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Differences in Amphibian Populations in Logged and Old Growth Redwood Forest

Abstract

Surveys of amphibians were done on 8 plots (0.125 ha each), consisting of 4 paired comparisons (logged and unlogged) in or near the Redwood National Park, California. The number and percentage cover of perennial vegetation were greater on old growth plots than on logged sites. Amphibian populations had more individuals and greater biomass, and different species composition on the old growth sites than on logged plots. Abundance of amphibians was lower in the redwood forests that had been logged 6-14 years ago. This evidence suggests that logging has a long-term effect on resident herpetofaunas of redwood forests. Apparently, opening of the canopy favors a few species to the detriment of the majority of forest-dependent species.

Introduction

Advertisements in national magazines imply that productive, abundant wildlife populations inhabit logged lands and that successional stages contain better habitat conditions for wildlife than do mature (sometimes termed decadent) forests. These claims are simplistic because the complexity and variability of mature forest ecosystems or the important roles of nongame wildlife are not considered in these systems.

Hassinger *et al.* (1975) stated that the net worth of a clearcut to wildlife must be viewed as a balance of values, since processes detrimental to one species may be beneficial to another. Logging creates vegetational diversity (e.g., edges and openings) and thus is generally beneficial to game because it promotes increased growth of herbaceous and shrubby foods that many game species require (Teague 1968, Noble 1974, Umber and Harris 1974, Costa *et al.* 1976). But game may constitute only a small fraction of forest wildlife, especially in mature stands (Bury *et al.* 1980).

Logging may drastically change or adversely affect the habitats of many animal species. In western North America, for example, small mammal communities are altered by timber harvesting. Deer mice (*Peromyscus maniculatus*) generally increase in numbers after logging, whereas red-backed voles (*Clethrionomys californicus*), red squirrels (*Tamiasciurus hudsonicus*), and other forest-adapted species decrease (Gashwiler 1970, Wolff and Zasada 1975, Hooven and Black 1976, Sullivan 1980). One study revealed that even big game (deer, elk, and moose) declined during the first 5 years after logging and that the carrying capacity of the forest when measured 17 years after logging was lower than expected (Stelfox *et al.* 1976).

Several authors have suggested that clean logging (removal or burning of downed wood and understory vegetation) reduces the abundance of small mammals (Lovejoy 1975, Martell and Radvanyi 1977, Hansson 1978) and game (Stelfox *et al.* 1976) by decreasing the supply of cover available to them. Recent studies indicate that logging

variously affects different animal taxa and decreases many wildlife species (Umber and Harris 1974, Glowacinski and Järvinen 1975, Shepard 1975, White *et al.* 1975, Bunnell 1976, Ahlén 1976, Franzeb 1977, Webb *et al.* 1977, Kessler 1979, Luman and Neitro 1980, Meslow *et al.* 1981, Schoen *et al.* 1981).

Because of diverse habitat conditions and forest types, the response of wildlife to logging is difficult to predict. More comprehensive data about the effect of timber harvesting on specific types of forests and on the nongame animals in these ecosystems would be useful in designing forest management practices favorable to wildlife populations. This study is the first to examine the effect of clearcut logging on the herpetofauna of old growth redwood forests.

Description of Study Areas

Four study areas were established in or adjacent to the Redwoods National Park in northwestern California: (1) Hill Plot and (2) Valley Plot, both in North Fork drainage of Lost Man Creek (Sec. 13, T.11N, R.1E), 3.5 km E of Hwy. 101 (from the Prairie Creek Fish Hatchery), Humboldt County; (3) Bald Hills (Sec. 1, T.10N, R.1E), 4.3 km E of Orick, along the Bald Hills road, Humboldt County; and (4) Yurok Redwood Experimental Forest (Sec. 21, T.14N, R.1E), 1.3 km N of the Ranger Station, Del Norte County. All distances are direct line.

Each study area consisted of two sampling sites (old growth and clear-cut logged) that had similar steepness (percent slope), slope direction, and major vegetation types (Table 1). On the Hill and Valley Plots and Bald Hills, the total number of live trees plus natural stumps more than 1 m DBH (diameter at breast height) were comparable to the number of stumps (cut trees) on the logged site. The Experimental Forest was more variable. The old growth site had more large trees ($N=12$) than the logged site had large stumps ($N=5$). But these two areas were only 200 m apart and seemed to have similar plant composition, and the entire area was once a contiguous stand of redwood.

Old growth sites at Lost Man Creek and the Experimental Forest were predominantly redwood (*Sequoia sempervirens*) with a few scattered Douglas fir (*Pseudotsuga menziesii*) and Sitka spruce (*Picea sitchensis*). Lost Man Creek was harvested 6-7 years before this study and had no trees larger than 10 cm DBH on logged sites. Logging had occurred 15 years earlier in the Experimental Forest (an area dominated by redwood), and the site had regrown with a tangle of small red alder (*Alnus oregana*). At Bald Hills, both sites had originally contained redwoods mixed with a few tanbark oak (*Lithocarpus densiflora*) and western hemlock (*Tsuga heterophylla*), and many small Douglas fir. Logging at the Bald Hills site had occurred about 10 years before this study.

Methods and Materials

Each sampling site measured 25 x 50 m (0.125 ha). All trees larger than 10 cm DBH were individually measured. On 10 squares (1 x 1 m), arranged in 10 domino configuration at each site, I recorded the number of perennial plants present and visually estimated the percentage of surface area that they covered. The number and sizes of pieces of surface debris (branches, downed small trees, and logging litter) that could be turned over were counted on all sites except the Hill Plot. This characteristic repre-

TABLE 1. Site characteristics and trees (>10cm DBH) of 8 sampling plots (0.125 ha each). Trees or stumps over 1 m DBH are given in bold type.

Character	Lost Man Creek Hill Plot		Lost Man Creek Valley Plot		Experimental Forest		Bald Hills RNP	
	Old Growth	Logged	Old Growth	Logged	Old Growth	Logged	Old Growth	Logged
Slope Direction	NE	NE	NNE	ENE	ENE	E	NNW	NNW
Slope (%) Est.	20	20	15	25	15	20	5	10
Canopy (%) Est.	85	0	75	0	80	10	65	5
TREES:								
<i>Sequoia</i>								
Live	32	11	23	6	13	12	10	7
Stumps	1s	10	1s	1s	—	14m	0	29m
<i>Pseudotsuga</i>								
Live	—	—	1	1	—	3	51	7
Stumps	1s	3	1s	1	—	—	3	—
<i>Picea</i>								
Live	—	—	3	2	—	—	—	2
<i>Tsuga</i>								
Live	—	—	—	—	—	—	3	—
<i>Lithocarpus</i>								
Live	—	—	—	—	—	—	7	4
Stumps	—	—	—	—	—	—	—	1
<i>Alnus</i>								
Live	—	—	—	—	—	32	—	—
Total	32	11	27	9	13	12	71	33
Live	2	1	2	1	0	7	3	10
Stumps	—	—	—	—	—	—	—	—

s=snag
m=mostly in clumps

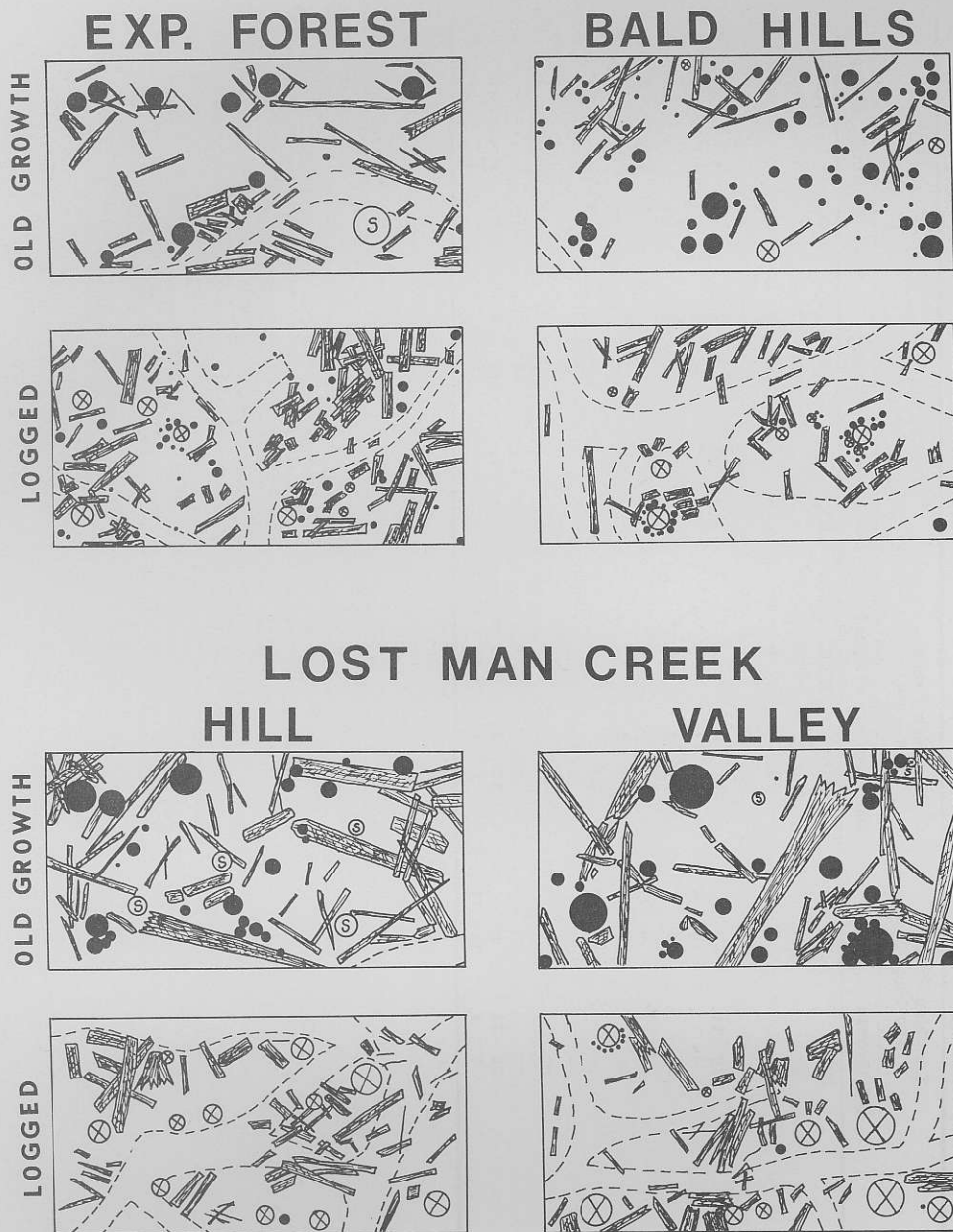


Figure 1. Trees and large downed wood of four paired plots (old growth and logged). Solid circles represent live trees; circles with an "X" are stumps and circles with an "S" are snags. Dashed lines depict logging (skid) roads. Each plot is 25 x 50 m.

sents the amount of small cover available to animals at each site. Larger debris that could not be moved (Fig. 1) also provided important cover.

Thorough searches for amphibians were conducted on each site by turning surface debris and small logs (less than 0.5 m diameter), and by raking through leaf litter. A team of two to five people worked each site and examined paired plots consecutively in order to minimize differences due to weather conditions. Field work was done from mid-January to early February 1975.

Animals were weighed to the nearest 0.1 g on field spring scales. Representative series were preserved as vouchers, and these specimens are deposited at the National Museum of Natural History, Washington, D.C.

Significance levels were $P < 0.05$, unless otherwise stated.

Comparison of Vegetation and Cover

In general, old growth areas had more ferns, huckleberry, and salal than logged sites on which small conifers and alders predominated (Table 2.) The average number and percent cover of perennial plants on old growth sites was 40.2 (31-51) and 60.1 percent (32.5 -75.0 percent), respectively, which was greater than the average values of 30.0 (22-51) and 31.5 percent (20.0-52.5 percent) on logged sites. There were significantly more perennials at two old growth sites (Hill Plot, Bald Hills) and the logged area at the Experimental Forest (because of more small conifers and alders) than on their paired plots, but no difference at Lost Man Creek-Valley (χ^2 test). Percent cover was significantly greater on the unlogged than logged plots, except at Bald Hills (Test of Percentages).

Two of the old growth sites had significantly more surface debris than their logged counterparts (χ^2 test), but one logged site (Valley Plot) had almost the same amount of debris as the old growth site (Table 3). The percent of litter smaller than 0.6 m long was greater on logged sites ($\bar{x} = 66.8$ percent; range 61-73 percent) than on old growth sites ($\bar{x} = 48.0$ percent; range 44-52 percent). The large number of short pieces of litter on logged sites is partially produced by breakage of branches and trees during logging operations.

Differences in Amphibian Populations

Numbers of species and individuals, and the biomass of amphibians differed between old growth and logged sites (Table 4). The old growth sites had slightly more species ($\bar{x} = 3.5$; range 3-6) than did logged areas ($\bar{x} = 3.3$; range 2-4). This difference was not statistically significant, but there were distinct qualitative differences since certain species were found either in old growth or only on logged sites. The Olympic salamander (*Rhyacotriton olympicus*) and tailed frog (*Ascaphus truei*) occurred only in a rivulet through the old growth Hill Plot (Lost Man Creek), whereas the Pacific treefrog (*Hyla regilla*) was found only in a logged plot. Search of a rivulet in the logged area yielded no *Ascaphus* nor *Rhyacotriton*. Pacific giant salamanders (*Dicamptodon ensatus*) occurred on half of the old growth sites, but none were found in logged areas.

For each paired comparison, there were more individuals and greater biomass in old growth plots than in logged sites ($P < 0.01$, χ^2 test). Further, the relative abundance of species in old growth and logged sites was noticeably different (Table 4). There were more individuals of *Ensatina eschscholtzi* in old growth area ($N = 52$; $\bar{x} = 13$, range 4-22) than in logged sites ($N = 20$; $\bar{x} = 5$, range 3-8), and more *Batrachoseps attenuatus* in old growth ($N = 136$; $\bar{x} = 34$, range 18-61) than in

TABLE 2. Perennial plants recorded at 10 stations (total area=10 m²).
Abbreviations: N=Total number of individuals; C(%)=Percent cover.

Plants	Lost Man Creek Hill Plot				Lost Man Creek Valley Plot				Experimental Forest				Bald Hills RNP			
	Old Growth		Logged		Old Growth		Logged		Old Growth		Logged		Old Growth		Logged	
	N	C(%)	N	C(%)	N	C(%)	N	C(%)	N	C(%)	N	C(%)	N	C(%)	N	C(%)
Ferns (mostly <i>Polystichum</i>)	24	40.5	7	4.5	31	60.5	2	1.0	23	60.5	13	12.5	3	1.5	3	2.5
Huckleberry (<i>Vaccinium ovatum</i>)	10	12.0	—	—	3	8.5	1	0.5	5	6.0	9	11.5	11	12.0	1	1.0
Blackberry (<i>Rubus vitifolius</i>)	—	—	3	2.0	—	—	—	—	—	—	—	—	—	—	4	2.5
Thimbleberry (<i>Rubus parviflorus</i>)	—	—	—	—	—	—	—	—	—	—	5	4.5	—	—	—	—
Salmon Berry (<i>Rubus spectabilis</i>)	—	—	—	—	—	—	—	—	1	1.0	1	1.0	—	—	—	—
Salal (<i>Gaultheria shallon</i>)	8	7.0	—	—	2	4.0	2	2.5	2	7.5	1	0.5	7	3.5	1	1.0
Rhododendron (<i>Rhododendron macrophyllum</i>)	—	—	—	—	—	—	—	—	—	—	—	—	9	6.0	—	—
California Lilac (<i>Ceanothus</i> sp.)	—	—	1	5.0	—	—	6	15.5	—	—	17	20.0	—	—	—	—
Small Conifers (<i>Sequoia</i> , <i>Pseudotsuga</i>)	—	—	14	10.0	1	0.5	11	11.0	—	—	—	—	17	6.5	13	13.0
Small Alders (<i>Alnus oregana</i>)	—	—	—	—	—	—	—	—	—	—	5	2.5	—	—	—	—
Small Tan Bark Oak (<i>Lithocarpus densiflora</i>)	—	—	—	—	—	—	—	—	—	—	—	—	4	3.0	—	—
Totals	42	59.5	25	21.5	37	73.5	22	30.5	31	75.0	51	52.5	51	32.5	22	20.0

TABLE 3. Comparison of surface debris at 6 sampling plots.

LOST MAN CREEK—VALLEY PLOT																
Length (m)	OLD GROWTH Diameter (cm)							LOGGED Diameter (cm)								
	<30			30-59	60-119	>120	TOTALS (%)	<30			30-59	60-119	>120	TOTALS (%)		
	<10	10-19	20-19					<10	10-19	20-29						
<0.6	242	80	22	2	0	0	345 (43.6)	360	111	58	5	0	0	534 (67.1)		
0.6-1.2	168	30	10	2	0	0	210 (26.5)	90	47	27	9	2	0	175 (22.0)		
1.2-1.8	114	18	6	0	3	0	141 (17.8)	34	13	5	2	3	0	57 (7.2)		
1.8-2.4	50	3	1	1	0	0	55 (6.9)	9	10	1	1	0	0	21 (2.6)		
2.4-3.0	19	1	4	1	0	0	25 (3.2)	0	1	2	1	0	0	4 (0.5)		
>3.0	9	2	3	2	0	0	16 (2.0)	1	2	2	0	0	0	5 (0.6)		
TOTALS (%)	602 (75.9)	134 (16.9)	46 (5.8)	8 (1.0)	3 (0.4)	0	793	494 (62.1)	184 (23.1)	95 (11.9)	18 (2.3)	5 (0.6)	0	796		

EXPERIMENTAL FOREST																
Length (m)	OLD GROWTH Diameter (cm)							LOGGED Diameter (cm)								
	<30			30-59	60-119	>120	TOTALS (%)	<30			30-59	60-119	>120	TOTALS (%)		
	<10	10-19	20-19					<10	10-19	20-29						
<0.6	483	109	62	8	0	0	662 (51.9)	395	101	34	2	0	0	532 (72.7)		
0.6-1.2	283	56	45	7	1	0	392 (30.8)	63	35	28	3	0	0	129 (17.6)		
1.2-1.8	89	37	14	5	0	1	146 (11.5)	5	20	14	4	4	0	47 (6.4)		
1.8-2.4	23	13	10	3	1	0	50 (3.9)	2	4	4	3	0	0	13 (1.8)		
2.4-3.0	10	4	3	1	0	0	18 (1.4)	0	1	0	1	0	0	2 (0.3)		
>3.0	2	2	1	2	0	0	7 (0.5)	0	2	3	1	3	0	9 (1.2)		
TOTALS (%)	890 (69.8)	221 (17.3)	135 (10.6)	26 (2.0)	2 (0.2)	1 (0.1)	1275	465 (63.5)	163 (22.3)	83 (11.3)	14 (1.9)	7 (1.0)	0	732		

Length (m)	OLD GROWTH Diameter (cm)					TOTALS (%)	LOGGED Diameter (cm)					TOTALS (%)
	<30		30-59	60-119	>120		<30		30-59	60-119	>120	
	<10	10-19	20-29				<10	10-19	20-29			
<0.6	404	53	15	1	0	473 (52.5)	283	77	29	3	0	392 (60.7)
0.6-1.2	207	15	6	3	0	231 (25.7)	83	33	15	11	1	143 (22.1)
1.2-1.8	106	10	3	2	0	121 (13.4)	44	17	7	2	0	70 (10.8)
1.8-2.4	29	3	2	0	0	34 (3.8)	11	6	4	1	0	22 (3.4)
2.4-3.0	22	0	0	0	0	22 (2.4)	7	3	3	1	0	14 (2.2)
>3.0	15	2	2	1	0	20 (2.2)	3	0	1	1	0	5 (0.8)
TOTALS (%)	783 (86.9)	83 (9.2)	28 (3.1)	7 (0.8)	0	901	431 (66.7)	136 (21.1)	59 (9.1)	19 (2.9)	1 (0.2)	646

logged sites ($N = 21$; $\bar{x} = 3.3$, range 1-9). *Aneides ferreus* was more abundant in logged areas ($N = 35$; $\bar{x} = 8.8$, range 0-30) than in old growth ($N = 12$; $\bar{x} = 4$, range 0-9). This species constituted 68 percent of the herpetofauna at the Bald Hills logged area.

Sampling of quadrats required intensive search effort and relatively few animals were found per person-hour (Table 4). More time was required to sample old growth plots due to the greater amount of leaf litter present there than in logged areas.

Discussion

This study indicates that there is a distinct change in the species composition of both the perennial plants and the amphibians following logging of redwood forests. Relative abundances of animals also differ in old growth and post-logging habitats.

Logging opens the forest canopy and apparently favors only a few species of amphibians to the detriment of the majority—the forest-dependent species. The salamanders *Ensatina* and *Batrachoseps* were found principally in old growth redwood stands, in agreement with results of an earlier study at a locality about 100 km farther south (Bury and Martin 1973). Also, *Aneides ferreus* at this southern area was more prevalent in second-growth than in primary forests, the pattern that held in the present study. Because this species frequents crevices and bark under downed timber in California (Stebbins 1951, Bury and Martin 1973), logging apparently provides its preferred habitat conditions. Old growth sites examined in the present study had several species (*Ascapbus*, *Rhyacotriton*, and *Dicamptodon*) that were absent on logged areas. *Ascapbus* and *Rhyacotriton* frequent cold, flowing waters (Bury 1968, Stebbins 1966), whereas *Dicamptodon* usually occurs in forested environs.

Amphibians were more abundant in old growth forests than in logged areas. Similarly, in South Carolina, Bennett *et al.* (1980) found a higher number of amphibians in natural oak-hickory habitat than in nearby managed pine habitats.

I suggest a scenario of events that resulted in these changes of amphibians. Clearcut logging opens the redwood forest canopy. The increased light penetration on the forest floor leads to increased soil temperatures and, in turn, greater evaporative water loss from the soil and understory. Opened areas also are subject to greater daily fluctuations in temperature and humidity than in primary forests.

Barren soil occurs in parts of logged areas, apparently a result of increased microbial activity (related to higher ambient temperatures) combined with erosion of the organic top soil and humus, which occurs rapidly in a region receiving about 180 cm of precipitation each year. Also, logged areas lack nutrients through leaf fall from large trees. These conditions reduce leaf litter as a microhabitat for amphibians.

Available cover for amphibians in both old growth and logged redwood forests was ample (Table 3), particularly since these counts did not include immovable fallen trees, buried debris, and stumps (Fig. 1). Also, leaf litter (which was not measured) provided refuge for animals in old growth forests.

Although two of the three old growth sites contained greater amounts of cover, logged plots also had large numbers of cover items. The difference in cover supply apparently was not responsible for the differences in terrestrial vertebrates occurring in native or harvested redwood forests. Rather, microclimatic, vegetational and other

TABLE 4. Herpetofauna taken on 8 sampling plots (0.125 ha each). Weight (Wt) is in grams.

Species	Lost Man Creek Hill Plot				Lost Man Creek Valley Plot				Experimental Forest				Bald Hills RNP			
	Old Growth	Logged	Old Growth	Logged	Old Growth	Logged	Old Growth	Logged	Old Growth	Logged	Old Growth	Logged	Old Growth	Logged	Old Growth	Logged
	N	Wt	N	Wt	N	Wt	N	Wt	N	Wt	N	Wt	N	Wt	N	Wt
<i>Ensatina eschscholtzi</i>	4	6.5	5	12.8	8	15.3	3	7.7	18	39.4	8	18.1	22	55.0	4	8.5
<i>Anelides ferreus</i>	—	—	—	—	1	1.4	—	—	9	20.9	5	13.2	2	3.2	30	67.5
<i>Batrachoseps attenuatus</i>	18	11.5	1	0.3	20	13.1	2	1.8	61	34.8	9	6.0	37	27.3	9	7.4
<i>Ambystoma gracile</i>	—	—	—	—	—	—	—	—	—	—	2	31.2	—	—	—	—
<i>Dicamptodon ensatus</i>	3	2.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
larvae	1	28.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
juvenile	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Rhyacotriton olympicus</i>	2	0.6	—	—	—	—	—	—	—	—	—	—	2	88.8	—	—
<i>Plethodon elongatus</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	3.8	—	—
<i>Ascaphus truei</i>	1	6.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Hyla regilla</i>	—	—	1	0.3	—	—	—	—	—	—	—	—	—	—	—	—
Total	29	55.7	7	13.4	29	29.8	5	9.5	88	95.1	24	68.5	64	178.1	43	83.4
Person-hours	19.5	—	7.5	—	36.0	—	7.5	—	44	—	16.5	—	31.5	—	9	—
N/person-hr	1.5	—	0.9	—	0.8	—	0.7	—	2.0	—	1.5	—	2.0	—	4.8	—

changes that occur after logging apparently result in unsuitable conditions for many amphibians.

The resident, forest-dependent amphibians are drastically altered in both species composition and abundance after logging. Amphibians had not recovered on sites sampled 6-14 years after logging. It is not known how long a logged area requires to revert naturally to a condition in which the fauna typical of old growth redwood is regained. Further, it is not known what can be done to expedite the recovery of these wildlife communities after timber harvesting.

Amphibians are often neglected in studies of ecosystems, but they are important. For example, Burton and Likens (1975) demonstrated that salamanders in a forest ecosystem may comprise a biomass twice that of birds and equal to mammals. Amphibians may be equally important to redwood forests. In old growth stands, I found 420 amphibians per ha, and I believe that this figure probably underestimated the resident populations, since my sampling was conducted during a time of cool to freezing temperatures and low rainfall, conditions that are not favorable for surface activity by amphibians.

Recently, the Redwood National Park acquired logged land adjacent to the park as buffer zones. These areas had been logged by clearcutting with little or no regard for the unique wildlife communities associated with the old growth redwood. Large block cuts left no shade or islands of natural forest (to provide reservoirs for reinvasion), and the terrain is scarred and strewn with logging debris.

Because national and state redwood parks are managed for aesthetic and biotic values, we face a challenge in the rehabilitation of logged redwood forests that have been acquired as buffer zones for parks. The present study suggests that logging has a long term detrimental effect on most species of amphibians in the redwood region, and that the addition of cover or the piling of debris in logged redwood areas would probably not promote the recovery of amphibians. Although amphibians are the most abundant vertebrate of redwood forests, we cannot manage their populations because we lack knowledge of the unique fauna of old growth redwood forests; we also do not understand how logged wasteland can be restored to suitable habitat for forest-dependent wildlife.

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