3401

Douglas-fir Forests in the Oregon and Washington Cascades: Relation of the Herpetofauna to Stand Age and Moisture[1]

R. Bruce Bury[2] and Paul Stephen Corn[3]

Abstract.—Pitfall traps effectively sampled amphibians but not reptiles in Douglas-fir *(Pseudotsuga menziesii)* forests. The abundance of only one amphibian species varied across an age gradient or a moisture gradient. Salamanders and frogs that breed in ponds or streams were captured in large numbers in some stands, likely due to the presence of nearby breeding habitat rather than forest conditions. Lizards occurred mostly in dry stands and clearcuts. Time-constrained searches showed different use of downed woody debris among terrestrial salamanders. The occurrence and abundance of species in naturally regenerated forests markedly differed from clearcut stands.

The value of old-growth forests for wildlife is highly debated (Fosburg 1986, Harmon et al. 1986, Harris 1984, Kerrick et al. 1984, Ruggiero and Carey 1984, Salwasser 1987, Wilcove 1987). Most attention has been directed toward the spotted owl *(Strix occidentalis)*, which is one of several hundred vertebrate species occurring in the Pacific Northwest (Bruce et al. 1985). Franklin and Spies (1984) distinguished old-growth forests of Douglas-fir *(Pseudotsuga menziesii)* as having a wide range of tree sizes and ages, a deep multilayered crown canopy, large individual trees, and accumulations of coarse woody debris (CWD), including snags and downed logs of large dimension. They reported that these forests are productive, diverse ecosystems, and highly specialized habitats.

We need to evaluate sampling techniques continually to better describe, understand and predict the species richness, abundance and biomass of herpetological assemblages. However, few herpetological communities or their habitats have been sampled using more than one quantitative technique.

Recently, field techniques for the study of herpetological communities have improved (Scott 1982). Some of the most promising methods employ pitfall traps and drift fences to capture amphibians and reptiles. Several promising pitfall designs have been developed for varied habitats in Australia (Friend 1984, Webb 1985) and in North America (Bennett et al. 1980, Bury and Corn 1987, Bury and Raphael 1983, Campbell and Christman 1982, Enge and Marion 1986, Gibbons and Semlitsch 1981, Jones 1981, 1986, Raphael 1984, Raphael and Rosenberg 1983, Rosenberg and Raphael 1986, Vogt and Hine 1982). Pitfall traps are effective for capture of commmon terrestrial species and they are particularly valuable in sampling secretive or rare forms.

Searches by hand (either based on specific areas or time of collecting) or observation are used to sample herpetofaunas (see reviews by Bury and Raphael 1983, Jones 1986, Pough et al. 1987). Campbell and Christman (1982) suggested that time-constrained collecting (searching within a specific period of time by trained collectors) can sample terrestrial species that are under-sampled or not taken in pitfall traps.

The first year of our old-growth study (1983) was partly devoted to refining field techniques. A comparison of different pitfall designs is reported elsewhere (Bury and Corn 1987). Here, we employ a standardized pitfall array and time-constrained searches to determine the occurrence and abundance of the terrestrial (upland) herpetofauna in the Cascade Mountains of the Pacific Northwest.

The current work on small mammals (Anthony et al. 1987, Corn et al. 1988, West 1985), birds (Carey 1988, Manuwal and Huff 1987), and bats (Thomas *in press*) are part of an interdisciplinary effort to better understand the relationship of nongame wildlife in old-growth forest stands (Ruggiero and Carey 1984). Our study is the first to attempt to identify which species of the herpetofauna, if any, are associated with age and moisture gradients in forests of the Cascade Mountains.

Our specific objectives were (1) to compare effectiveness and relative merits of time-constrained collecting versus pitfall trapping, (2) to compare the species richness and relative abundance of amphibians and reptiles between different forest stands, and (3) to examine the association of the herpetofauna with old-growth forest conditions.

DESCRIPTION AND CLASSIFICATION OF STUDY SITES

We sampled 30 sites: 18 in or near the H. J. Andrews Experimental Forest in eastern Linn and Lane counties, Oregon, and 12 stands in the

[1] *Paper presented at symposium, Management of Amphibians, Reptiles, and Small Mammals in North America (Flagstaff, AZ, July 17-21, 1988).*

[2] *R. Bruce Bury is Zoologist (Research), USDA Fish and Wildlife Service, National Ecology Research Center, 1300 Blue Spruce Drive, Fort Collins, CO 80524.*

[3] *Paul Stephen Corn is Zoologist, USDA Fish and Wildlife Service, National Ecology Research Center, 1300 Blue Spruce Drive, Fort Collins, CO 80524.*

Wind River Experimental Forest, Skamania County, Washington. All sites are on the western slopes of the Cascade Mountains. Specific locations, stand classification, elevations and other details are provided in Corn et al. (this volume).

Study sites represent a range of forest development across a chronosequence (principally age) and, for old-growth, a moisture gradient. These stands were independently selected and assessed by Spies et al. (*in press*). They were all in naturally regenerated forest caused by wildfire. There were three development stages in moderate moisture conditions: young (30-76 years old), mature (105-150 years) and old-growth (195-450 years). Clearcut sites represent recent timber harvest (<10 years old). For old-growth stands only, there were representative moisture conditions: wet, moderate and dry sites. Stand classification was based on age determined by increment boring of trees or other methods, characteristic plant species in the understory, physiography, and soils. These methods and other parameters are described by Corn et al. (this volume), Franklin et al. (1981) and Spies et al. (*in press*).

Following the initial stand selection, there were minor adjustments in assignment of stand classification (Corn et al., this volume). We rejected a few sites that were either not continually accessible for our weekly checking of pitfall traps or were being actively logged.

Figure 1.—Conducting time-constrained searches in an old-growth stand, Oregon. Note large amounts of downed woody debris.

MATERIAL AND METHODS

Time-Constrained Searches (TCS)

Details of this technique are provided elsewhere (Campbell and Christman 1982, Bury and Raphael 1983, Raphael and Rosenberg 1983). A team of 3-8 people intensively searched each stand for 8 person-hrs in the spring (8-25 April 1983 in Oregon and 3-12 May 1983 in Washington). We turned over moveable surface objects (twigs to logs <1 m diamater), dug into decayed wood, and removed bark from downed wood or the bases of standing snags by hand or with potato rakes (fig. 1).

Collectors remained within boundaries of habitat typical of the stand, avoiding conspicuous specialized habitats such as ponds, creeks or rock outcrops. Further, we searched 4 sites in each state again during warm weather (July-Aug 1983). These surveys were performed for 4 hrs per plot. We recorded information on exact position of capture for each animal, including vertical position (e.g., on or under litter; on, under or in log; etc.), identification of cover object, length and diameter of object, time of capture, total length, and mass of animal.

We determined the decay class of coarse woody debris occupied by animals on the forest floor. Large woody debris or felled trees (logs) occur in five progressive broad decay classes (Bartels et al. 1985, Franklin et al. 1981, Harmon et al. 1986, Maser et al. 1979, Maser and Trappe 1984): (1) intact, recently downed trees; (2) logs with loose bark; (3) loss of bark and stem partly rotted; (4) invasion of roots and deep decomposition of stem; and (5) hummocks of wood chunks and organic material. Once fallen, a large tree might require 200 or more years to progress from class 1 to 5 (Spies et al. *in press*), providing habitat for many generations of resident wildlife.

Pitfall Arrays

We installed a pitfall array at each site in Oregon and Washington (details in Bury and Corn 1987). Each array had two triads with their centers 25 m apart. Each triad was composed of three drift fences 5 m long and 0.5 m tall; about 0.3 m of fence was above ground. Fences radiated at 120° angles, beginning 3 m from the center point. The compass directions of the arms depended on openings between trees or large logs on the forest floor. Pitfall traps were constructed from two stacked #10 tin cans (3.2 l volume) connected with

Table 1.—Numbers of amphibians and reptiles captured during time-constrained searches (TCS) conducted 8-25 April 1983 at the H. J. Andrews Experimental Forest in Oregon. Old-growth stands are arranged in order of increasing dryness.

	Old growth																	
	Wet		Moderate			Dry			Mature			Young				Clearcut		
Species / Stand No.	15	03	24	[a]02	17	33	25	29	11	35	42	39	47	48	75	55	291	391
Clouded Salamander		3	8	6	9		3	11	17	4		2			1	2	12	2
Oregon Slender Salamander	2	6	4	12	9				11	5	1			9	1		1	
Oregon Ensatina	4	3	1	9	5	7	22	2	10	6	4	5	3	9	8	9	4	1
Dunn's Salamander				2			1											
Rough-skinned Newt				2												1	1	
Pacific Tree Frog								1		4		1					1	1
Western Skink																1		
Norhtern Alligator Lizard																1		
Western Fence Lizard																2		

[a]Two surveys were conducted in this stand and the results are combined here.

duct tape. A pit trap was placed flush with the ground surface at each end of the fence. Funnel traps were constructed of aluminum screening, rolled into a tube 1 m long by 0.1 m diameter, with inward funnels stapled at each end of the trap. A funnel trap was placed midway on either side of the fence. No water or preservatives were added to the traps. A wooden shingle was propped over each pitfall and funnel trap, but water entered pitfalls during heavy rains. We routinely removed water from traps with scoops or a hand-operated aquarium siphon.

We operated pitfall traps continously for 180 days, from the last week of May to late November 1983. Traps were checked 1-2 times each week. Captures were usually taken to a field laboratory for identification and measurements. All retained specimens are deposited at the National Museum of Natural History.

Table 2.—Numbers of amphibians and reptiles captured during TCS 3-12 May at the Wind River Experimental Forest in Washington. Old-growth stands are arranged in order of increasing dryness.

	Old growth											
	Wet	Moderate			Dry	Mature			Young		Clearcut	
Species / Stand No.	14	12	21	20	31	41	42	50	60	61	70	71
Olympic Salamander	2											
Oregon Ensatina	3	7	13	5	5	4	1	1	1	1		
Larch Mountain Salamander		14										
Western Red-backed Salamander		6										
Rough-skinned Newt			3	2					1			
Red-legged Frog	1											
Pacific Tree Frog											1	
Rubber Boa								2			1	
Common Garter Snake					1							

RESULTS

Time-Constrained Searches (TCS)

Yield

During spring TCS, we collected 258 amphibians and 4 reptiles (table 1) at the 18 Oregon sites (1.8 animals per person-hr) and we took 78 amphibians and 4 reptiles (table 2) at 12 Washington sites (0.85 per person-hr). For summer TCS, all Washington captures included only 4 lizards from one clearcut, one mature (drier aspect) and an old-growth dry stand (0.25 animals per hr) whereas in Oregon we captured 13 salamanders (no new species) and 2 lizards from 4 sites (0.9 animals per hr).

Although we report the abundance of herpetofauna collected by TCS (tables 1 and 2), we did not analyze these results based on the age and moisture gradients because such abundance data can be biased.

Habitat Use

TCS provided useful information on the exact position where individuals were found (table 3). Oregon ensati-

Table 3.—Number of salamanders (Oregon data only) captured in different microhabitats. Percentages are in parentheses.

Position	Oregon Ensatina	Clouded Salamander	Oregon Slender Salamander
On/Under Litter	3 (2.4)	0 (0)	1 (1.6)
On/Under Rock	3 (2.4)	0 (0)	1 (1.6)
On/Under Log	14 (11.5)	8 (10.2)	6 (6.8)
Inside Log	52 (42.6)	27 (34.2)	38 (62.3)
Under Bark on Log	12 (9.8)	37 (46.8)	7 (11.5)
Under Bark on Ground	38 (31.1)	7 (8.9)	8 (13.1)

nas (*Ensatina eschscholtzi*; fig. 2) occurred more evenly and in more microhabitats than did the other two species. Clouded salamanders (*Aneides ferreus*) were mostly under bark on logs and, secondarily, often were in logs (81% of the sites occupied were related to logs). The Oregon slender salamander (*Batrachoseps wrighti*) predominately occurred in logs (62%) and then under bark on ground or on logs (87% in or near logs). Most bark on the ground occurred in piles sloughed from fallen trees or snags and is essentially an extension of the log environment.

Terrestrial salamanders that were captured in or near downed wood markedly differed in their use of different decay classes of CWD (fig. 3). We did not include decay class 1 logs, because few of these were searched and none had salamanders. These logs are intact material and offer little cover for salamanders.

We calculated Chi-square statistics for three species in Oregon. The clouded salamander was most abundant in younger (class 2) logs ($P < 0.001$), while Oregon slender salamanders were found more often than expected in the more decayed class 4 and 5 logs ($P < 0.05$). Numbers of Oregon ensatina generally followed the pattern of log abundance (fig. 3), except that they were found less often than expected in class 3 logs ($P < 0.05$). These results are consistent with microhabitats where the salamanders were captured (table 3).

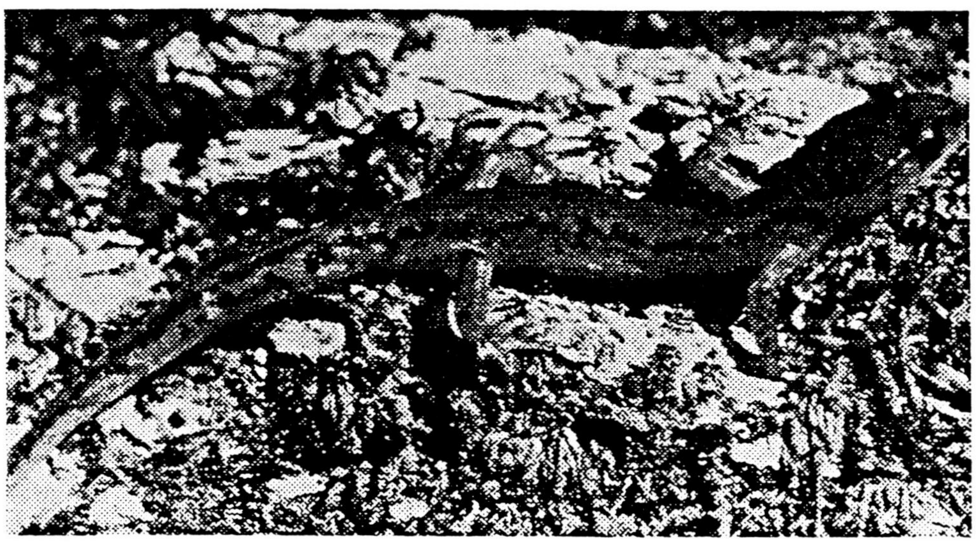

Figure 2.—Adult ensatina *(Ensatina eschscholtzi)* from Douglas Co., Oregon.

Pitfall Trapping

Total Numbers

Pitfall arrays at 18 Oregon sites provided 1,028 captures (table 4): 685 salamanders, 252 frogs, 64 lizards and 27 snakes. Pitfalls at 12 Washington sites yielded 1,152 animals (table 5): 460 salamanders, 663 frogs and 29 snakes. Two Washington sites had exceptional catches: 253 tailed frogs *(Ascaphus truei)* at #21 Old-growth Moderate and 119 red-legged frogs *(Rana aurora)* at #42 Mature.

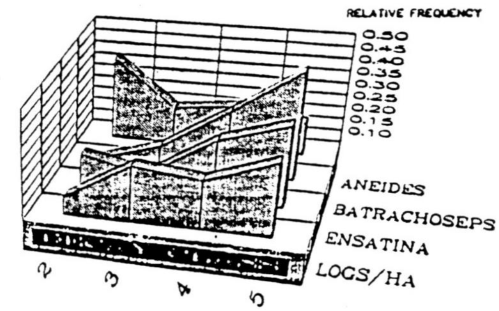

Figure 3.—Frequency of occurrence of clouded salamanders, Oregon slender salamanders, and Oregon ensatinas occupying downed wood in decay classes 2-5. Density of logs in each decay class are provided. Data are from 18 sites at the H. J. Andrews Experimental Forest, Oregon.

Yield

Summer operation of the pitfall arrays added a few reptiles but the bulk of the catch was amphibians in the fall months during and after heavy seasonal rains (Bury and Corn 1987). There was a low catch of reptiles (Oregon, mean = 5 per site; Washington, mean = 2.4).

Species richness did not differ across the chronosequence gradient (table 6, fig. 4). Moderate and dry old-growth stands had the highest mean abundance across the moisture gradient, which was caused by the capture of large numbers of several migratory species.

Table 4.—Abundance of amphibians and reptiles captured by pitfall arrays at the H. J. Andrews Experimental Forest in Oregon. Arrays of pitfall traps with drift fences were operated continuously for 180 days in 1983. Old-growth stands are arranged in order of increasing dryness.

	Old growth								Mature			Young				Clearcut		
	Wet			Moderate		Dry												
Species / **Stand No.**	**15**	**03**	**24**	**02**	**17**	**33**	**25**	**29**	**11**	**35**	**42**	**39**	**47**	**48**	**75**	**55**	**291**	**391**
Northwestern Salamander							1	27			5		1		1		8	1
Pacific Giant Salamander				1				7				2			2	1	1	
Clouded Salamander		1	2	1			2	4				1	1				3	1
Oregon Slender Salamander	1	3	1		1					1			4			1	1	
Oregon Ensatina	8	2	10	18	22	13	26	21	9	15	10	16	14	20	30	12	10	1
Dunn's Salamander						1		1										
Rough-skinned Newt	21		3	26	5		119	62			15		13	36	5	14	16	2
Tailed Frog		28	5	3	4	17		46	7		6	28		30			3	
Red-legged Frog								23		28					2		4	
Pacific Tree Frog	2									3		1		3	3		2	5
Western Skink								3								11	9	
Norhtern Alligator Lizard					1		3	4								14	8	2
Western Fence Lizard							1									5	3	
Rubber Boa														1				
Northwestern Garter Snake	1			2	1											1	11	
Common Garter Snake	1	1	2			1					1			2	1		1	

Table 5.—Abundance of amphibians and reptiles captured by pitfall arrays at the Wind River Experimental Forest in Washington. Arrays of pitfall traps with drift fences were operated continuously for 180 days in 1983. Old-growth stands are arranged in order of increasing dryness.

	Old growth					Mature			Young		Clearcut	
	Wet	Moderate			Dry							
Species / **Stand No.**	**14**	**12**	**21**	**20**	**31**	**41**	**42**	**50**	**60**	**61**	**70**	**71**
Northwestern Salamander		2	5	15	4	1	1	1	9	10	2	
Pacific Giant Salamander			1									
Olympic Salamander	3		1			1						
Oregon Ensatina	7	35	29	18	39	14	13	3	24	25	0	1
Larch Mountain Salamander		10										
Western Red-backed Salamander		19										
Rough-skinned Newt	10	4	5	40	1	10	4	7	38	37	7	4
Tailed Frog	44	22	253	4	27	50	4		2	1	4	
Red-legged Frog	8	1	3	15		1	19	119	40	5	23	6
Pacific Tree Frog								3				9
Northern Alligator Lizard					1			1		12	1	
Northwestern Garter Snake					2	1				4		
Common Garter Snake			6									1

Differences in Closed-Canopy Stands

For Oregon and Washington data combined, mean abundance of common species (3 salamanders, 2 frogs) appeared to differ across either forest development (age) or moisture gradient (fig. 5). However, except for the Oregon ensatina, none of the differences were statistically significant (table 6). High numbers of individuals at a few stands resulted in large variances in catch at stand types.

Large numbers of both the rough-skinned newt *(Taricha granulosa)* and Northwestern salamander *(Ambystoma gracile)* were captured in a few stands (tables 4-5). Most of the tailed frogs taken were juveniles at one old-growth site in Washington (table 5), and these were apparently dispersing away from a nearby stream. Similarly, most (78%) of the red-legged frogs were taken at 5 sites (tables 4-5); the largest number (n =

119) were juveniles captured at one mature stand in Washington.

The only species showing a significant difference (table 6) across the chronosequence of stands was the Oregon ensatina. Its numbers were lower in mature stands (fig. 5), perhaps related to amounts of CWD in different age classes (fig. 6). Abundance of Oregon ensatinas was most highly correlated with the number of decay class 4 and 5 logs per hectare (Pearson $r = 0.48$, $n = 29$, $P < 0.01$) and the mean diameter (d.b.h.) of large-sized canopy trees ($r = 0.51$, $n = 29$, $P < 0.01$). A discussion of the habitat variables used here is provided in Corn et al. (1988). Mean abundance of Oregon ensatina also differed across the moisture gradient in old-growth stands with fewer present in wetter sites than drier. Paradoxically, most OGW stands have large amounts of CWD (fig. 6). Oregon ensatina may be associated with the amount of CWD, but there are other components of the habitat that may be underrepresented in OGW stands.

Clearcut Stands

We also trapped 5 clearcut sites (all <10 years old) to describe herpetofauna occurrence in managed stands. The relative abundance of the herpetofauna in these clearcuts markedly differed from 6 comparable young stands (fig. 7). Reptiles predominate in clearcuts, most likely responding to increased ambient temperature in such areas. The Pacific treefrog *(Hyla regilla)* also was most abundant in clearcuts.

DISCUSSION

Comparison and Improvements in Techniques

Time-constrained searches (TCS) provided insufficent animals for quantitative analyses in most stands. The technique might be more worthwhile under optimal environmental conditions (e.g., after heavy rains for amphibians) and with increased effort (16+ person-hr per site). Summer searches added the occurrence of lizards to some stands, but in general the effort was not worth the time investment in forested stands of the Cascade Mountains.

However, TCS can be effective to sample terrestrial species of salamanders. Our pitfall trapping (180 days) caught 257 ensatina, 44 clouded salamanders, and 13 Oregon slender salamanders, whereas TCS yielded 113 ensatina (0.44 times that of pitfalls), 76 clouded salamanders (1.7 X pitfalls), and 57 slender salamanders (4.4 X pitfalls). The clouded salamander is a common denizen of Oregon forests and sometimes the most frequently encountered species, but pitfall traps caught few. This species has large toes and is adept at climbing, and perhaps escaped. Or, they rarely free-fall into traps on the ground. The Oregon slender salamander seems to be associated with

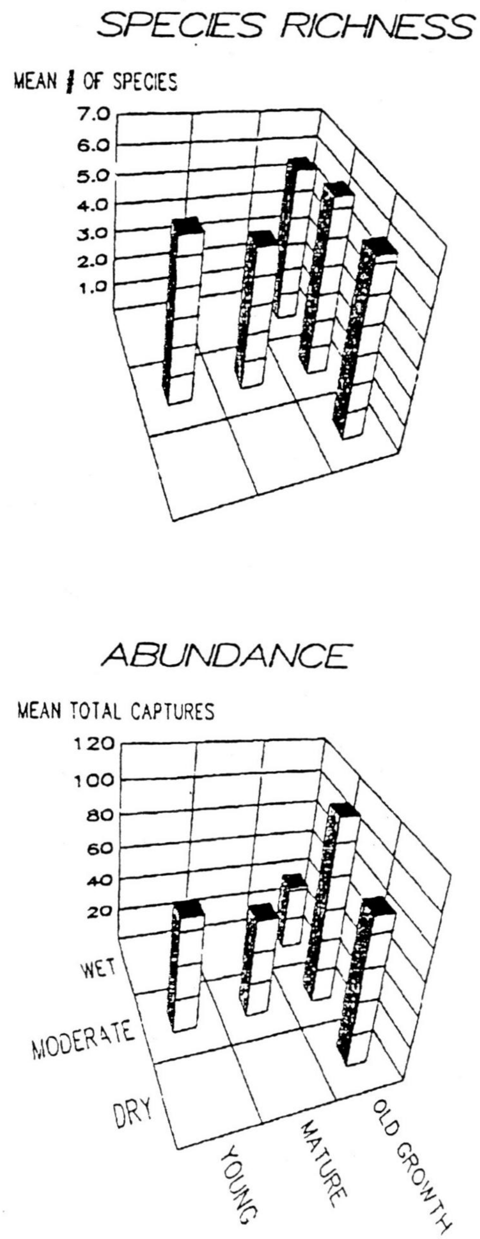

Figure 4.—Mean species richness and mean total abundance of amphibians and reptiles in closed-canopy forest stands.

Table 6.—Analysis of variance of species richness and abundance (log transformed) categorized by age (old growth, mature, and young) and moisture (wet, moderate, and dry). Wet and dry old growth stands were not used in the analysis of stand age, and mature and young stands were not used in the analysis of stand moisture.

	Age (n = 17)		Moisture (n = 13)	
	F	P	F	P
Species Richness	2.02	0.17	0.30	0.75
Total Abundance	0.92	0.42	2.40	0.14
Northwest Salamander	0.38	0.69	1.90	0.20
Rough-skinned Newt	0.91	0.43	0.26	0.78
Oregon Ensatina	8.09	0.005	11.4	0.003
Tailed Frog	0.92	0.42	0.06	0.94
Red-legged Frog	0.65	0.54	0.12	0.89

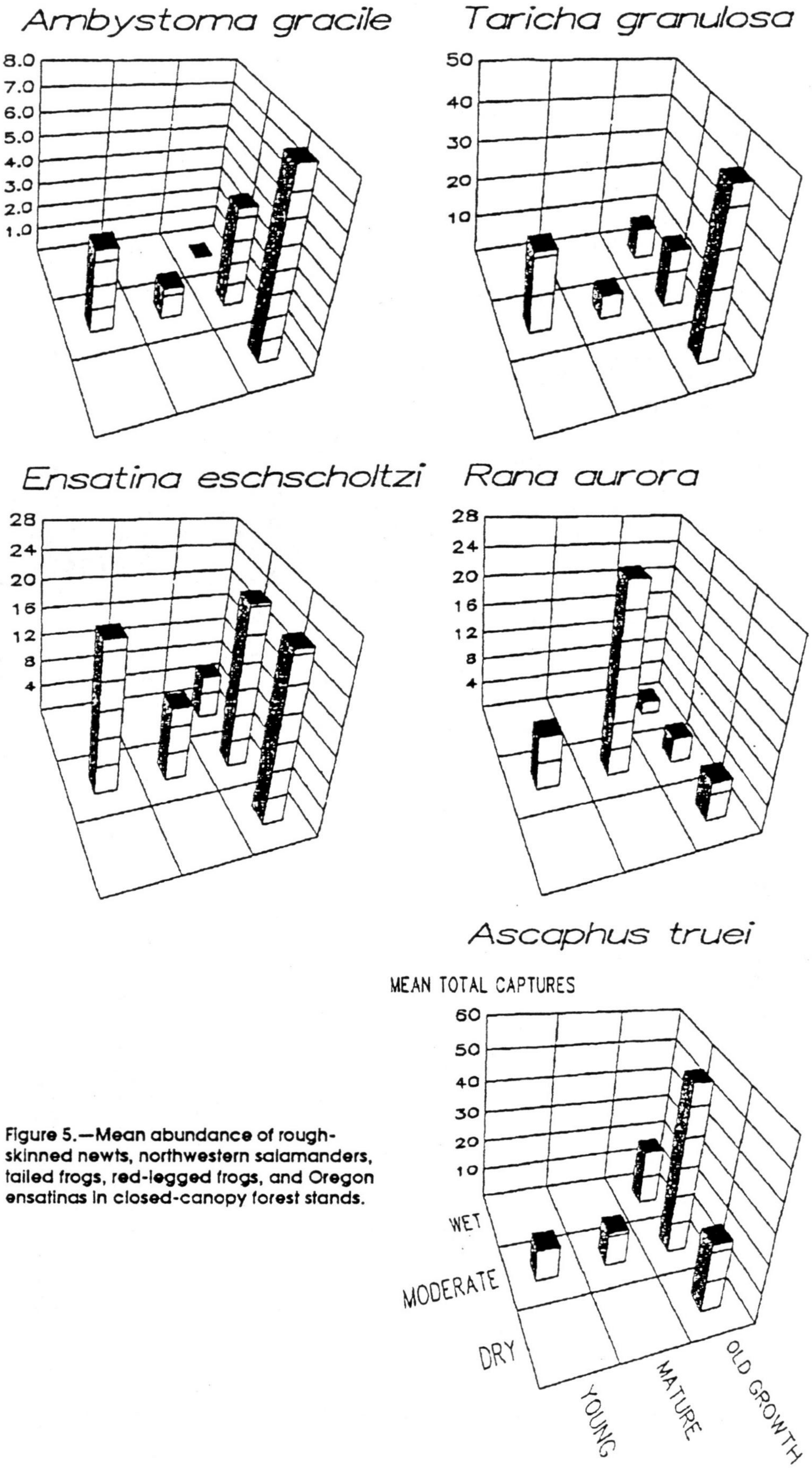

Figure 5.—Mean abundance of rough-skinned newts, northwestern salamanders, tailed frogs, red-legged frogs, and Oregon ensatinas in closed-canopy forest stands.

downed woody debris and the best-known method to sample such material is with TCS, area-constrained searches (Bury and Raphael 1983, Raphael and Rosenberg 1983), or hand-collecting of specific amounts and types of CWD.

For several reasons, we refrained from using TCS to compare differences in herpetofauna across stand ages and moisture gradients. In 1983, we did not record the number nor amount of litter (CWD) searched in each study site, which could have affected the results. Unless cover items are scarce, TCS will result in equivalent numbers of cover items searched, e.g., 20 logs per person-hr of search. However, the type, number and biomass of logs differs among stands. Thus, the number of animals collected is not related to the availability of cover (Corn and Bury unpublished data).

On the other hand, sites with large amounts of CWD may be occupied by many individuals yet few are revealed because they are dispersed. Douglas-fir forests can have over 1600 m^3/ha of CWD (Spies et al. *in press*). Recently, we found that the density of salamanders in the Oregon Coast Range (number/m^3 of CWD) was inversely related to the amount of CWD present in the stand (Corn and Bury unpublished data). TCS will underestimate abundance in stands with large amounts of CWD relative to stands with less CWD. Underestimation of the numbers of amphibians and reptiles in ecosystems is often more common than overestimation. Furthermore, we discovered that some collectors tended to focus on older decay classes of CWD (that often yield the highest catch) rather than uniformly searching all objects.

To estimate abundance of salamanders, we suggest recording the volume of CWD searched, control for time per object (e.g., 15 minutes maximum), balance effort (e.g., equivalent search between different decay classes of CWD), and relate catch per volume of objects to separate estimates of the total CWD per hectare. These changes are needed to improve the value of TCS techniques for sampling the herpetofauna of forest ecosystems.

Pitfall traps catch the large numbers of individuals needed for quantified analyses of differences between forest stand types. They proved to be particularly important for sampling migratory species of amphibians, which we found to be common in Cascade forests. Also, our recent results indicate for the first time that tailed frogs occur in "upland" forested habitats.

Vogt and Hine (1982) pointed out that pitfall traps were most efficient during periods of precipitation or soon thereafter. Our results confirm these observations and, lately, we have reduced pitfall operations to 30-50 days in the fall only. Also, the triad design used here was highly effective but required great effort (900 m of drift fence was installed) in Pacific Northwest forests, which have large tree roots and rocky soils. Drift fences are more cost-effective in sandy areas where they can be more readily installed.

We caught few reptiles in the Cascade Mountains and pitfall traps were ineffective for these animals, even in the warmer summer months. Reptiles may be numerous in certain clearcuts (e.g., tables 4-5), in drier regions such as interior areas of northern California (e.g., Raphael and Barrett 1984, Raphael, this volume) and, based on our prior experience, in some young managed stands (10-30 years old). When present, these would be worth sampling with pitfall traps.

Pitfall traps alone are adequate to capture most amphibians and small mammals (Bury and Corn 1987) but overall sample size can be improved by increasing the number of traps per site. Thus, we have more recently employed a 6 by 6 pitfall grid (36 traps; 15-m spacing) and the catch is large enough for quantitative analyses. These adjustments greatly increase the use and effectiveness of pitfall trapping in the Pacific Northwest and, likely, in other forested habitats.

Association of Herpetofauna with Old-Growth Forests

TCS revealed microhabitat differences between terrestrial species of salamanders, confirming general observations about these species (e.g., see Nussbaum et al. 1983, Stebbins 1985). However, the habitat requirements of these forms need better investigation.

The Oregon slender salamander seems to be associated with coarse woody debris in older decay classes, which is a characteristic feature of old-growth forests. This species is endemic to the Oregon Cascades, occurring only in Douglas-fir and subalpine forests. Thus, timber harvest might affect populations of slender

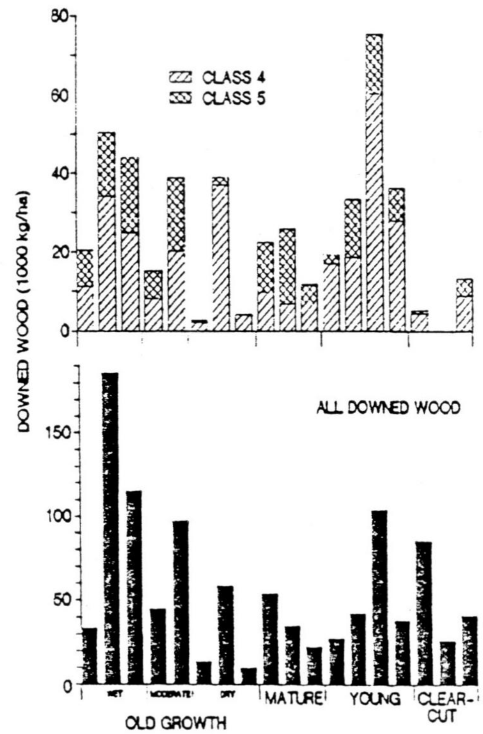

Figure 6.—Biomass of all (top) and class 4 and 5 (bottom) downed wood at 18 stands at the H. J. Andrews Experimental Forest, Oregon.

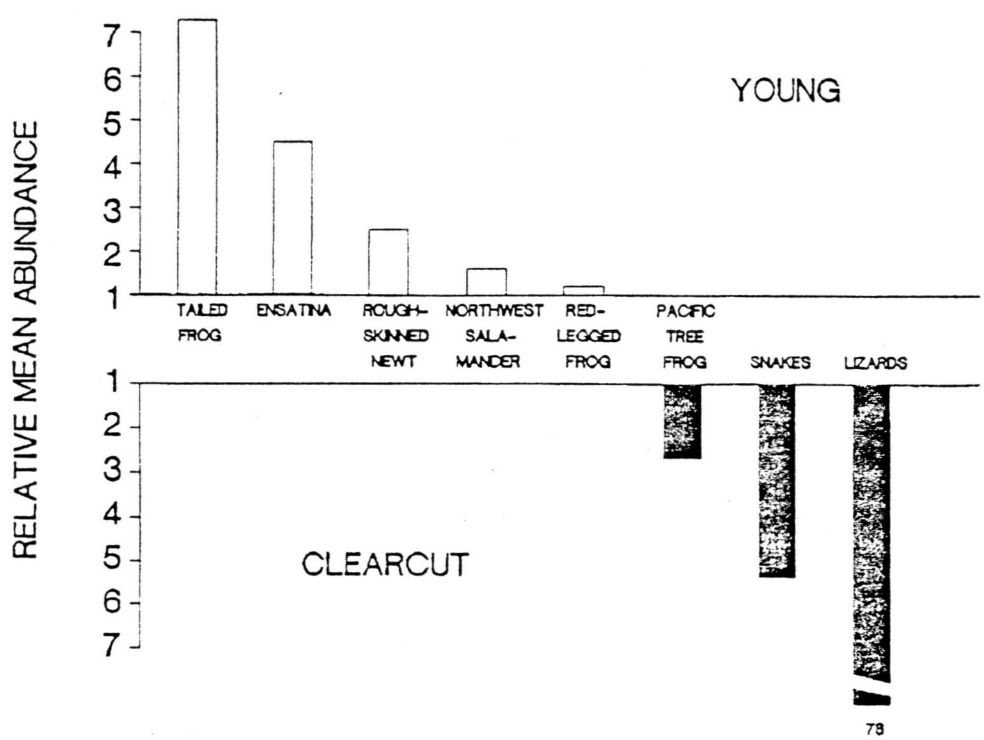

Figure 7.—Relative abundance of herpetofauna in young stands and clearcuts. Above the horizontal: species more abundant in young stands. Below: species more abundant in clearcuts. Values are the greater mean adundance divided by the lesser, e.g., lizards were 78 times more abundant in clearcuts than in young forest stands.

salamanders, and this species merits special study.

The Olympic salamander *(Rhyacotriton olympicus)* occurs in or near small streams, which can be disrupted by timber harvest (Bury 1988, Bury and Corn 1988, Welsh, this volume). Our techniques sampled terrestrial habitats and we found few of this species (pitfall traps took only 4 in old-growth and 1 in mature stands). Many tailed frogs were captured in pitfall traps in closed-canopy forests, but they were absent or rare in clearcuts (only 1% of the total catch). Both the Olympic slamander and the tailed frog seem to be sensitive to timber harvest, and the survival of these species may depend on protection of cool, flowing streams (required for breeding and larval development) as well as adjacent forested habitats (for shade and retention of stream substrate quality, see Bury and Corn 1988). There is a need to assess the effects of logging in streamside and upland forests, which may directly or indirectly affect amphibians in headwaters and small streams (Cooper et al. 1988, Bury and Corn 1988).

Adults of the rough-skinned newt and Northwestern salamander migrate to ponds for breeding and, later, the adults and juveniles move back to land, which obfuscates their relation to forest type. The red-legged frog breeds in slow-moving creeks or ponds, and the proximity of such waters may have influenced the abundance of the frog in adjacent stands.

Tailed frogs breed in small streams and the location of these waters can greatly influence the occurrence of the species in nearby forest stands. Also, we captured some juvenile and adult tailed frogs 100 to >300 m from the nearest stream (Bury 1988). Before our study, tailed frogs were not thought to move far from water (Metter 1964, Nussbaum et al. 1983). Proximity of aquatic breeding sites apparently influenced the capture of several species in upland habitat. At the same time, aquatic and semi-aquatic species might depend on the forest habitat for part of their life history, e.g., dispersal. We suggest that future research emphasize the life history requirements and movement patterns of amphibians, which might help to resolve which factors are most important to their continued local occurrence and abundance.

Fewer Oregon ensatina were captured in mature forests than either young or old-growth stands, and this salmander might be associated with large amounts of CWD in the Oregon Cascades. Mature forests lack input from large trees and snags (see discussions by Franklin et al. 1981, Harmon et al. 1986, Spies et al. *in press*). Disturbance (fire or blow-down) creates new young stands with appreciable amounts of CWD.

Similar to our results, Raphael and Barrett (1984) found that the abundance of Oregon ensatina in northern California was correlated to density of large Douglas-fir trees. However, they found few ensatina in the youngest stands (<150 years) they studied, and they included ensatina with species associated with old-growth stands. In the Oregon Cascades, ensatina were ubiquitous and there is no apparent correlation with old-growth stands.

Clouded salamanders were most abundant under the bark of relatively young logs. They may prefer class 2 and 3 logs, particularly occupying logs with loose bark. Also, clouded salamanders appear to be common in clearcuts (table 1). This species does not appear to be associated with old-growth conditions.

In Washington, we only found the Larch Mountain salamander *(Plethodon larselli)* at one old-growth stand (table 2). This species may be associated with forested stands (Herrington and Larson 1985), but the relation needs further inquiry and verification.

Management Considerations

Current evidence suggests that rich, abundant populations of herpetofauna occur in naturally regenerated forests. Within these stands, however, we found few differences in amphibians between wet, moderate, and dry old-growth sites and between young, mature, and old-growth stands. These results might be related to "old-growth" features occurring in many or all of these stands. For example, young and mature sites retained many characteristics of old-growth forests: complex structure, snags, and large amounts of downed woody debris, particularly in older decay classes (fig. 6). Such material is the result of wildfire that burns and kills larger trees, which later fall to the ground.

Wildfire often burns unevenly through stands, resulting in patches of lightly burned or unburned vegetation surrounded by areas more intensively affected by fire. Some large trees might not be killed during fires and these persist into the regenerated stand. Burned trees become snags that later fall to the forest floor, creating huge amounts of CWD. This heterogeneity and large amounts of CWD in naturally regenerated forest likely maintain favorable conditions for many species of the herpetofauna.

Managed stands (clearcuts) had little downed CWD in older decay clases (fig. 6) and, generally, no snags nor trees (except for a rare spar pole or small planted trees). Current forestry practices usually fell all trees and snags at sites, eliminating variability in stand age and structure. Logging is generally followed by prescribed burning of slash and cull logs, reducing CWD by 50% or more (Bartels et al. 1985, Maser et al. 1979). The large amount of CWD at one of our Oregon clearcuts reflects light burning (fig. 6). Also, this site was surrounded by dense, old-growth forest, which probably contributed large amounts of CWD before burning.

Often, the result of current timber harvest is even-aged stands with little CWD, especially in larger sizes. Present logging differs from that performed 30 or more years ago, when more CWD was left on the forest floor and smaller trees were left intact or ignored. Also, earlier practices tended to harvest larger, more valuable trees with little or no site preparation (except tree-planting), particularly on private lands. These were economic decisions, but the resultant second-growth stands may differ markedly from current intensive management of forests.

In contrast to clearcuts, young stands (naturally regenerated) we studied were closed-canopy and had much downed woody debris. The predominant species were the tailed frog and ensatina, and young stands had more newts, Northwestern salamanders and red-legged frogs than did clearcuts (fig. 7). Thus, there seem to be major differences in the herpetofaunas of pre-canopy clearcuts and naturally regenerated stands (young to old-growth).

There is a critical need to compare differences in wildlife in intensively managed stands and those subjected to other treatments (e.g., prior logging practices, select-cut). At this time, there is a lack of information on herpetofaunas or other wildlife in managed second-growth forests. Managed forests soon will be the predominate forest type in the Pacific Northwest and the bulk of our wildlife probably will occur in these stands. Wise management of these forests should be of foremost concern for wildlife managers, and done in concert with protection of isolated habitat patches (old-growth forest).

ACKNOWLEDGMENTS

We thank our field crew for their untiring efforts: S. Boyle, R. Hayes, L. Hanebury, S. Martin, T. Olson, and S. Woodis. We thank J. Dragavon, L. Jones, P. Morrison, R. Pastor, and D. Smith for checking traps. A. McKee and J. Moreau at the H. J. Andrews Experimental Forest, Oregon, and personnel at Wind River Experimental Forest and the Carson National Fish Hatchery, Washington, supplied logistical support. Data in figure 6 was provided by T. Spies. We also thank R. E. Beiswenger, A. B. Carey, and M. G. Raphael for review comments. This is contribution number 67 of the USDA Forest Service Project, Wildlife Habitat Relationships in Western Washington and Oregon.

LITERATURE CITED

Anthony, R. G., E. D. Forsman, G. A. Green, G. Witmer, and S. K. Nelson. 1987. Small mammal populations in riparian zones of different-aged coniferous forests. Murrelet 68:94-102.

Bartels, Ronald, John D. Dell, Richard L. Knight, and Gail Schaefer. 1985. Dead and down woody material. p. 171-186. *In* E. Reade Brown, tech. ed., Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1 - chapter narratives. USDA Forest Service, Pacific Northwest Publ. No. R6-F&WL-192-1985.

Bennett, Stephen H., J. Whitfield Gibbons, and Jill Glanville. 1980. Terrestrial activity, abundance and diversity of amphibians in differently managed forest types. American Midland Naturalist 103:412-416.

Bruce, Charles, Dan Edwards, Kim Mellen, Anita McMillan, Tom Owens, and Harold Sturgis. 1985. Wildlife relationships to plant communities and stand conditions. p. 33-55. *In* E. Reade Brown, tech. ed., Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1 - chapter narratives. USDA Forest Service, Pacific Northwest Publ. No. R6-F&WL-192-1985.

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

Bury, R. Bruce. 1988. Habitat relationships and ecological importance of amphibians and reptiles. [In press] *In* Kenneth J. Raedeke, ed., Streamside management: riparian wildlife and forestry interactions. Proceedings of a Symposium [University of Washington, Seattle, February 11-13, 1987] Institute of Forest Resourses, University of Washington.

Bury, R. Bruce, and Paul Stephen Corn. 1987. Evaluation of pitfall trapping in northwestern forests: trap arrays with drift fences. Journal of Wildlife Management 51:112-119.

Bury, R. Bruce, and Paul Stephen Corn. 1988. Responses of aquatic and streamside amphibians to timber harvest. [In press] *In* Kenneth J. Raedeke, ed., Streamside management: riparian wildlife and forestry interactions. Proceedings of a Symposium [University of Washington, Seattle, February 11-13, 1987] Institute of Forest Resourses, University of Washington.

Bury, R. Bruce, and Martin G. Raphael. 1983. Inventory methods for amphibians and reptiles. p. 416-419. *In* John F. Bell and Toby Atterbury, eds., Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference. [Corvallis, Oregon, August 15-19, 1983] Society of American Foresters 83-14.

Campbell, Howard W., and Stephen P. Christman. 1982. Field techniques for herpetofaunal community analysis. p. 193-200. *In* Norman J. Scott, Jr., ed., Herpetological Communities. U.S. Fish and Wildlife Service, Wildlife Research Report No. 13.

Carey, Andrew B. 1988. The influence of small streams on the composition of upland bird communities. [In press] *In* Kenneth J. Raedeke, ed., Streamside management: riparian wildlife and forestry interactions. Proceedings of a Symposium [University of Washington, Seattle, February 11-13, 1987] Institute of Forest Resourses, University of Washington.

Cooper, Edward J., William J. Trush, and Allen W. Knight. 1988. Effects of logging on Pacific giant salamanders: influence of age-class composition and habitat complexity. Bulletin of the Ecological Society of America 69(suppl.):104-105.

Enge, Kevin E., and Wayne R. Marion. 1986. Effects of clearcutting and site preparation on herpetofauna of a north Florida flatwoods. Forest Ecology and Management 14:177-192.

Fosburg, Whit. 1986. Wildlife issues in the National Forest system. p. 159-173. *In* Roger L. Di Silvestro ed., Audubon Wildlife Report 1986. The National Audubon Society, New York. 1094 p.

Franklin, Jerry F., and Thomas A. Spies. 1984. Characteristics of old-growth Douglas-fir forests. p. 328-334. *In* Proceedings, Society of American Foresters national convention. [Portland, Oregon, October 16-20, 1983] Society of American Foresters, Washington, D.C.

Franklin, Jerry F., Kermit Cromack, Jr., William Denison, Arthur McKee, Chris Maser, James Sedell, Fred Swanson, and Glen Juday. 1981. Ecological characteristics of old-growth Douglas-fir forests. U.S. Forest Service, General Technical Report PNW-118. 48 p.

Friend, Gordon R. 1984. Relative efficiency of two pitfall-drift fence systems for sampling vertebrates. Austalian Zoologist 21:423-433.

Gibbons, J. Whitfield, and Raymond D. Semlitsch. 1981. Terrestrial drift fences with pitfall traps: an effective technique for quantitative sampling of animal populations. Brimleyana 7:1-16.

Harmon, M. E., J. F. Franklin, F. J. Swanson, P. Sollins, S. V. Gregory, J. D. Lattin, N. H. Anderson, S. P. Cline, N. G. Aumen, J. R. Sedell, G. W. Lienkaemper, K. Cromack, Jr., and K. W. Cummins. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research 15:133-302.

Harris, Larry D. 1984. The Fragmented Forest: Island Biogeography Theory and the Preservation of Biotic Diversity. University of Chicago Press. 211 p.

Herrington, Robert E., and John H. Larson. 1985. Current status, habitat requirements and management of the Larch Mountain salamander *Plethodon larselli* Burns. Biological Conservation 34:169-179.

Jones, K. Bruce. 1981. Effects of grazing on lizard abundance and diversity in western Arizona. Southwest Naturalist 26:107-115.

Jones, K. Bruce. 1986. Amphibians and reptiles. p. 267-290. *In* Allen Y. Cooperrider, Raymond J. Boyd, and Hanson R. Stuart eds., Inventory and monitoring wildlife habitat. U.S. Dept. Interior, Bureau of Land Management, Service Center, Denver, Colorado. 858 p.

Kerrick, Michael A., Kathy Johnson, and Richard J. Pedersen. 1984. What information is necessary for planning the management of old-growth forest for wildlife? p. 383-386. *In* Proceedings, Society of American Foresters national convention. [Portland, Oregon, October 16-20, 1983] Society of American Foresters, Washington, D.C.

Manuwal, David A., and Mark H. Huff. 1987. Spring and winter bird populations in a Douglas-fir forest sere. Journal of Wildlife Management 51:586-595.

Maser, Chris, Ralph G. Anderson, Kermit Cromack, Jr., Jerry T. Williams, and Robert E. Martin. 1979. Dead and down woody material. p. 78-95. *In* Jack Ward Thomas, tech. ed., Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agricultural Handbook 553. U.S. Dept. Agriculture, Washington, D.C.

Maser, Chris, and James M. Trappe (tech. eds.). 1984. The seen and unseen world of the fallen tree. USDA Forest Service General Technical Report PNW-164. 56 p.

Metter, Dean E. 1964. A morphological and ecological comparison of two populations of the tailed frog, *Ascaphus truei* Stejneger. Copeia 1964:181-195.

Nussbaum, Ronald A., Edmund D. Brodie, Jr., and Robert M. Storm. 1983. Amphibians and Reptiles of the Pacific Northwest. University Press of Idaho, Moscow. 332 p.

Pough, F. Harvey, Ellen M. Smith, Donald H. Rhodes, and Andres Collazo. 1987. The abundance of salamanders in forest stands with different histories of disturbance. Forest Ecology and Management 20:1-9.

Raphael, Martin G. 1984. Wildlife populations in relation to stand age and area in Douglas-fir forests of northwestern California. p. 259-274 *In* William R. Meehan, Theodore R. Merrell, Jr., and Thomas A. Hanley, eds., Fish and wildlife relationships in old-growth forests. Proceedings of a symposium. [Juneau, Alaska, April 12-15, 1982] 425 p. American Institute of Fishery Research Biologists. (available from John W. Reintjes, Rt. 4, Box 85, Morehead City, North Carolina 28557).

Raphael, Martin G., and Reginald H. Barrett. 1984. Diversity and abundance of wildlife in late successional Douglas-fir forests. p. 352-360. *In* Proceedings, Society of American Foresters national convention. [Portland, Oregon, October 16-20, 1983] Society of American Foresters, Washington, D.C.

Raphael, Martin G., and Kenneth V. Rosenberg. 1983. An integrated approach to wildlife inventories in forested habitats. p. 219-222. *In* John F. Bell and Toby Atterbury, eds., Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference. [Corvallis, Oregon, August 15-19, 1983] Society of American Foresters 83-14.

Rosenberg, Kenneth V., and Martin G. Raphael. 1986. Effects of forest fragmentation on vertebrates in Douglas-fir forests. p. 263-272. *In* Jared Verner, Michael L. Morrison, and C. John Ralph, eds., Wildlife 2000. University of Wisconsin Press. 470 p.

Ruggiero, Leonard F., and Andrew B. Carey. 1984. A programmatic approach to the study of old-growth forest—wildlife relationships. p. 340-345. *In* Proceedings, Society of American Foresters national convention. [Portland, Oregon, October 16-20, 1983] Society of American Foresters, Washington, D.C.

Salwasser, Hal. 1987. Spotted owls: turning a battleground into a blueprint. Ecology 68:776-779.

Scott, Norman J., Jr. (Ed.). 1982. Herpetological Communities. U.S. Fish and Wildlife Service, Wildlife Research Report 13. 239 p.

Spies, Thomas A., Jerry F. Franklin, and Ted B. Thomas. *In press*. Coarse woody debris in Douglas-fir forests of western Oregon and Washington. Ecology.

Stebbins, Robert C. 1985. A Field Guide to Western Reptiles and Amphibians. Houghton Mifflin Co., Boston. 336 p.

Thomas, Don. *In press*. Forest age association of bats in western Oregon and Washington. Journal of Wildlife Management.

Vogt, Richard C., and Ruth L. Hine. 1982. Evaluation of techniques for assessment of amphibian and reptile populations in Wisconsin. p. 201-217. *In* Norman J. Scott, Jr., ed., Herpetological Communities. U.S. Fish and Wildlife Service, Wildlife Research Report 13.

Webb, G. A. 1985. Habitat use and activity patterns in some southeast Australian skinks. p. 23-30. *In* Gordon Grigg, Richard Shine, and Harry Ehmann, eds., Biology of Australasian Frogs and Reptiles. Surrey Beatty & Sons Pty Ltd, New South Wales, Australia.

West, Stephen D. 1985. Differential capture between old and new models of the Museum Special snap-trap. Journal of Mammalogy 66:798-800.

Wilcove, David S. 1987. Public lands management and the fate of the spotted owl. American Birds 41:361-367.

2401. Bury, R. Bruce; Corn, Paul Stephen. 1988. Douglas-fir forests in the Oregon and Washington Cascades: relation of the Herpetofauna to stand age and moisture. In: Management of amphibians, reptiles, and small mammals in North America: Proceedings of the symposium; 1988 July 17-21; Flagstaff, AZ. Gen. Tech. Rep. RM-166. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 11-22.