aerial photos and stand maps with foresters and biologists from the U.S. Forest Service (USFS), Bureau of Land Management (BLM), and private timber companies, then verifying stand condition by a field survey. All sampling units were within 40 m of a permanent, 1st-, 2nd-, or 3rd-order streams so that sampling effort was concentrated in those portions of stands typically reserved in riparian buffer strips under current management practices on state and federal lands. All study sites were dominated by Douglas-fir (or appeared to have been dominated by Douglas-fir prior to harvesting). Study sites representing unmanaged and managed stand conditions were replicated among 6 geographic blocks. Study sites within each block were close enough in proximity to be contained in a 10-km circle drawn on a map. The purpose of blocking was to control for regional variation among amphibian populations and plant communities. Each block contained 5 stands: 2 unmanaged stands > 100 years in age and with no evidence of silvicultural treatment (other than boundary markings), and 3 managed stands recently clear-cut (< 5 years prior to survey) representing 3 buffer width classes: narrow = no buffer to buffers 20 meters wide (one side of stream), intermediate = 21 to 40 meters, and wide = > 40 meters. For the purposes of this study, I defined buffer width as the average of 6 buffer strip width estimates. Width was measured from the stream to the edge of reserved vegetation > 4 m in height. Riparian buffer sites were selected based on buffer-width class, lack of evidence of tree harvest or stream-crossings by logging equipment, and were > 200 m from roads and stand boundaries. Two blocks are unbalanced because it was not possible to find one of the buffer-width classes in a radius of 10-km of the other study sites so a different width class was substituted.

Seventeen managed study sites (buffer width classes: narrow = 7, intermediate = 4, wide = 6) and 12 unmanaged sites were selected. Data were collected on three 20- X 40-m quadrats placed at random intervals along the stream at each study site. The lower side of each quadrat was within 1 m of the active channel and the long axis of the quadrat was parallel to the fall line of the hillslope. Quadrats were divided into eight 10- X 10-m subplots to equalize sampling effort over the whole plot, and to further classify plots according to forest condition. Each subplot was assigned to 1 of 3 forest condition classes: buffer, harvest, or unmanaged. At managed study sites, subplots that were closer to the stream than the average buffer width at a quadrant were classified as in buffer condition and subplots that were further away from the stream than the average buffer width were classified as in harvest condition (Figure 1). Study sites with buffer strips < 5 m wide were classified as completely in harvest condition and sites with buffer strips > 35 m wide were classified as completely in buffer condition. The sampling unit used to compare forest conditions was a plot derived by aggregating subplots among the 3 quadrats by condition at a study site. The land area in each of the conditions varied across sites according to the presence or width of riparian buffer strip. I have assumed this will not bias the results of this comparison for 3 reasons. First, the amphibian response (density index) and habitat variable means have been standardized according to area sampled. Secondly, the number of experimental units in each condition is closely balanced: harvest = 13, buffer = 12, unmanaged = 12. Finally, the total land area that I sampled in each condition is relatively balanced: harvest = 20,600 m^2, buffer = 20,200 m^2, and unmanaged = 28,800 m^2.

Data Collection

Amphibians I surveyed amphibians during 3 seasons: April - May and November - December in 1994, and March - May in 1995 using time-constrained searches (TCS) on each 20- X 40-m quadrat. Study site blocks were randomly assigned to the 3 survey seasons (2 blocks per survey season) and individual study sites were surveyed in order by random assignment within the block. Each quadrat was searched by at least two

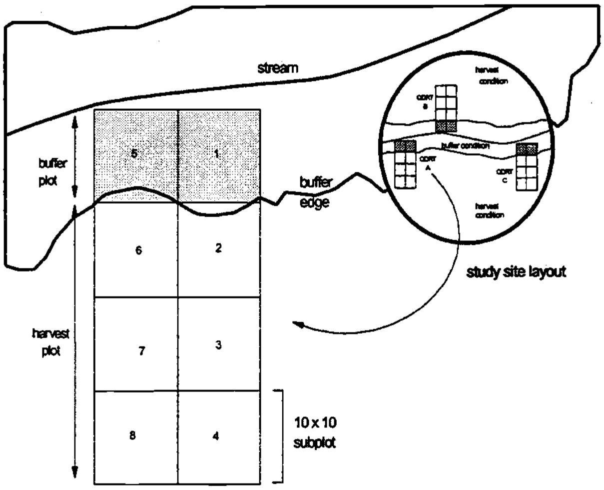


Figure 1. Study site design: schematic diagram of a managed study site with a riparian buffer approximately 10 m wide. Shaded subplots aggregated among the 3 quadrats represent 1 buffer plot. Unshaded subplots aggregated among the 3 quadrats represent 1 harvest plot.

surveyors to minimize the effect of individual surveyor biases between quadrats. Surveyors searched for amphibians for 15 minutes at each subplot on the quadrat, for a total effort of 4 search hours / quadrat. Each surveyor used a stopwatch to time the search and was instructed to stop timing whenever the search was interrupted to process captured amphibians. TCS was conducted on all 3 quadrats at a study site during the same day, except one site where surveys were completed on 2 consecutive days. Surveyors that were relatively inexperienced in amphibian identification were paired with personnel having greater experience in identifying amphibian species. All surveyors followed a written protocol that described search objectives and strategy (Appendix I). Surveyors used steel pry bars (approximately 30 cm long) to excavate logs and dig through rocky soils. Captured amphibians were placed in transparent, plastic bags while data were recorded. Data recorded for each amphibian observation included species, study site identification, distance-to-stream, weight and length, and cover used. Amphibians were held in plastic bags containing damp moss until the TCS was completed, then released on the quadrat.

Habitat Variables Thirty-nine vegetation and topographic variables were measured at each TCS quadrat (Table 1). Aspect and slope were estimated at the center of the 20- X 40-m quadrat. Tallies of live trees, snags, and logs, and cover estimates of shrubs and hydrological features were recorded at four 10- X 10-m subplots in each quadrat. The selection of 10- X 10-m subplots to be sampled was based on a stratified-random procedure: subplots sharing common boundary along the center-line of the long axis of the quadrat were considered as a pair (subplots 1 and 5, 2 and 6, 3 and 7, 4 and 8; Figure 1) and a coin-toss determined which subplot of each pair was sampled. Ground cover characteristics and litter/humus (O_2 soil horizon) were estimated on a 2- X 2-m subplot nested in the right (looking upslope from the stream), upslope corner of the 10- X 10 m subplots sampled. Snag decay classes follow those of Cline et al. (1980) and log decay classes follow those of Maser et al. (1979).

Table 1. Descriptions of 39 habitat variables measured or estimated at 29 riparian study sites in the Oregon Coast Range, 1994-1995.

VARIABLE TYPE	VARIABLE	DESCRIPTION
Topographic	ASPECT	cosine transformed azimuth based on Beers et al. (1986)
	SLOPE	incline (%) of hill-slope at center of quadrat
	ELEV	mean elevation above sea level (m) at study site
Overstory	CONIFER	conifer stem density (stems > 4 m in height / 1000 m^2)
	HARDW	hardwood stem density (stems > 4 m in height / 1000 m^2)
	DBH < 10	tree stem density (stems / 1000 m^2) <10 cm dbh, height ≥ 4 m
	DBH 10-49	tree stem density (stems / 1000 m^2) 10-49 cm dbh, height ≥ 4 m
	DBH 50-99	tree stem density (stems / 1000 m^2) 50-99 cm dbh, height ≥ 4 m
	DBH ≥100	tree stem density (stems / 1000 m^2) ≥100 cm dbh, height ≥ 4 m
	CANOPY	% cover > 4.0 m in height, spherical densiometer measurement
Woody debris	SNAG 10-49	snag density (stems / 1000 m^2) 10-49 cm dbh, height ≥ 1 m
	SNAG 50-99	snag density (stems / 1000 m^2) 50-99 cm dbh, height ≥ 1 m
	SNAG ≥ 100	snag density (stems / 1000 m^2) ≥100 cm dbh, height ≥ 1 m
	SNAG D-1	snag density (stems / 1000 m^2) decay class 1, height ≥ 1 m
	SNAG D-2-3	snag density (stems / 1000 m^2) decay class 2-3, height ≥ 1 m
	SNAG D-4-5	snag density (stems / 100 m^2) decay class 4-5, height ≥ 1 m
	LOG 10-29	log length (m / 1000 m^2) 10-29 cm mean dia.
	LOG 30-59	log length (m / 1000 m^2) 30-59 cm mean dia.
	LOG 60-99	log length (m / 1000 m^2) 60-99 cm mean dia.
	LOG ≥ 100	log length (m / 1000 m^2) ≥100 cm mean dia.
	LOG D-1	log length (m / 1000 m^2) decay class 1
	LOG D-2-3	log length (m / 1000 m^2) decay class 2-3
	LOG D-4-5	log length (m / 1000 m^2) decay class 4-5

Table 1. continued

Table 1. Continued

VARIABLE TYPE	VARIABLE	DESCRIPTION
Aquatic cover	PERMSEEP	% cover, permanent minor stream or seep
	INTRSEEP	% cover, intermittant minor stream or seep
Shrub layer	SCREEN	% cover > 1.4 m in height, spherical densiometer measurement
	TSHRB	% cover, shrubs 1.4 to 4.0 m in height
	LSHRB	% cover, shrubs < 1.4 m in height
	EVSHRB	% cover, evergreen shrubs
	DESHRB	% cover, deciduous shrubs
Ground cover	GRASS	% cover, gramineous species
	HERB	% cover, herbaceous species
	FERN	% cover, pteridophitic species
	MOSSG	% cover, moss on ground
	MOSSL	% cover, moss on logs or bark
	BARK	% cover, bark fragments not attached to logs
	FWOOD	% cover, fine woody debris < 10-cm diameter
	BARE	% cover, no organic matter on ground
	LITDEP	depth of O_2 horizon (mm)

Statistical Analysis

Distance-to Stream I summarized the density indices (detections / 1000 m^2) of 8 species and the total amphibian density index among 4 distance-to-stream classes. The data represent detections at unmanaged study sites only so that the comparison would not be confounded by buffer strip effects.

Buffer Width Classes I estimated the total density index of amphibians (detections / 1000 m^2) as the sum detections of combined amphibian species from 3 quadrats at each managed study site and dividing by total area searched (2400 m^2 / study site). The density index of each amphibian species with detections ≥ 20 were calculated similarly. I compared density indices among streams of narrow, intermediate, and wide buffer width classes by averaging amphibian densities from study sites within each class and using a two-way analysis of variance (ANOVA) to test for the effects of class and block. If all observations of a species occurred at a single level of buffer width class, the within-group error term could not be calculated for the ANOVA. In this case, I used a Student's t-test to test the hypothesis that the mean abundance of the class with observations was equal to zero, in effect, comparing this class to the classes with means of zero. When residuals generated by the ANOVA suggested non-linearity or non-constant variance, I transformed the response variable by ($\log_{10} + 1$). A nonparametric Kruskal-Wallis k-sample test (Steel and Torrie 1980:544-45) was used to compare mean densities among buffer width classes when the transformation failed to create homogeneous variances and linear relationships.

Forest Condition Amphibian response and habitat variable means were derived by pooling data from subplots by forest condition at each study site. I estimated the density index of amphibians by dividing the number of detections within each condition at a study site by the area (m^2) of the site in each condition. Habitat variables were compared between unmanaged and harvest, and between unmanaged and buffer forest conditions using one-way ANOVA (the block factor was dropped because of unbalanced forest conditions within blocks) or a Wilcoxon-Mann-Whitney test (Steel and Torrie 1980:542-43). Amphibian density indices were compared between unmanaged and harvest, unmanaged and buffer, and between harvest and buffer forest conditions using a Wilcoxon-Mann-Whitney test for those species having ≥ 20 detections. For species with < 20 detections, buffer and harvest areas at managed study sites were classsified by occurrence of the species and occurrence was tested for homogeneity by forest condition by Fisher's "exact" test (Steel and Torrie 1980:504-06).

Amphibian / Habitat Associations Associations between amphibian densities and habitat characteristics were examined using stepwise multiple regression. Data for analysis of amphibian habitat associations was derived from the 37 harvested, buffer, and unmanaged plots. To reduce the dimensionality of the habitat data set, Pearson product-moment correlations between the 39 variables were examined prior to regression analysis and highly correlated ($\underline{r} > 0.75$, $\underline{P} < 0.01$) pairs of habitat variables were identified. The variable thought to be most useful to land managers was retained, and the less useful variable excluded, in an effort to create an easily interpetetable model (McGarigal and McComb 1995). Model-building began with a stepwise variable selection procedure and then fitting a full model based on least sum-of-squares regression (SAS Institute 1990: 1354-56, 1397-1402). Models were assessed for linearity and constant variance by a residual analysis and a transformation was applied to the response variable (amphibian density index) when it improved the goodness-of-fit. When the stepwise procedure resulted in more than one explanatory variable being significant, reduced models were compared to the full model by an extra-sum-of-squares $\underline{F}$-test (Ramsey and Schafer 1994: 197-201) and the reduced model judged as adequate when $\underline{P} > 0.05$. I used log-linear regression for Poisson counts (Poisson regression) in cases where response transformation failed to normalize the data (SAS Institute 1993). The response variable for the Poisson regression model was the number of detections of an amphibian species on a plot. Stepwise variable selection was performed and a full Poisson model was fitted using maximum likelihood estimation (SAS Institute 1993:28-30). The full model was assessed with a deviance goodness-of-fit test (Ramsey and Shafer 1994:650-652) and level of significance set at $\underline{P} > 0.10$. The significance of individual explanatory parameters was examined with drop-in-deviance tests (Ramsey and Shafer 1994: 652-653).

RESULTS

Habitat Analysis

All strata of forest vertical structure differed between harvested plots and plots in unmanaged areas (Table 2). I found most components of the overstory layer in lower densities on harvested plots than on plots in unmanaged stands: conifer and hardwood stems, tree stems > 10 cm dbh, and canopy cover were lower on harvested plots (Table 2). Only tree stems < 10 cm dbh were not detectably different between harvested and unmanaged plots. Cover by shrubs < 1.4 m tall was twice as great on harvested plots as in unmanaged stands. Cover by shrubs > 1.4 m tall was less dense on harvested plots than in unmanaged stands. Screening was more than four times greater on plots in unmanaged stands than on harvested plots. Harvested plots had lower densities of well-decayed snags and logs (classes 4 and 5) and logs >100 cm, and greater densities of decay class 1 logs compared to plots in unmanaged stands (Table 2). Estimates of fine woody debris were twice as great on harvested plots compared to plots in unmanaged stands. Among the ground cover variables, fern and moss cover estimates were lower on harvested plots, while grass and herbaceous cover were greater on harvested plots compared to plots in unmanaged stands (Table 2). Litter depth also was lower on harvested plots than on plots in unmanaged stands.

Vegetation structure was similar between buffer plots and unmanaged stands; only 9 of the habitat variables differed. Plots in buffer strips had lower densities of large tree stems (>50 cm dbh) and canopy cover (Table 2). Densities of decay class 4 and 5 snags were lower on plots in buffer strips compared to unmanaged stands, while estimates of small logs (10-29 cm) and decay class 1 logs were greater on plots in buffer strips (Table 2). Fine woody debris was greater on plots in buffer strips than unmanaged stands. Screening was lower and low shrub cover was greater on plots in buffer strips compared to unmanaged stands.

Table 2. Means and standard errors of 39 habitat variables compared among unmanaged, harvested, and buffer forest condition plots at 29 riparian study sites in the Oregon Coast Range, 1994-95.

	UNMANAGED n = 12	HARVESTED n = 13		BUFFER n = 12	
VARIABLE[1]	$\bar{x}$ (SE)	$\bar{x}$ (SE)	P[2]	$\bar{x}$ (SE)	P[3]
ASPECT	216.2 (12.2)	164.2 (15.7)	0.34	204.1 (17.8)	0.30
ELEV	246.7 (26.2)	231.7 (45.0)	0.40[4]	195.5 (42.7)	0.15[4]
SLOPE	66.3 (5.2)	63.6 (5.8)	0.98[6]	60.0 (5.9)	0.51[6]
CONIFER	13.8 (2.8)	6.4 (2.3)	0.01[6]	9.4 (2.5)	0.16[6]
HARDW	26.8 (4.6)	24.0 (15.7)	0.30[6]	21.0 (4.6)	0.03[6]
DBH <10	22.8 (4.0)	28.3 (15.3)	0.24[6]	18.4 (3.9)	0.27[6]
DBH 10-49	9.7 (1.9)	1.9 (1.4)	<0.01[6]	8.7 (2.8)	0.45[6]
DBH 50-99	4.9 (0.6)	0.1 (0.1)	<0.01[6]	2.1 (0.5)	<0.01[6]
DBH ≥100	3.1 (0.8)	0.1 (0.1)	<0.01[6]	1.3 (0.4)	0.05[6]
CANOPY	87.7 (1.5)	4.6 (1.9)	<0.01[5]	43.1 (6.7)	<0.01[5]
SNAG 10-49	4.3 (1.1)	3.0 (1.1)	0.25[6]	3.6 (1.5)	0.31[6]
SNAG 50-99	2.2 (0.5)	4.7 (1.2)	0.25[6]	2.1 (1.0)	0.10[6]
SNAG ≥100	1.1 (0.4)	2.4 (1.1)	0.95[6]	0.8 (0.3)	0.67[6]
SNAG D-1	1.3 (0.5)	6.9 (2.1)	0.13[6]	2.4 (1.3)	0.74[6]
SNAG D-2-3	2.4 (0.7)	3.0 (0.8)	0.64[6]	1.2 (0.5)	0.31[6]
SNAG D-4-5	5.0 (0.6)	2.2 (1.0)	0.01[6]	3.8 (1.6)	0.05[6]
LOG 10-29	70.4 (11.1)	99.4 (17.5)	0.22[6]	126.4 (22.3)	0.04[6]
LOG 30-59	65.6 (8.3)	60.5 (8.2)	0.65[4]	87.0 (10.5)	0.16[4]
LOG 60-99	44.5 (11.3)	26.3 (7.0)	0.13[4]	46.3 (13.3)	0.88[4]

Table 2. continued

Table 2. continued

	UNMANAGED	HARVESTED		BUFFER	
VARIABLE[1]	$\bar{x}$ (SE)	$\bar{x}$ (SE)	P[2]	$\bar{x}$ (SE)	P[3]
LOG ≥100	16.8 (4.4)	8.3 (3.9)	0.04[6]	15.3 (5.9)	0.36[6]
LOG D-1	25.9 (8.3)	54.3 (9.6)	0.04[6]	79.5 (16.0)	< 0.01[6]
LOG D-2-3	81.3 (14.2)	91.9 (17.1)	0.89[6]	109.2 (12.0)	0.17[6]
LOG D-4-5	90.1 (16.8)	48.3 (11.0)	0.06[6]	85.8 (15.9)	0.98[6]
SCREEN	94.3 (0.6)	20.5 (6.2)	< 0.01[5]	73.8 (4.1)	0.04[5]
TSHRB	45.7 (5.6)	32.7 (6.6)	0.07[5]	40.5 (6.7)	0.56[5]
LSHRB	25.5 (3.4)	50.1 (4.9)	< 0.01[3]	38.4 (6.2)	0.04[3]
EVSHRB	9.0 (3.0)	9.8 (2.4)	0.59[6]	8.3 (3.5)	0.79[6]
DESHRB	55.2 (7.2)	58.1 (7.5)	0.78	56.8 (7.6)	0.88
GRASS	1.3 (0.4)	6.9 (1.5)	< 0.01[3]	3.1 (1.3)	0.21[3]
HERB	16.2 (2.7)	22.8 (3.4)	0.11[5]	16.7 (1.5)	0.75[5]
FERN	41.3 (3.2)	21.4 (3.7)	< 0.01[4]	30.9 (4.6)	0.06[4]
MOSSG	16.9 (2.7)	9.4 (2.1)	0.02[4]	13.2 (1.7)	0.52[4]
MOSSL	8.6 (0.8)	3.7 (0.8)	< 0.01[4]	9.4 (1.5)	0.85[4]
BARK	1.5 (0.4)	2.4 (0.8)	0.53[6]	3.1 (1.6)	0.44
FWOOD	5.9 (0.8)	10.5 (1.6)	0.02[6]	14.6 (2.4)	< 0.01[6]
BARE	25.8 (2.1)	25.1 (4.3)	0.58[5]	20.3 (3.2)	0.19[5]
PERMSEEP	0.0 (-)	0.2 (0.2)	0.38[6]	0.1 (0.05)	0.36[6]
INTRSEEP	0.0 (-)	0.3 (0.2)	0.05[6]	0.0 (-)	1.0[6]
LITDEP	47.0 (4.2)	30.9 (5.7)	< 0.01[4]	45.0 (3.7)	0.85[4]

[1] see Table 1 for definitions and units

[2] probability to reject H_0: $\bar{x}_{unmanaged} = \bar{x}_{harvest}$, type III sum of squares ANOVA unless otherwise noted

[3] probability to reject H_0: $\bar{x}_{unmanaged} = \bar{x}_{buffer}$, type III sum of squares ANOVA unless otherwise noted

[4] log + 1 transformation of response

[5] square-root + 0.5 transformation of response

[6] Wilcoxon 2-sample test

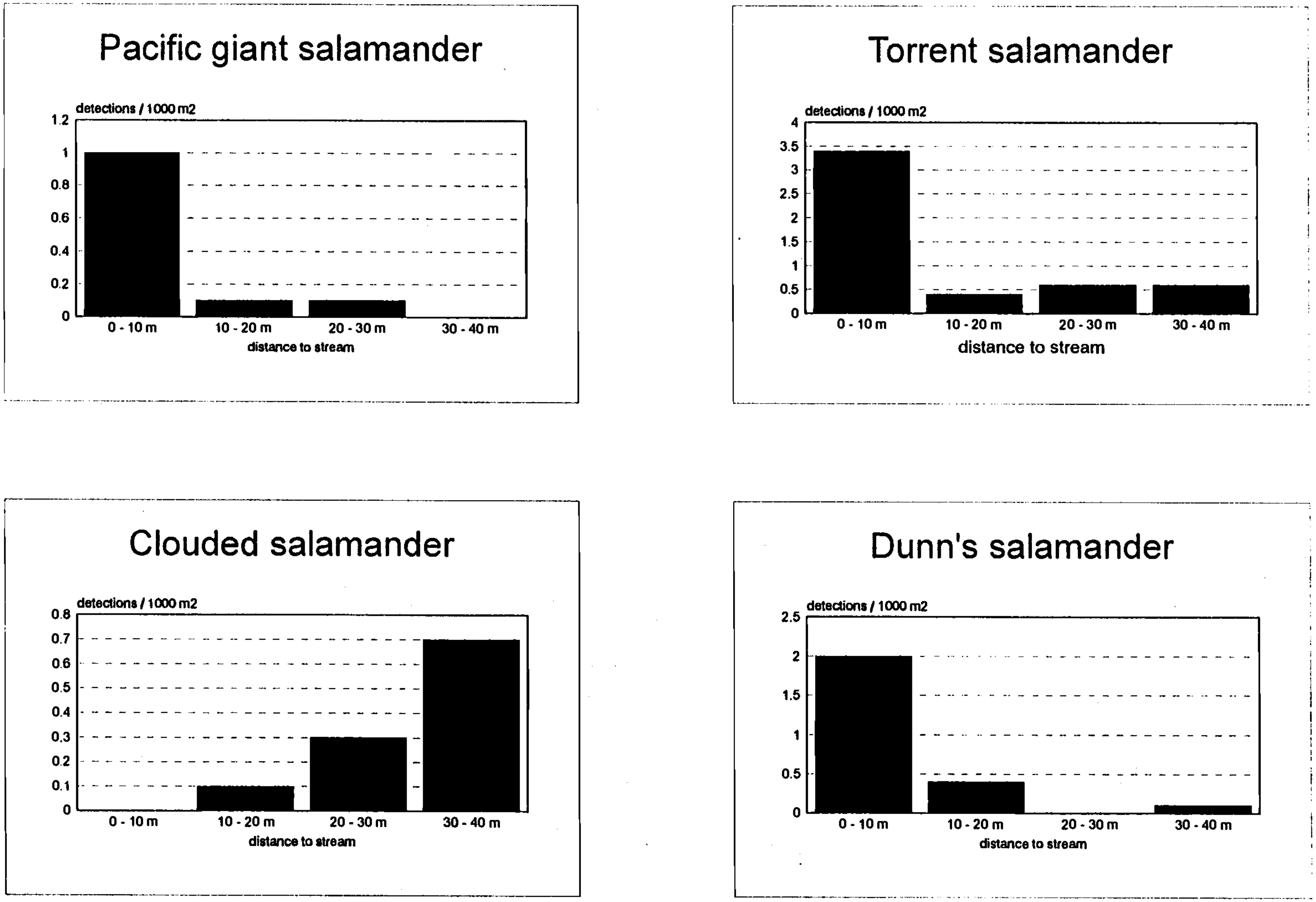
Amphibian Detections

I detected a total of 736 individual amphibians representing 10 species during the study. Time-constrained searches resulted in an average of 2.1 detections per surveyor hour among the combined study sites. Amphibian density averaged 11.0 amphibians / 1000 m^2 among the combined study sites. This is probably a conservative estimate of amphibian density because amphibians are able to exploit a variety of habitats beyond the reach of surveyors (e.g., deep underground burrows, interior spaces of large diameter logs) and because most subplots had more cover objects than could be searched within the time constraint. The mean number of amphibian detections per study site did not differ among survey seasons ($\underline{P} = 0.76$, $\underline{F}$-test).

A single species, the western red-backed salamander (*Plethodon vehiculum*) accounted for 71% of all observations. I pooled detections of two non-sympatric species of torrent salamanders (*Rhyacotriton kezer*i and *R. variagatus*) because of the difficulty of differentiating between the species in the field and because all species of this genus seem to select very similar microhabitats (Blaustein et al. 1995, Leonard et al. 1993). Four species (torrent salamander, ensatina (*Ensatina eschscholtzii*), Dunn's salamander (*Plethodon dunni*), and western red-backed salamander) were represented by ≥ 20 detections which was the minimum number of observations I considered necessary for ANOVA and multiple regression analysis of density index estimates. I examined the occurrence of 4 other uncommon amphibian species (Pacific giant salamander (*Dicamptodon tenebrosus*), clouded salamander (*Aneides ferreus*), rough-skinned newt (*Taricha granulosa*), and tailed frog (*Ascaphus truei*)) on buffer strip and harvested plots in a separate comparison (Appendix II).

Figure 2. Density (detections / 1000 m^2) of 8 amphibian species and total amphibian density summarized according to 4 distance-to-stream classes. Data are from time-constrained searches at 12 unmanaged stands in the Oregon Coast Range, 1994-95.

Figure 2.



Pacific giant salamander

Torrent salamander

Clouded salamander

Dunn's salamander

Figure 2 (continued).

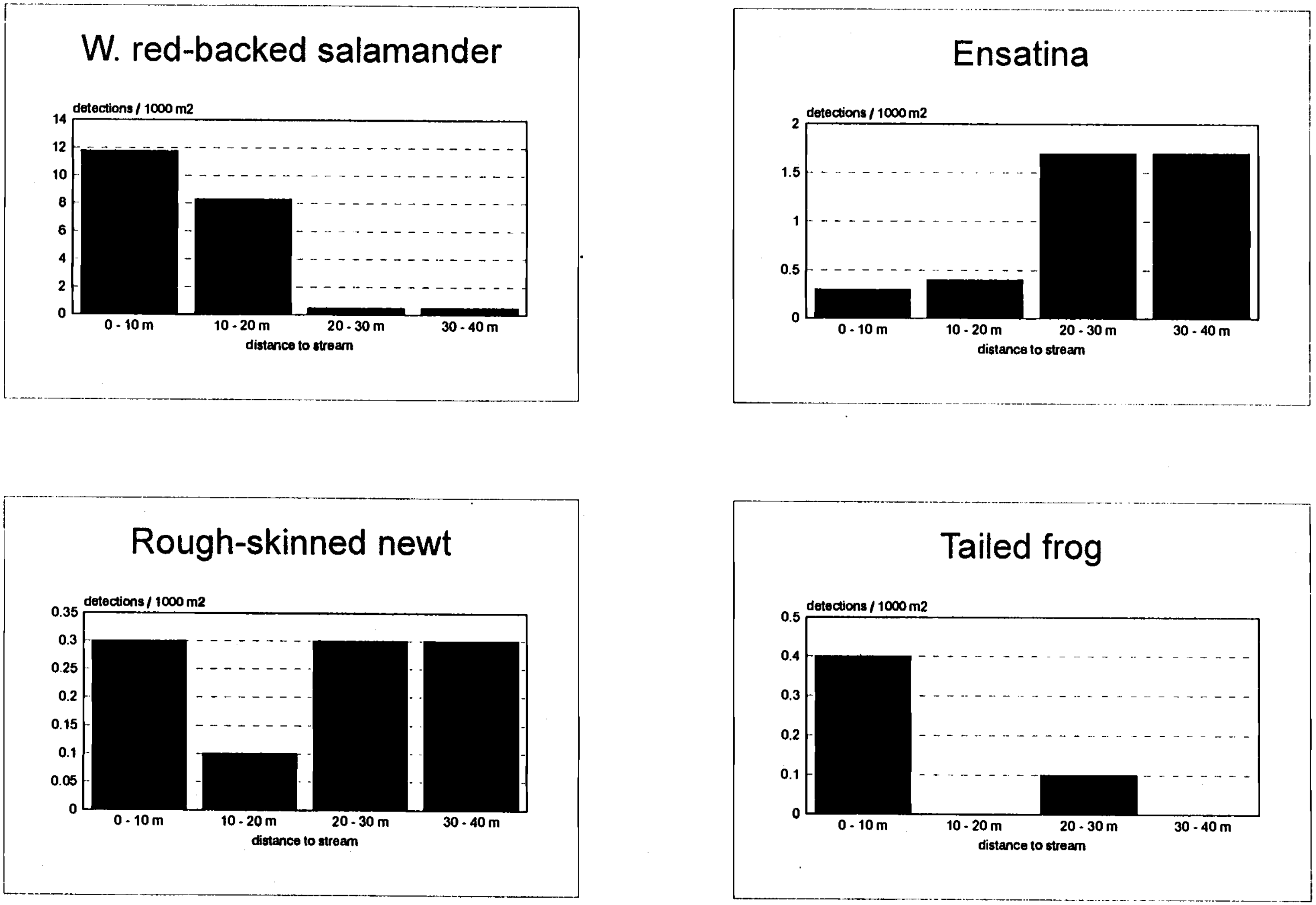
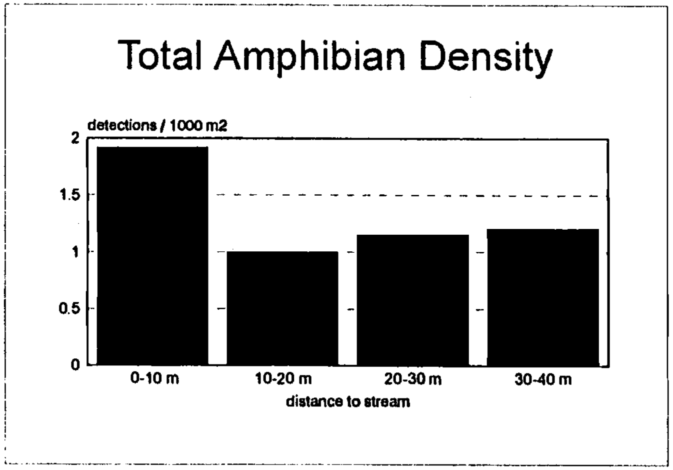


Figure 2 (continued).



Distance-to-Stream Density of Pacific giant salamanders in unmanaged stands was approximately 10-times greater within 10 m of the stream than between 10 - 40 m to the stream (Figure 2). Density of torrent salamanders was approximately 7-times greater within 10 m of the stream than between 10 - 40 m to the stream. Density of clouded salamanders increased with increasing distance-to-stream. Density of Dunn's salamanders was approximately 5-times greater within 10 m of the stream than between 10 - 40 m to the stream. Density of western red-backed salamanders was approximately 10-times greater within 20 m of the stream than between 20 - 40 m to the stream. Density of ensatinas was approximately 5-times greater between 20 - 40 m distance-to-stream than within 20 m of the stream. Density of rough-skinned newts was similar among most of the distance-to-stream classes, though lower between 10 - 20 m to the stream. Density of tailed frogs was greater within 10 m of the stream than between 10 - 40 m of the stream. Total amphibian relative density was approximately twice as great within 10 m of the stream as between 10 - 40 m to the stream.

Buffer Width Species richness was positively associated with buffer width class (Table 3), but even wide buffer strips (mean richness = 4.5) were lower in species richness than unmanaged stands (mean richness = 5.0, $P = 0.02$, F-test). The total relative density of amphibians was approximately 2.5 times greater in managed stands with wide buffers than with narrow buffers (Table 3). Density indices of ensatinas, Dunn's salamanders and western red-backed salamanders were greater in wide buffer strips than narrow buffers strips, but I could not detect a difference in relative densities of torrent salamanders between narrow and wide buffers (Table 3).

Forest Condition Total density of amphibians on harvested plots was less than half the density on plots in unmanaged stands. The density indices of each species in unmanaged stands ranged from approximately twice as great to 10 times as great than on harvested plots (Table 4). Amphibian total density of on buffer strip plots did not differ from unmanaged stands, nor was there a difference for any of the species compared between these 2 forest condition plots (Table 4). Total density of amphibians on buffer strip plots was approximately twice as great as on harvest plots (Table 4). The density index differed between buffer and harvested plots for Dunn's salamanders, western red-backed salamanders, and torrent salamanders.

Amphibian / Habitat Association Models

Habitat associations were modeled for 3 amphibian species with detections ≥ 20, as well as average species richness using multiple regression based on the density index as the amphibian response (Table 5). A Poisson log-linear model was developed for Dunn's salamander based on count / plot for this species (Table 6) . The coefficient of determination (adjusted R^2) for each of the models was relatively low (0.20 to 0.42). Overstory characteristics were the habitat variables most often correlated with amphibian detections. The abundance of Dunn's salamander was negatively correlated with the density of conifer stems and the ensatina was positively correlated with stem density of 50- to 99-cm trees. The density indices of western red-backed salamanders, torrent salamanders, and species richness was positively correlated with canopy cover. Abundance of Dunn's salamanders was associated with screening. The density index of torrent salamanders and Dunn's salamanders was positively correlated with evergreen shrub cover. The density indices of 2 species were correlated with one of the ground cover characteristics: density of ensatinas was positively correlated with fine woody debris, and torrent salamander density was positively associated with bare ground.

Table 3. Mean density indices (detections / 1000 m^2) of amphibian species (detections > 20) and species richness compared among narrow, intermediate, and wide riparian buffer strips in the Oregon Coast Range, 1994-95.

Species (Detections)	Narrow (< 20 m) n = 7 $\bar{x}$ (SE)	Intermediate (20 - 40 m) n = 4 $\bar{x}$ (SE)	Wide (> 40 m) n = 6 $\bar{x}$ (SE)	P
Ensatina (55)	0.48 (0.23) AB^1	0.31 (0.10) A^1	1.04 (0.41) B^1	0.05
Dunn's salamander (36)	0.06 (0.06)	0.63 (0.36)	0.69 (0.69)	0.04^2
W. red-backed salamander (520)	3.51 (1.12) A^1	6.56 (1.48) AB^1	9.00 (2.09) B^1	0.07
Torrent salamander (72)	0.36 (0.36)	1.45 (1.20)	1.18 (0.79)	0.40^2
Total density (736)	4.70 (1.50) A^1	9.58 (2.61) AB^1	12.57 (2.26) B^1	0.05
Species richness (736)	2.3 (0.5) A^1	3.8 (0.5) B^1	4.5 (0.6) B^1	<0.01

1. means sharing a commom letter are not significantly different ($P \le 0.05$, least significant difference test).
2. Kruskal-Wallis k-sample test

Table 4. Mean density indices (detections / 1000 m^2) of amphibian species (detections > 20) compared among 12 unmanaged, 13 harvested, and 12 buffer plots in the Oregon Coast Range, 1994-95.

Species (Detections)	Unmanaged n = 12 $\bar{x}$ (SE)	P[1] (U =H)	Harvested n = 13 $\bar{x}$ (SE)	P[2] (H =B)	Buffer n = 12 $\bar{x}$ (SE)	P[3] (U =B)
Ensatina (55)	1.01 (0.23)	0.04	0.40 (0.17)	0.36	0.64 (0.24)	0.28
Dunn's salamander (36)	0.66 (0.24)	< 0.01	0.05 (0.05)	< 0.01	0.85 (0.27)	0.77
W. red-backed salamander (520)	9.34 (1.28)	< 0.01	4.89 (1.38)	0.04	7.83 (0.117)	0.40
Torrent salamander (72)	1.22 (0.51)	< 0.01	0.19 (0.19)	0.06	1.26 (0.64)	0.43
Total density (736)	13.19 (1.77)	< 0.01	5.57 (1.46)	< 0.01	11.87 (1.50)	0.56

[1] probability to reject $H_0 : \bar{x}_{unmanaged} = \bar{x}_{harvested}$; Wilcoxon 2-sample test

[2] probability to reject $H_0 : \bar{x}_{harvested} = \bar{x}_{buffer}$; Wilcoxon 2-sample test

[3] probability to reject $H_0 : \bar{x}_{unmanaged} = \bar{x}_{buffer}$; Wilcoxon 2-sample test

Table 5. Significant regression parameters for terrestrial amphibian densities and habitat characteristics of 37 riparian plots surveyed in the Oregon Coast Range, 1994-95.

Species	Parameter	Coefficient estimate	Coefficient P	adj. R^2
W. red-backed salamander	Canopy	0.003	< 0.01	0.20
Ensatina	Fine wood	0.004	< 0.01	0.26
	DBH 50-99	0.146	< 0.01	
Torrent salamander	Bare	0.005	< 0.01	0.42
	Litter	-0.003	0.04	
	Evshrub	0.006	< 0.01	
	Canopy	0.002	< 0.01	
Species richness	Canopy	0.025	< 0.01	0.30

Table 6. Significant regression parameters for Dunn's salamander (count / plot) and habitat characteristics of 37 riparian plots surveyed in the Oregon Coast Range, 1994-95.

Model	Parameter	Est. of max. likelihood	Deviance / parameter[1]	P	Deviance / model[2]
Poisson	Evshrub	0.094	18.727	< 0.01	38.449
	Screen	0.040	24.156	< 0.01	
	Conifer	-0.583	4.288	0.05	

[1] (deviance of model without the parameter) minus (deviance of full model).

[2] sum of squared deviance residuals, full-model.

DISCUSSION

Habitat Structure of Riparian Buffer Strips

The habitat structure of riparian buffer strips generally resembled that of unmanaged riparian forests. Only 9 of the 39 topographic and vegetation variables I measured or estimated differed between these two conditions. The overstory layer of riparian buffer strips had lower densities of large (≥ 50 cm dbh) tree stems and lower canopy density than unmanaged stands. Densities of well-decayed snags also were lower in riparian buffer strips. There are 2 likely explanations for the differences in tree and snag densities. First, trees near clearcut edges are more prone to windthrow (Ruth and Yoder 1953, Chen et al. 1992). Second, portions of harvested plots may have been misclassified as buffer strip plots because of the ragged character of buffer strip edges. This would result in underestimation of the actual tree density.

There were only 2 understory characteristics that differed between buffer strips and unmanaged forests. Buffer strips had lower screening and a greater amount of low shrub cover than unmanaged forests. Screening is an index of vegetation density > 1.4 m in height, in effect, the combined densities of the canopy and tall shrub layers in this study. The lower screening density in buffer strips suggests that a greater amount of light penetrates the upper vegetation strata and is available to plants on the forest floor.

Buffer strips had 3 times more new logs (decay class 1) than unmanaged riparian forest. The additional logs in the buffer strip may be from trees and snags that have fallen in the buffer since harvest or may be slash that fell into the buffer strip when the adjacent unit was harvested.

Perhaps the most important difference between buffer strips and unmanaged riparian forests is the proximity of the harvest unit boundary to the stream that forms a high contrast edge between a recent clearcut and reserved vegetation in the buffer strip. Riparian buffer strips are linear landscape features by definition and have high edge-to-interior ratios. Chen et al. (1990) found that a clearcut edge may affect the level of solar radiation and soil moisture for a distance of 60 m into adjacent forest and Chen et al.

(1993) found microclimatic gradients from a clearcut edge extending up to 400 m into interior forest. Given the edge effect found by these authors, the microclimate within buffer strips of the widths I examined may be warmer and dryer than within the interior of a unmanaged riparian forest.

Not surprisingly, I found the vegetation structure on recently harvested plots to be very different than that of unmanaged riparian forests. All components of the forest overstory were reduced after harvesting. I found approximately 50% less tall shrub cover, and twice as much low shrub cover on harvested plots compared to unmanaged forests. The shift in density among the shrub layers may be caused by mortality of tall shrubs during logging operations and a corresponding release of the low shrubs or, the tall shrub layer may have been trampled during logging and the same plants lay closer to the ground. I also found differences in types of logs and ground cover vegetation among clearcuts and unmanaged forests.

Amphibian Species Richness, Abundance, and Occurrence

The amphibian detection frequency in my study (2.1 detections / surveyor hour) was slightly higher than 2 previous studies that used TCS to survey amphibians in old-growth conifer stands in the western Cascades: Bury and Corn (1988) reported 1.8 amphibians / surveyor hour and Gilbert and Allwine (1991) reported 1.7 amphibians / surveyor hour. However my detection frequency is low compared to 5.1 amphibians / surveyor hour Welsh (1986) detected with TCS among mixed conifer-hardwood stands in northwest California and southwest Oregon. While these results provide an estimate of the effort required to successfully detect amphibians within a habitat type, it may be misleading to compare relative abundance among studies based on these estimates because of design- or protocol-based differences among studies.

I found the total amphibian density on plots in buffer strips to be approximately twice as great as in recently harvested riparian areas, and 3 of the 4 commonly detected species (Dunn's salamander, western red-backed salamander, and torrent salamander) had greater densities in buffer strips than harvested areas.

The occurrence of 3 less frequently detected species (Pacific giant salamander, clouded salamander, and rough-skinned newt) also was greater in buffer strips than in harvested areas (Appendix II). Although I was unable to find previous research conducted on terrestrial amphibian abundance in riparian buffer strips, earlier studies that have compared amphibian abundance between harvested and mature or old-growth stands generally have found depauperate amphibian assemblages in young, disturbed stands (Bury 1983, Pough et al. 1987, Gomez 1992, Petranka et al. 1993). In my study, total amphibian density in buffer strips did not differ from that of unmanaged stands, nor did any of the density indices of the 4 species compared independently differ between buffer strips and unmanaged stands. The similarity in amphibian abundance among buffer strips and unmanaged stands may reflect the similarity among habitat characteristics I measured in both forest conditions. Canopy cover was lower in buffer strips but still averaged > 40%, and the increased average low shrub cover I found in buffer strips may have provided added ground shade. Small (10-29 cm diameter) logs and decay class 1 logs were the only types of woody debris that differed between buffer strips than unmanaged stands.

The results of my comparison of amphibian response among narrow, intermediate, and wide buffer strips provide evidence for a trend of increasing amphibian relative density associated with increasing buffer width: amphibian density in buffer strips > 40 m was approximately 2.5 times as great as buffer strips < 20 m wide. Only one of the species (torrent salamanders) differed from the response pattern of the assemblage as a whole.

Amphibian species richness in buffer strips also demonstrated a positive trend with buffer strip width, but even wide buffers had a lower number of species than found in unmanaged stands. Since the most frequently detected species (ensatina, Dunn's salamander, western red-backed salamander, and torrent salamander) did not differ in relative density between buffer strips and unmanaged stands, the loss of species richness in buffer strips may be due to a management effect among the species I encountered less frequently (Pacific giant salamander, clouded salamander, rough-skinned newt, and tailed frog).

Species / Habitat Associations

Ensatina I found the relative abundance of the ensatina to be positively correlated with cover of fine woody debris and density of trees 50- to 99-cm dbh. Previous literature has noted an association with the occurrence or abundance of ensatinas and various classes of woody debris (Nussbaum et al. 1983, Aubry et al. 1988, Aubry and Hall 1991, Gilbert and Allwine 1991). Several studies that have examined habitat relationships of the ensatina have reported contradictory correlations between the abundance of this species and tree size- or age-classes: Welsh and Lind (1991) found ensatinas more abundant in old-growth than in mature or young forests; Aubry and Hall (1991) found ensatinas in more common in young stands; and others have not detected a stand age or tree size-class response (Corn and Bury 1991, Gilbert and Allwine 1991, Gomez 1992). The density of 50- to 99-cm trees among my study sites was highly correlated with forest condition (harvested, buffer strip, or unmanaged). I hypothesize that the stepwise procedure may have selected this habitat characteristic as a surrogate variable for forest condition. The ensatina is reported to favor, or be more abundant in upslope habitats as compared to riparian areas (Gomez 1992, McGarigal and McComb 1993) and are associated with dry forest stands (Bury and Corn 1988, Corn and Bury 1991, Gilbert and Allwine 1991). My data also suggest ensatinas are more abundant farther from the stream in unmanaged stands.

Western red-backed salamander The relative abundance of western red-backed salamanders was positively correlated with canopy density. This species represented 71% of the total detections in my study and is widespread in most Pacific Northwest coniferous forests (Nussbaum et al. 1983, Blaustein et al. 1995). Corn and Bury (1991) found that the abundance of western red-backed salamanders was positively associated with stand age, while other studies have found this species more abundant in young stands (Aubry and Hall 1991, Bury et al. 1991). Occurrence or abundance of western red-backed salamanders is reported to be associated with slope (Corn and Bury 1991, Suzuki 1992) and talus (Nussbaum et al. 1983, Herrington 1988, Corn and Bury 1991). McGarigal and McComb (1993) reported that the western red-backed salamander favors upslope areas, while Gomez (1992) was not able to detect a difference in abundance between upslope and riparian transects. In contrast, my data suggests a strong trend of decreasing density at greater distances from the stream in unmanaged stands.

Torrent salamander The density index of torrent salamanders was positively correlated with bare ground cover, evergreen shrub cover, and canopy density, and negatively correlated with litter depth. Corn and Bury (1991) and Welsh and Lind (1991) found the abundance of torrent salamanders to be greater in old-growth forests than in young or mature forest stands, and Thomas et al. (1993) considered the occurrence of the torrent salamander to be closely associated with old-growth forests. Torrent salamanders are obligate, aquatic breeders and most frequently occur in seeps and small, headwater streams (Nussbaum et al. 1983, Bury and Corn 1988). Sixty-five percent of torrent salamander detections in my study were in seeps or stream-side splash zones (Appendix III), although the stepwise procedure failed to correlate abundance of the species with estimated seep cover. Seeps were among the most uncommon cover types on my quadrats and there may be considerable sampling error in my estimates of seep cover, leading to the failure of the stepwise procedure to estimate the significance of this parameter. I detected most torrent salamanders within 10 m of the stream, although several individuals were captured on, or under leaf litter, > 20 m from any aquatic feature on the plot. The correlations that I found between torrent salamander abundance, litter depth and bare ground is not surprising: litter tends to be flushed from stream-side areas frequently exposed to high energy flooding, exposing bare soil (Bell and Sipp 1975), and riparian plants common in the Pacific Northwest generally produce material that decomposes faster than litter from upslope plants (Edmonds 1980).

Dunn's salamander Counts of Dunn's salamander were positively correlated with evergreen shrub cover and screening, and negatively correlated with conifer stem density. Previous studies that have examined the microhabitat relationships of Dunn's salamander (Corn and Bury 1991, Gilbert and Allwine 1991, Gomez 1992) have not reported an association between it's occurrence and stand age or tree size-class . The negative correlation I found between abundance of Dunn's salamander and conifer density is surprising given the dramatically lower abundance of this species I found in harvested plots compared to unmanaged stands. The explanation may be that conifer density in unmanaged stands corresponds to a transriparian gradient inverse to the distribution of Dunn's salamander. This species is usually associated with stream-side habitats (Nussbaum et al. 1983, Bury 1988, Gomez 1992, McGarigal and McComb 1993) and I found most detections of Dunn's salamander within 10 m of the stream. In contrast, Douglas-fir is poorly adapted to flooding and related riparian disturbances (Agee 1988), and even western red-cedar and western hemlock may be excluded from some stream-side areas because of competition from shrubs and hardwoods (Robert Pabst, pers. comm.).

Species richness species richness was positively correlated with canopy density. Canopy density was strongly associated with forest condition among my study sites, and given the results of the ANOVA for species richness and forest condition, the association of species richness with canopy should be expected.

Conclusions

Results from my study suggest that terrestrial amphibian abundance and species richness is dramatically lower on recently harvested riparian plots than in unmanaged riparian forests. I also found evidence that common terrestrial amphibians persist in buffer strips for at least 5 years after the adjacent stand was logged at levels of abundance similar to that in unmanaged forests. I hypothesize that the differences in amphibian abundance and species richness between harvested and reserved riparian areas is largely caused by canopy cover. Canopy density also was the most prominent explanatory variable among the species / habitat models, though none of the amphibians I studied actually inhabit or exploit the mid- to upper-level forest strata. Given the sensitivity that amphibians demonstrate along gradients of temperature and moisture, it is not surprising that amphibians are most abundant in areas of the forest floor insulated from direct solar radiation.

Species richness of riparian amphibian assemblages in buffer strips is lower than in unmanaged stands and I hypothesize the loss of richness is caused by harvesting effects on some species that were infrequently detected by my survey methods (Pacific giant salamander, clouded salamander, rough-skinned newt, tailed frog). Summary data of amphibian detections according to distance-to-stream suggests that abundance of the terrestrial amphibian assemblage is greatest within 10 m of the stream at unmanaged stands, though each species demonstrated a different distribution along the transriparian gradient. Ten of the 12 amphibian species occurring in forests of the Oregon Coast Range are reported to favor riparian areas (McGarigal and McComb 1993). Five species probably are restricted to closed-canopy, headwater riparian habitats, or require high-gradient streams to complete their breeding cycle (Pacific giant salamander, southern torrent salamander, Olympic torrent salamander, Dunn's salamander, tailed frog).

The ground cover and woody debris variables I measured or estimated were generally poor predictors of amphibian abundance among my study sites. Stepwise regression analysis resulted in models that described less than half the total variation in occurrence or abundance of the 4 species examined. This suggests I may have failed to identify important components of amphibian habitat in my study, or the measurement scale I used for a given habitat parameter did not correspond to the scale in which the organism perceives and responds to the habitat feature.

Management Implications

Guidelines for managing headwater riparian buffer strips differ among state and federal agencies that regulate forest practices in the Pacific Northwest. In Oregon, recently revised water protection rules do not require landowners to retain buffer strips along small streams (< 2 cubic feet / second (0.61 cms)) that do not support fish; medium streams without fish (2 - 10 cfs (0.61 - 3.0 cms)) are required to have a riparian management area (RMA) 50 feet (15.2 m) wide in which conifers and hardwoods are to be retained at a rate of 50 ft^2 (15.2 m^2) basal area per 1000 linear feet (304 m) of stream length (Oregon Department of Forestry 1994). In California, headwater streams that contain non-fish aquatic wildlife are required to have a protection zone 50 to 100 feet (15.2 to 30.4 m) wide, depending on the sideslope with 25-50% of the original overstory to be retained (California Department of Forestry 1990). In Washington, there is no general buffer strip requirement for small streams that do not bear anadromous fish, though some small streams may be required to have a buffer strip if there are likely to be measurable downstream effects (Art Tasker pers. comm.). Recently amended guidelines for management activities on federal lands within the range of the northern spotted owl (*Strix occidentalis caurina*) require no-entry riparian reserves ≥ 300 feet wide (91.2 m) on permanent flowing, non-fish streams and ≥ 100 feet wide (30.4 m) on intermittent streams (BLM and USFS Standards and Guidelines 1994).

The results of my analysis suggest that clear-cut harvesting in headwater riparian areas, a practice generally allowed on private and state lands in Oregon and Washington, may lead to a 50% decrease in total amphibian density when compared to mature, unmanaged riparian stands. My data also demonstrate that total amphibian density did not increase when only a narrow buffer strip (< 20 m wide) was retained. Species richness of riparian amphibian communities along streams with narrow buffer strips was approximately half that of amphibian communities along streams with wide (> 40 m) buffer strips. Wide buffer strips had total amphibian densities similar to mature, unmanaged stands, although species richness was slightly lower in wide buffers.

Forest management practices that affect the structural components of terrestrial amphibian habitats (particularly canopy cover) or the microenvironment within 10 m of headwater streams will probably have the strongest impact on the abundance and distribution of amphibians.

As an amphibian conservation measure, riparian buffer strips are probably most effective in protecting those species closely associated with aquatic and stream-side habitats, and which probably do not make long-distance terrestrial movements (e.g., torrent salamanders, Dunn's salamander). Based on my findings (no detectable difference between intermediate and wide buffers), buffer strips 30 to 40 m wide are probably adequate to insure the persistance of most riparian-associated amphibians for at least 5 years after harvest in the area I sampled. Species richness in buffer strips of these widths was still lower than unmanaged stands, but the additional richness was likely caused by the presence of upland amphibian species in the unmanaged stands. Species that are primarily associated with uplands (e.g., ensatina, clouded salamander) will derive only marginal habitat protection from buffer strips. Riparian buffer strips also may fail to benefit populations of vagile, aquatic breeding species (e.g., rough-skinned newt, red-legged frog) if adjacent managed lands remain impermeable to dispersal movements. I suggest a more successful conservation strategy for these species may be to protect natural refugia (seeps, rock outcrops, cliff faces, large logs) throughout harvest units by retaining vegetation cover and minimizing logging-related disturbance at these microsites.

LITERATURE CITED

Agee, J.K. 1988. Successsional dynamics in forest riparian zones. Pages 31-43. *In* K.J. Raedeke, ed. Streamside Management: Riparian Wildlife and Forestry Interactions. Contrib. No. 59, Inst. of For. Res., Univ. of Washington, Seattle.

Aubry K.B., and P.A. Hall. 1991. Terrestrial amphibian communities in the southern Washington Cascade Range. Pages 327-338 *In* L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, Tech. Coords. Wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, Gen. Tech. Rep. PNW-GTR-285. Portland.

Aubry K.B., L.C. Jones, and P.A. Hall. 1988. Use of woody debris by plethodontid salamanders in Douglas-fir forests in Washington. Pages 32-37 *In* R.C. Szaro, K.E. Severson, and D.R. Patton, Tech. Coords. Proc. Symp. on Management of Amphibians, Reptiles, and Small Mammals in North America, July 19-21, 1988, Flagstaff, AZ. USDA Forest Service, Gen. Tech. Rep. RM-166. Fort Collins.

Beers, T.W., P.E. Dress, and L.C. Wentzel. 1986. Aspect transformation in site productivity research. J. Forestry 64:691-692.

Bell, D.T. and S.K. Sipp. 1975. The litter stratum in the streamside forest ecosystem. Oikos, 26:391-397.

Belt G.H. and J. O'Laughlin. 1994. Buffer strip design for protecting water quality and fish habitat. West. J. Appl. For., 9(2):41-45.

Beschta, R.L. 1978. Long-term patterns of sediment production following road construction and logging in the Oregon Coast Range. Water Resour. Res., 14:1011-1016.

Blaustein, A.R., J.J. Beatty, D. Olson. and R.M. Storm. 1995. The biology of amphibians and reptiles in old-growth forests of the Pacific Northwest. USDA Forest Service, Gen Tech. Rep. PNW-GTR-337. Portland. 98 pp.

Brazier, J.R. and G.W. Brown. 1973. Buffer strips for stream temperature control. Res. Pap. 15, For. Res. Lab., Oregon State Univ., Corvallis. 9 pp.

Brown, G.W. and J.T. Krygier. 1970. Effects of clear-cutting on stream temperature. Water Resour. Res., 6:1133-1139.

Brown, G.W. and J.T. Krygier. 1971. Clear-cut logging and sediment production in the Oregon Coast Range. Water Resour. Res., 7:1189-1198.

Bureau of Land Management and Forest Service. 1994. Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl, Attachment A. USDI Bureau of Land Management and USDA Forest Service. Washington D.C. 101 pp.

Bury, R.B. 1983. Differences in amphibian populations in logged and old growth redwood forest. Northwest Sci., 57:167-178.

Bury, R.B. 1988. Habitat relationships and ecological importance of amphibians and reptiles. Pages 61-71 *In* K.J. Raedeke, Ed. Streamside Management: Riparian Wildlife and Forestry Interactions. Contrib. no. 59, Inst. of For. Res., Univ. of Washington, Seattle.

Bury, R.B. and P.S. Corn. 1988. Responses of aquatic and streamside amphibians to timber harvest: a review. Pp. 165-181 *In* K.J. Raedeke, Ed. Streamside Management: Riparian Wildlife and Forestry Interactions. Contrib. no. 59, Inst. of For. Res., Univ. of Washington, Seattle.

California Department of Forestry. 1990. Title 14, California Code of Regulations, section 916.5. Register 92, No. 25. Sacramento. Pp. 233-235.

Chen, J., J.F. Franklin, and T.S. Spies. 1990. Microclimatic pattern and basic biological responses in old-growth Douglas-fir forests. Northwest Enviro. J., 6:424-425.

Chen, J., J.F. Franklin, and T.S. Spies. 1992. Vegetation responses to edge environments in old-growth Douglas-fir forests. Ecol. Appl., 2:387-396.

Chen, J., J.F. Franklin, and T.S. Spies. 1993. Contrasting microclimates among clearcut, edge, and interior old-growth Douglas-fir forest. Agri. For. Metero., 63:219-237.

Chen, J., J.F. Franklin, and T.S. Spies. 1995. Growing-season microclimatic gradients from clearcut edges into old-growth forests. Ecol. Appl., 5(1):74-86.

Cline, S.P., A.B. Berg, and H.M. Wight. 1980. Snag characteristics and dynamics in Douglas-fir forests, western Oregon. J. Wildl. Manage., 44(4):773-786.

Corn, P.S and R.B. Bury. 1989. Logging in western Oregon: responses of headwater habitats and stream and amphibians. For. Ecol. Manage., 29:39-57.

Corn, P.S and R.B. Bury. 1991. Terrestrial amphibian communities in the Oregon Coast Range. Pp. 305-317 *In* L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, Tech. Coords. Wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, Gen. Tech. Rep. PNW-GTR-285. Portland.

Doyle, A.T. 1990. Use of riparian and upland habitats by small mammals. J. Mamm., 71:14-23.

Edmonds, R.L. 1980. Litter decomposition and nutrient release in Douglas-fir, red alder, western hemlock, and Pacific silver fir ecosystems in western Washington. Can. J. For. Res., 10:327-337.

Forest Ecosystem Management Assessment Team. 1993. Forest ecosystem management: an ecological, economic, and social assessment. U.S. Dept. Ag., U.S. Dept. Int., and others. Portland. [irregular pagination].

Fowler, W.B., T.D. Anderson, and J.D. Helvey. 1988. Changes in water quality and climate after forest harvest in central Washington state. USDA Forest Service, Res. Pap. PNW-RS-388. Portland. 12 pp.

Franklin, J.F. and C.T. Dyrness. 1973. Natural Vegetation of Oregon and Washington. Oregon State Univ. Press, Corvallis. 452 pp.

Garrison, G.A., and J.G. Smith. 1974. Habitat of grazing animals. Pages1-10. *In* Environmental effects of forest residues management in the Pacific Northwest: A state-of-knowledge compendium. USDA Forset Service, Gen. Tech. Rep. PNW-24. Portland.

Gilbert, F.F. and R. Allwine. 1991. Terrestrial amphibian communities in the Oregon Cascade Range. Pages 319-324. *In* L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, Tech. Coords. Wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, Gen. Tech. Rep. PNW-GTR-285. Portland.

Gomez, D.M. 1992. Small-mammal and herpetofauna abundance in riparian and upslope areas of five forest conditions. M.S. Thesis, Oregon State Univ., Corvallis. 118 p.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. Bioscience, 41:540-551.

Hall, J.D. and R.L. Lantz. 1969. Effects of logging on the habitat of of coho salmon and cutthroat trout in coastal streams. Pages 353-375. *In* Proc. T.G. and Trout in Streams, Univ. of British Columbia, Vancouver.

Herrington, R.E. 1988. Talus use by amphibians and reptiles in the Pacific Northwest. Pages 216-221 *In* R.C. Szaro, K.E. Severson, and D.R. Patton, Tech. Coords. Proc. Symp. on Management of Amphibians, Reptiles, and Small Mammals in North America, July 19-21, 1988, Flagstaff, AZ. USDA Forest Service, Gen. Tech. Rep. RM-166. Fort Collins.

Hawkins, C.P., M.L. Murphy, N.H. Anderson, and M.A. Wilzbach. 1983. Density of fish and salamanders in relation to riparian canopy and physical habitat in streams of the northwestern United States. Can. J. Fish. Aquat. Sci., 40:1173-1185.

Hungerford, R.D. 1979. Microenvironmental response to harvesting and residue management. Pages 37-73. *In* Proc. Sympos. Environmental Consequences of Timber Harvesting in Rocky Mountain Coniferous Forests, Sept. 11-13, 1979. USDA Forest Service, Gen. Tech. Rep. INT-90. Ogden.

Kelsey, K.A. 1995. Responses of headwater stream amphibians to forest practices in western Washington. Ph.D Dissertation, Univ. of Washington, Seattle. 167 pp.

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

Levno, A. and J. Rothacher. 1967. Increases in maximum stream temperatures after logging in old-growth Douglas-fir watersheds. USDA Forest Service, Res. Note PNW-65. Portland. 12 pp.

Maser, C., R.G. Anderson, K. Cromack, J.T. Williams, and R.E. Martin. 1979. Dead and down woody material. Pages 78-95 *In* J.W. Thomas, Tech. Ed. Wildlife Habitats in Managed Forests: the Blue Mountains of Oregon and Washington, USDA Forest Service, Agric. Handb. No. 553. Portland.

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

McComb, W.C., K. McGarigal, and R.G. Anthony. 1993. Small mammal and amphibian abundance in streamside and upslope habitats of mature Douglas-fir stands, western Oregon. Northwest Sci., 67:7-15.

McGarigal, K. and W.C. McComb. 1993. Research problem analysis on biodiversity conservation in western Oregon forests. The Pacific Forest and Basin Rangeland Systems Cooperative Research and Technology Unit, USDI Bureau of Land Management, Corvallis. 174 pp.

McGarigal, K. And W.C. McComb. 1995. Relationships between landscape structure and breeding birds in the Oregon Coast Range. Ecol. Mono., 65:235-260

Meehan, W.R., W.A. Farr, D.M. Bishop, and J.H. Patric. 1969. Effect of clearcutting on salmon habitat of two southeast Alaska streams. USDA Forest Service, Res. Pap. PNW-82. Portland. 45 pp.

Moring, J.R. and R.L. Lantz. 1974. Immediate effects of logging on the freshwater environment of salmonids, final report, project AFS-58. Oregon Wildlife Comm., Res. Div., Corvallis. 101 pp.

Naiman, R.J., H. Décamps, and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecol. Appl., 3:209-212.

Nussbaum, R.A., E.D. Brodie, and R.M. Storm. 1983. Amphibians and Reptiles of the Pacific Northwest. University of Idaho Press, Moscow. 332 p.

Oregon Department of Forestry. 1994. Forest Practice Water Protection Rules, Division 57. Oregon Department of Forestry, Salem. 32 p.

Petranka, J.W., M.E. Eldridge, and K.E. Haley. 1993. Effects of timber harvesting on southern Appalachian salamanders. Conserv. Biol., 7:363-370.

Pough, F.H., E.M. Smith, D.H. Rhodes, and A. Collazo. 1987. The abundance of salamanders in forest stands with different histories of disturbance. For. Ecol. Manage., 20:1-9.

Power, M.E., R.J. Stout, C.E. Cushing, P.P. Harper, F.R. Hauer, W.J. Matthews, P.B. Moyle, B. Statzner, and I.R. Wais De Badgen. 1988. Biotic and abiotic controls in river and stream communities. J. N. Am. Benthol. Soc., 7:456-479.

Ruth, R.H. and R.A. Yoder. 1953. Reducing wind damage in the forests of the Oregon Coast Range. USDA Forest Service Res. Paper PNW-7, Portland. 30 pp.

Ramsey F. and D. Schafer. 1994. The Statistical Sleuth: A Second Course in Statistical Data Analysis. *In prep.*

SAS Institute, Inc. 1990. SAS/STAT User's Guide, Version 6, Vol. 2. SAS Institute Inc., Cary, NC. 846 pp.

SAS Institute, Inc. 1993. SAS/STAT Software: The GENMOD Procedure, Release 6.09, SAS tech. rep. P-243. SAS Institute, Cary, NC. 88 p.

Sedell, J.R., and G.H. Reeves. 1993. Aquatic ecosystem assessment. Pages V 1 - V 95 *In* J.W. Thomas, Team Leader, Forest Ecosystem Management: An Ecological, Economic, and Social Assessment, Report of the Forest Ecosystem Management Assessment Team. Forest Conference Executive Committee. Washington, D.C.

Streetby, L. 1971. Buffer strips- some considerations in the decision to leave. *In* Proc. Sympos. Forest Land Uses and the Stream Environment, Oct. 19-21, 1970, Oregon State University, Corvallis.

Suzuki, N. 1992. Habitat classification and characteristics of small mammal and amphibian communities in beaver-pond habitats of the Oregon Coast Range. M.S. Thesis, Oregon State Univ., Corvallis. 91 pp.

Taylor, G. 1993. Normal Annual Precipitation, State of Oregon, 1961-1990. Oregon State Climate Service, Oregon State Univ., Corvallis. Map.

Thomas, J.W., M.G. Raphael, R.G. Anthony, E.D. Forsman, A.G. Gunderson, R.S. Holthausen, B.G. Marcot, G.H. Reeves, J.R. Sedell, and D.M. Solis. 1993. Viability assessments and management considerations for species associated with late-successional and old-growth forests of the Pacific Northwest: the report of the scientific analysis team, appendix 5-A. USDA Forest Service, Washington, D.C.
Pp. 307-334.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continum concept. Can. J. Aquat. Sci., 37:130-137.

Welsh H.H. 1986. Monitoring herpetofauna in woodland habitats of northwestern California and southwestern Oregon: a comprehensive strategy. Pages 203-213 *In* Proc. Sympos. on Multiple-Use Management of California's Hardwood Resources, Nov. 12-14, 1986, San Luis Obispo, CA. USDA Forest Service, Gen. Tech. Rep.
PSW-100. Berkeley.

Welsh H.H. and A.J. Lind. 1991. The structure of the herpetofauna assemblage in the Douglas-fir / hardwood forests of northwestern California and southwestern Washington. Pages 395-411 *In* L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, Tech. Coords. Wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, Gen. Tech. Rep. PNW-GTR-285. Portland.

APPENDICES

Appendix I. Time-constrained search protocol used by surveyors during amphibian data collection at 29 managed and unmanaged riparian study sites in the Oregon Coast Range, 1994-95.

Riparian Buffer Strip / Amphibian Study:
Time-Constrained Search (TCS) Instructions for Surveyors

Equipment List:

- 50 gm Pescola scale
- 300 gm Pescola scale
- stopwatch
- 150 mm plastic ruler
- 300 mm plastic ruler
- data collection sheets
- clipboard
- pencils
- plastic bags
- compass
- 12" pry bar
- flagging (pink)

Study Site Layout

Each stream to be surveyed for amphibians will have three 20- X 40-m quadrats previously flagged at each site. Typically, there are 2 quadrats on one side of the stream > 60 m apart, and a single quadrat on the opposite side. Each quadrat is subdivided into eight 10- X 10-m subplots. The corners of each subplot are flagged (pink) and numbered according to it's position within the quadrat.

TCS Method

Each subplot within a quadrat is searched by 2 surveyors (15 minute search per surveyor). The 2 surveyors begin the TCS at subplots in opposite corners of the quadrat, and proceed by performing a timed search in one subplot, moving on to another subplot, until all subplots have been completed by both surveyors.

Before beginning the search, fill in the header of the data sheet and make sure you can find the boundary of the subplot. Zero your watch and begin the search.

Most amphibians are nocturnal and usually retreat to cover during daylight. However, it is not uncommon to find them exposed during wet weather. Each species is adapted to a particular microhabitat type. Logs, bark piles, rocks, seeps, and leaf litter are commonly used cover. Some species retreat into small mammal tunnels (during a pilot study we found small salamanders 50 cm underground). The objective of the survey is to examine a sample of cover objects that are representative of all the microhabitats available on each subplot...this is not the same as attempting to maximize the number of amphibian captures. If the objective was to catch as many amphibians as possible, I would ask you to concentrate your effort on large, decayed logs. Search the most likely cover objects thoroughly, but also examine other areas in the subplot.

It is very important to examine cover objects methodically. Many of the juvenile salamanders could fit between these brackets [ ] and it's easy to miss them if you work too quickly. Decayed logs should usually be examined top downward; if there's a layer of moss, check under that first. Then, peel the bark and examine cavities underneath. If the log is soft, it may be possible to break it open with the prybar. Finally, lift the log (if possible) and check underneath. Rock outcrops, bark piles, and cobbles near the stream should be searched in the same systematic manner. Replace the cover object to as close as possible to it's original position when you are finished.

If the subplot contains a portion of the stream or another hydrological feature, keep looking ahead in the direction you are moving so you may be able to observe amphibians as they attempt to seek cover underwater.

Place captured amphibians in a plastic bag, then stop your watch so as not to include processing time as search time. Take the required measurement and fill in the data sheet as each amphibian is caught. Amphibians can be measured and weighed in the bag, but check the bag weight for each capture. If you can not conclusively ID the species, ask the crew leader to check the animal. Distance-to-stream may be estimated by checking the nearest flag marker along subplot boundaries. Hold captured animals in another bag (with damp moss) until both surveyors have finished the quadrat. Amphibians that escape during capture, may be entered on your data sheet if you are able to ID the species. Mark the location of the escape with a flag and notify the other surveyor if (s)he has not already searched the plot (it's important not to double-count the same animal).

Restart your watch and continue the search until the 15 minutes for that subplot has expired. Move to the next subplot, and perform another 15 minute search in a similar manner. Continue until the entire quadrat has been searched by both surveyors.

Be sure to record the end time on the data sheet and make any corrections. Release all amphibians as close as possible to their original position. At some study sites you may be asked to take down flags or collect habitat data.

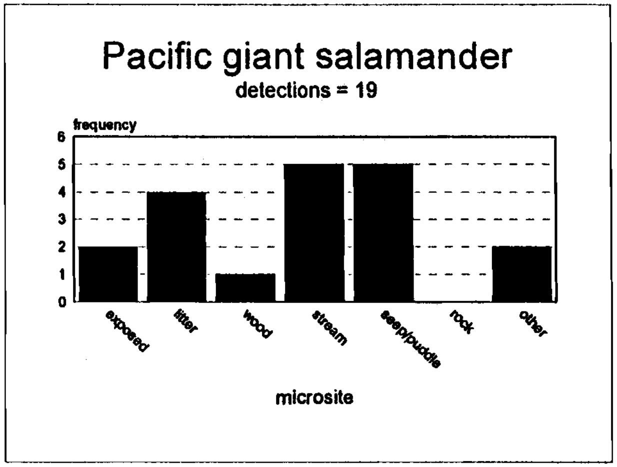
Appendix II. Occurrence of uncommon amphibian species (captures < 20) on harvested (n = 13) and buffer strip plots (n = 12) surveyed in the Oregon Coast Range, 1994-95.

Species (detections)	Harvest (present/absent)	Buffer (present/absent)	P[1]
Pacific giant salamander (19)	1 / 12	5 / 7	0.06
Clouded salamander (11)	0 / 13	3 / 9	0.10
Rough-skinned newt (13)	0 / 13	3 / 9	0.10
Tailed frog (6)	0 / 13	2 / 10	0.22

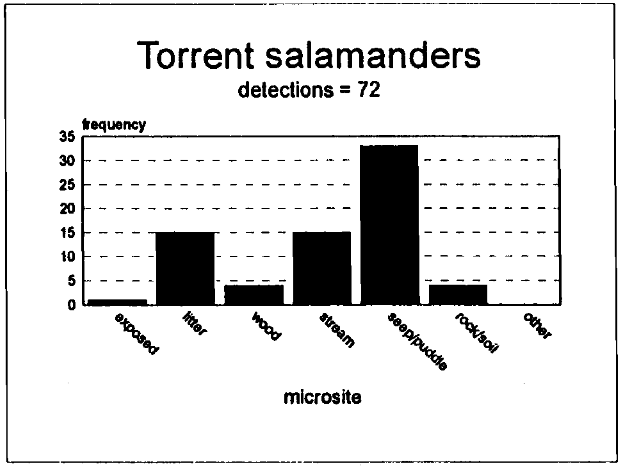
1. Probability to reject H_0: occurrence is independent of plot type; Fisher's "exact" test

Appendix III. Summary of terrestrial amphibian detections by 7 microsite classes (exposed = not using hiding cover; litter = detected in or under fine organic matter; wood = detected in or under log, snag, bark pile; stream = detected in main stream that defined study site; seep/puddle = detected in a minor aquatic feature on quadrat; rock = detected under a rock or within loose gravel/cobble; other = detected in an undefined microsite). Oregon Coast Range, 1994-95.

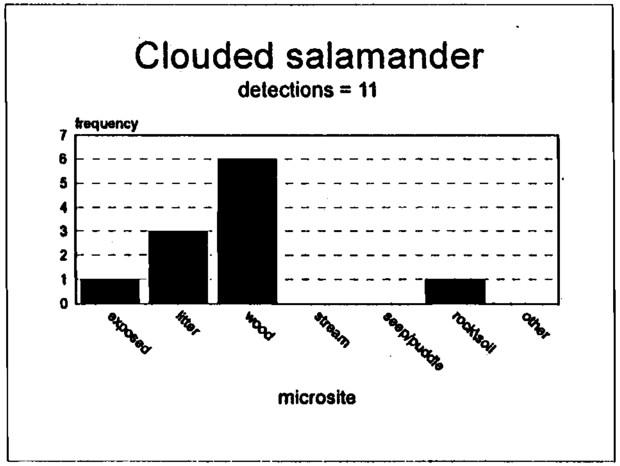
Appendix III.


Pacific giant salamander

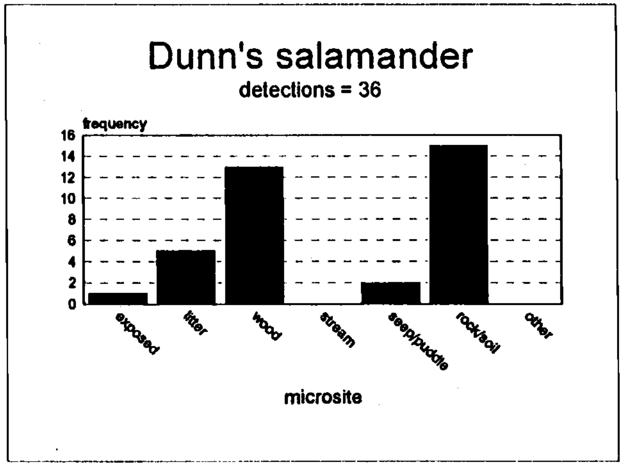
detections = 19


Torrent salamanders

detections = 72

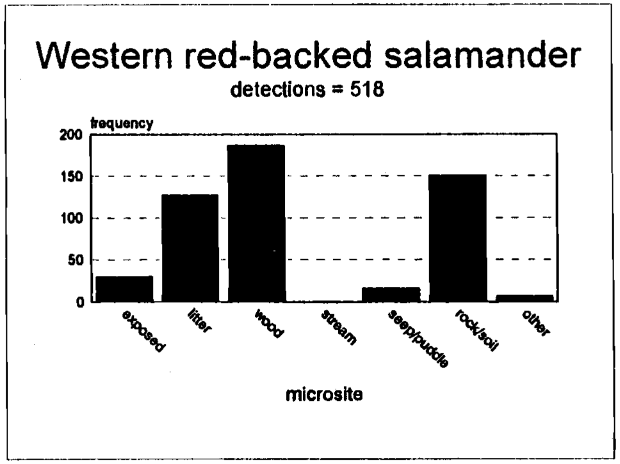

Clouded salamander

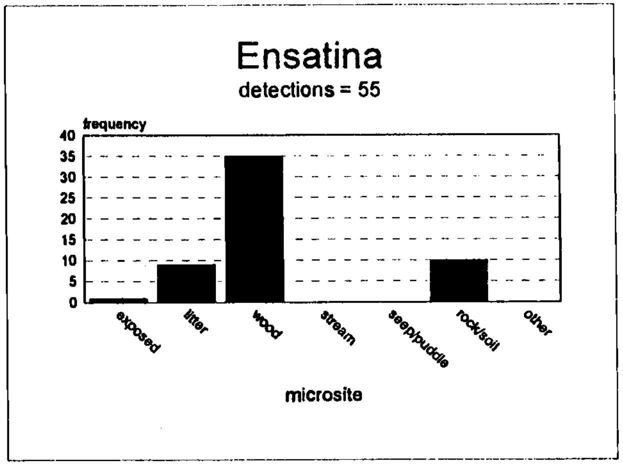
detections = 11

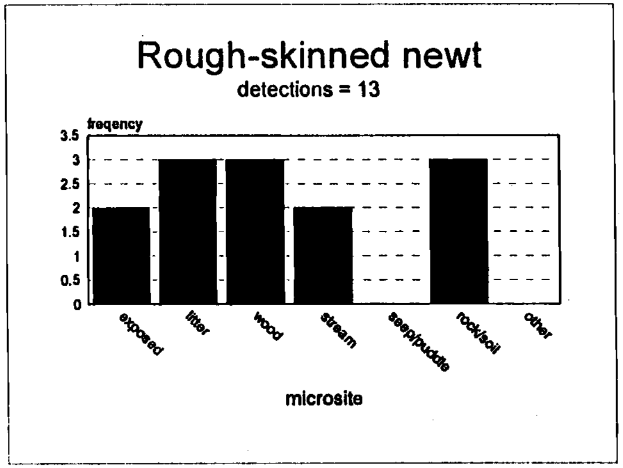

Dunn's salamander

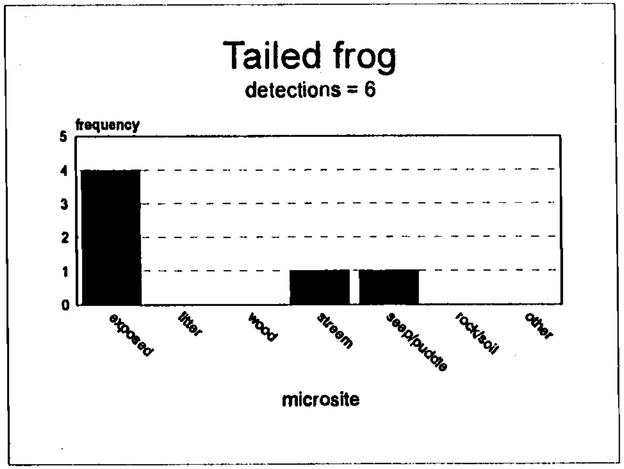
detections = 36

Appendix III (continued).


Western red-backed salamander
detections = 518


Ensatina
detections = 55


Rough-skinned newt
detections = 13


Tailed frog
detections = 6