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Small Mammal Abundance in Riparian and Upland Areas of Five Seral Stages in Western Oregon

Abstract

We compared species composition and relative abundance of small mammals between riparian and upland habitats among five seral stages in the Coast Range of Western Oregon to determine the significance of these areas to different species. Riparian- and upland-associated species were identified based on capture frequencies from pitfall trapping. Species richness was similar between stream and upland habitats and among the five seral stages. However, there were significant differences in the abundances of nine small mammal species among seral stages. Total captures were highest in deciduous stands and progressively lower from shrub to old-growth coniferous forests. *Neurotrichus gibbsii, Sorex bendirii, Sorex pacificus, Microtus longicaudus, Microtus townsendii. Phenacomys albipes*, and *Zapus trinotatus* were captured in significantly higher numbers in riparian than in upland habitats. *S. pacificus* and *M. longicaudus* should be considered riparian associated species; *S. bendirii* should be considered an obligate species of riparian habitat. In contrast, *Clethrionomys californicus* showed a strong association with upland habitat. Our results indicate that small (second- third- and fourth-order) riparian systems and adjacent upland areas provide important habitat for small mammals on the Oregon Coast Ranges. Conservation plans of these riparian systems should consider these species as important components of these ecosystems.

Introduction

Riparian areas are known as some of the most productive and diverse habitats available to wildlife (Thomas et al. 1979, Oakley et al. 1985). Kauffman (1988) suggested riparian habitats may be used by large numbers of wildlife species, and play a significant and often essential role in the maintenance of wildlife communities in the adjacent upland habitats (Hirsch and Segelquist 1978). Intergradation of riparian vegetation with the adjacent upland habitat provides increased structural diversity for wildlife and creates important habitat for the survival and reproduction of many species (Thomas et al. 1979, Oakley et al. 1985). The diverse composition and structure of vegetation and the variability in soil moisture in riparian areas may influence many species of wildlife by providing food and other essential resources. Thomas et al. (1979) suggested that riparian habitat provides a source of cover, food, and water to small mammals dispersing to different habitats. Campbell and Franklin (1979) were able to identify distinct plant communities within riparian and upland areas using a gradient approach.

The distinct vegetative communities and microclimates in riparian areas, along with their rarity (e.g. less than 1% of Western United States, Knopf et al. 1988) and linear nature, makes them sensitive to habitat loss and alterations. Hirsch and Segelquist (1978) and Hair (1988) cited the urgency of preservation of remaining riparian habitat, with an estimated 70-90% of all natural riparian areas already lost in the Eastern United States. Human disturbance of natural communities including timber harvesting, livestock grazing, road building, channeling and dam building has increased (Hall 1988). Changes in stream morphology, water quality, and vegetation often result from these disturbances, followed by a decrease in the productivity of aquatic systems and the terrestrial vertebrate community (Kauffman 1988). Ultimately, these changes produce a shift in dominance to the more adaptable species, which are associated with disturbed habitats (Kauffman 1988).

The importance of maintaining riparian forest vegetation for the benefit of fish populations on larger fish bearing streams has been recognized for years (Meehan et al. 1977, Sedell et al. 1982). However the importance to other vertebrates, especially on smaller streams, is less clear. Despite the large proportion of the vertebrate community that is comprised of small mammals (approximately 38 small-mammal species, Cross 1988), the significance of riparian areas to these species is not well documented. Simons (1985) found similar small-mammal communities between old-growth and logged riparian areas in the Siskiyou

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Range of Northern California. Small-mammal species richness was higher in riparian areas compared with adjacent fringe or upland habitats in the Oregon Cascades (Anthony et al. 1987, Cross 1985, and Doyle 1990). In addition, Anthony et al. (1987) suggested that mammalian insectivores could be particularly sensitive to alterations in riparian habitats in parts of the Cascade mountains. According to Cross (1985), use of riparian habitat was not restricted to obligate species; some rodents with larger home ranges utilized riparian components for part of their daily and seasonal activity.

We compared species composition and relative abundance of small mammals between riparian and upland habitats and among five seral stages. We hypothesized that there were differences in small mammal communities amongst seral stages, between riparian and upland habitats, and along the inter-riparian transects. We also comment on the importance of small perennial (second-forth order) mountainous streams for riparian associated mammals and their conservation.

Methods

Study sites

Fifteen study sites were located along perennial streams in the Central Coast Ranges, Lincoln and Benton Counties, Oregon. Franklin and Dyrness (1973:31-32) described the Coast Ranges as a zone which receives 170-300 cm of precipitation a year with average temperatures that seldom drop below 0° C in winter and never exceed 27° C in summer. Organic matter content is high and acidity is medium (Franklin and Dyrness 1973:9-10).

We located three study sites for each of five seral stages (Hall et al. 1985) including: (1) shrub conifer forests; 5-10 years old, trees <3 m tall, dbh <2.5 cm, <40% crown cover, with grass-forb condition intermittent, dominant tree species Douglas-fir (*Pseudotsuga menziesii*) (2) open sapling-pole conifer forests; 20-35 years old, trees usually >3 m tall, dbh 2.5-10 cm, <60% crown cover, dominant tree species Douglas-fir (3) large sawtimber conifer forests; 110-200 years old, trees usually >30 m tall, dbh >53 cm, 60-80% crown cover, dominant tree species Douglas-fir (4) old-growth conifer forests; 200+ years old, multilayered vertical structure, 60-80% crown cover, dominant tree species Douglas-fir and western hemlock (*Tsuga heterophylla*) and (5) deciduous forests; >70% cover, dominant tree species red alder (*Alnus rubra*) and bigleaf maple (*Acer macrophyllum*). The shrub, pole and deciduous seral stages regenerated following timber harvests, and the large sawtimber and old-growth seral stages developed after wildfires. Each stand had the same seral stage on both sides of the stream and was large enough to include the transects plus a buffer of at least 100-m to reduce edge effects. Aerial photos and field reconnaissance were used to locate the sites. The elevation of the study sites ranged from 110-378-m and slope was from 28 to 68%.

We measured habitat variables in 10-m radius plots at the trapping stations from June-September, 1990. The dominant tree species along the riparian transects was red alder, the dominant deciduous shrubs were salmonberry (*Rubus spectabilis*) and stinking current (*Ribes bracteosum*); the most common evergreen shrub was salal (*Gaultheria shallon*). In contrast, the dominant tree along the upland transects was Douglas-fir, the dominant deciduous shrubs were vine maple (*Acer circinatum*) and red huckleberry (*Vaccinium parvifolium*), and the most common evergreen shrubs were salal and Oregon-grape (*Berberis nervosa*).

Trapping Design and Method

The trapping design on each study site consisted of one 350-m riparian transect, one 350-m upland transect (200-m upland and parallel to the riparian transect), and two 200-m inter-riparian transects that attached to the ends of the riparian and upland transects in a rectangular arrangement. Eight trap stations with two pitfall traps/station were located at 50-m intervals along the riparian and upland transects and nine trap stations at 25-m intervals along the inter-riparian transects. The shorter distances between stations along the inter-riparian transects were chosen to provide an accurate measure of riparian influence. Greater distances were used between the riparian and upland stations to get a larger sample area of those habitat types. There were 60 pitfall traps per stand and a total 900 traps for all stands combined. Each pitfall trap (two #10 sized cans taped together at the ends) was placed within a 10-m radius of the station center by a fallen log, stump, live tree, rock, or slope break, which acted as natural drift fences. Pitfall traps with water were used in this study and all animals were removed from the sites, frozen, and examined later for positive identification.

The study included four 28-day trapping periods during May (cool-wet season) and August (hot-dry season) of 1989 and 1990. Each trap was checked weekly resulting in 100,800 trap nights. Occasionally there were specimens that were too decomposed to identify ($\underline{n} = 22$), these animals were not included in the data set.

Statistical Analyses

All data analysis was conducted using the SAS software system (SAS Institute 1987). The null hypothesis that relative abundance of each species did not differ among seral stages was tested using one-way Analysis of Variance (ANOVA) and Student-Newman-Kuels (SNK) mean comparison tests (Devore and Peck 1986:557). The null hypothesis that relative abundance of each species did not differ between riparian and upland habitats among seral stages, and stations along the inter-riparian transects among seral stages was tested using two-way ANOVA and Student-Newman-Kuels (SNK) mean comparison tests. SNK was chosen for power in detecting significant differences and because it works well with equal sample sizes. The seral stage-by-transect interaction and seral stage-by-station interaction were used to test the transect and station effects along the inter-riparian gradient, respectively. When necessary, variables were transformed [log10 (x+1) and arc sine square-root for percent cover] to correct for non-normality or to obtain homogeneous variances. In some cases transformations were unsuccessful in producing normally distributed variables or homogeneous variables. Although seasonal comparisons were made, some seasonal variation in capture rates (total captures at each trap station over all seasons and years) might occur due to trap removal in subsequent seasons. Comparisons were made between habitats and between transects for each species individually. Results for some species were not included, because small sample sizes ($\underline{n} < 20$ captures) made statistical analyses and interpretations tenuous.

Results

A total of 9,764 individuals representing 20 species of small mammals were captured. Species richness among the seral stages was similar (15 and 16 species, excluding the non-target species)(Table 1). The total captures were progressively lower from young shrub stands to the older mature coniferous forests and highest in the deciduous stands. Species richness was similar between riparian (18 species) and upland habitats (17 species)(Table 2). There were 400 more captures along the riparian than along the upland transects.

Insectivores

The 7,793 (~80% of all captures) insectivores captured included three mole and four shrew species. *Sorex trowbridgii* and *S. pacificus* together accounted for 86% of the insectivores and 69% of all small mammals captured. *S. trowbridgii* was captured more frequently in pole and deciduous seral stages ($P < 0.01$), but it was abundant in all of the seral stages (Table 1). *Sorex vagrans* and *Scapanus townsendii* were more abundant in the shrub seral stage ($P < 0.05$) than in any of the other seral stages (Table 1). *S. bendirii* was captured about 1.8 X more often in the large sawtimber seral stage than in all other stages (Table 1). The capture rate of *Neurotrichus gibbsii* was greatest ($P < 0.05$) in the deciduous seral stage (Table 1).

The capture rate of *S. vagrans* was at least 3 X greater in the upland of the shrub habitat than in the other seral stages along the riparian and upland transects ($P < 0.05$), and the capture rate along the riparian and upland transects was different among the forest types for *N. gibbsii* ($P < 0.05$) (Figure 1). *Sorex pacificus* and *Sorex bendirii* were more abundant along the riparian than upland transects ($P < 0.001$)(Table 2). In addition, capture rates of both species along inter-riparian transects were higher near riparian areas than further away ($P < 0.001$)(Figure 2).

There was significant variation in capture rates between seasons along the riparian and upland transects for *N. gibbsii*, *S. pacificus*, and *S. trowbridgii* (Figure 3); however because of significant interaction between season and transect in the analysis, these results are difficult to interpret. The distribution of captures within seasons changed from 1.5 X more individuals along the riparian transect in the spring ($P < 0.01$) to 2.2 X more individuals upland in the summer for *N. gibbsii* (Figure 3). There were 1.8 X more captures of *S. pacificus* along the riparian versus upland transect ($P < 0.01$) in the spring compared to only 1.1 more captures along riparian versus upland transect in the summer. Although there was not a

TABLE 1. Average number of small-mammal captures among the five different forest seral stages (n=3) in the Oregon Coast Ranges, 1989-1990. Letters (a and b) are used to distinguish between means with significant differences.

	SERAL STAGE[1]											
	S		P		L		O		D		Total	
Species	X̄	SE	X̄	SE	X̄	SE	X̄	SE	X̄	SE	Captures	P[2]
Insectivores												
Neurotrichus gibbsii	14.7	2.7b	15.3	1.3b	26.7	8.7ab	27.0	3.5ab	35.7	4.7a	358	0.0247
Scapanus orarius	1.3	0.7	5.0	2.0	5.3	1.2	7.7	2.7	8.7	4.6	84	0.3838
Scapanus townsendii	5.3	1.7a	0.3	0.3b	1.0	0.6b	0.7	0.7b	2.3	1.3ab	29	0.0382
Sorex bendirii	22.7	7.2	22.3	4.1	51.0	10.3	23.0	7.2	27.3	0.9	439	0.0556
Sorex pacificus	115.7	25.3	141.7	23.6	114.3	27.4	77.7	6.8	122.0	19.7	1714	0.3389
Sorex trowbridgii	208.0	59.5b	403.7	23.7a	290.0	17.1b	275.0	15.9b	468.3	50.5a	5016	0.0030
Sorex vagrans	33.0	6.1a	0.6	0.3c	3.0	1.5bc	3.7	2.7bc	10.7	2.0ab	153	0.0017
Subtotals	1202.0		1848.0		1474.0		1244.0		2025.0		7793	
Rodents												
Aplodontia rufra	4.7	1.7	3.0	1.7	3.7	0.9	0.3	0.3	1.7	0.9	40	0.1226
Clethrionomys californicus	21.3	15.2	18.7	2.7	45.3	16.8	56.0	20.1	4.0	3.1	436	0.0549
Microtus longicaudus	3.7	1.5	1.3	0.3	2.3	1.9	3.3	3.3	1.3	1.3	36	0.8627
Microtus oregoni	75.7	29.8a	5.7	1.5b	3.7	1.2b	2.3	0.7b	8.3	4.9b	287	0.0061
Microtus townsendii	5.3	3.2	0.7	0.7	0.3	0.3	0.0	0.0	1.0	0.6	22	0.2006
Peromyscus maniculatus	61.3	13.2a	7.3	2.7b	7.7	2.4b	5.0	1.2b	20.7	1.5b	306	0.0007
Phenacomy albipes	5.3	2.7	4.7	1.7	1.3	0.9	2.3	1.2	6.0	2.3	59	0.4827
Phenacomy longicaudus	0.7	0.3b	0.3	0.3b	1.3	0.3b	5.3	2.4a	0.0	0.0b	23	0.0033
Zapus trinotatus	47.0	26.3a	20.7	4.5b	23.0	9.3b	10.0	6.2b	33.3	10.4b	702	0.0096
Subtotals	975.0		187.0		266.0		254.0		229.0		1911	
Total Captures[3]	2191.0		2036.0		1741.0		1498.0		2257.0		9723	

[1]S=shrub, P=pole, L=large saw timber, O-old-growth, D=deciduous.
[2]One-way ANOVA with site as block and error term to test for seral stage effect. Underlined p-value indicates variable was $Log_{10} + 1$ transformed.
[3]Not including non-target species (*Mustela erminea, Thomomys mazama, Tamiasciurus douglasii,* and *Sylvilagus bachmani*) and the specimens which were in too poor condition to identify.

significant difference (P < 0.05) between riparian and upland captures of *S. trowbridgii* during the cool-moist season, there were 1.8 X more individuals captured in the upland during the hot-dry season (P < 0.01)(Figure 3).

Rodents

A total of 1,914 rodents was captured, which included 11 total species, and six of these were microtines. *Zapus trinotatus*, *Clethrionomys californicus, Peromyscus maniculatus* and *Microtus oregoni* accounted for more than 90% of the rodents captured and 18% of all small mammals captured. *P. maniculatus, M. oregoni* and *Z. trinotatus* were at least 3 X more abundant (P < 0.01) in the shrub stage than in the other habitats (Table 1). In contrast, *C. californicus* was captured more frequently in the large sawtimber and old-growth conifer stands and *Phenacomys longicaudus* was captured more frequently (P < 0.01) in the old-growth forests than in the other seral stages (Table 1). *Z. trinotatus* was captured 3.6 X more in the riparian than upland habitats (P < 0.001)(Table 2). It was more abundant near riparian transects than upland along inter-riparian transects (P < 0.001)(Figure 2). There were three microtine species that were captured 5 X more often (P < 0.05) in riparian than upland habitats (Table 2). *Microtus longicaudus* was captured exclusively in riparian habitat; *Microtus townsendii* also was captured almost entirely near the riparian area; and captures of *Phenacomys albipes* were significantly greater in riparian than upland habitats. In contrast, *C. californicus* was captured 6 X more

TABLE 2. Average number of small-mammal captures along stream (n=15) and upland (n=15) transects in five forest seral stages in the Oregon Coast Ranges, 1989-90.

	Transect					
	Stream		Upland		Total	
Species[1]	$\bar{X}$	SE	$\bar{X}$	SE	Captures	P[2]
Insectivores						
Scapanus orarius	1.5	0.4	1.7	0.4	47	0.6495
Scapanus townsendii	0.3	0.1	0.1	0.1	6	0.4238
Sorex bendirii	24.2	3.3	1.3	0.4	383	0.0001
Sorex pacificus	40.6	3.6	26.0	3.4	997	0.0007
Sorex trowbridgii	83.7	6.7	100.3	11.9	2760	0.1884
Subtotals	2419.0		2112.0		4531	
Rodents						
Aplodontia rufra	0.9	0.3	0.5	0.2	20	0.2845
Clethrionomys californicus	2.4	1.3	14.4	3.3	253	0.0009
Microtus longicaudus	2.4	0.8	0.0	0.0	36	0.0066
Microtus oregoni	3.4	1.4	7.6	4.5	165	0.3663
Microtus townsendii	1.3	0.8	0.0	0.0	20	0.0457
Peromyscus maniculatus	5.1	1.7	6.1	1.8	167	0.2843
Phenacomys albipes	2.1	0.6	0.4	0.2	38	0.0113
Phenacomys longicaudus	0.4	0.3	0.5	0.2	13	0.7787
Zapus trinotatus	24.9	6.1	6.9	3.7	477	0.0001
Subtotals	644.0		545.0		1089	
Total Captures[3]	3066.0		2662.0		5728	

[1]*N. gibbsii* and *S. vagrans* were not included because of significant differences among forest seral stages between stream and upland transects for these species (refer to figure 1).

[2]Two-way ANOVA with transect by seral stage interaction used to test for transect effect and site by seral stage used as an error term. Underlined p-value indicates variable was Log10 +1 transformed.

[3]Not including non-target species (*Mustela erminea, Thomomys mazama, Tamiasciurus douglasii, Sylvilagus bachmani*), and the specimens which were in too poor condition to identify.

frequently ($P < 0.001$) in upland habitat (Table 2). It was the only species which was significantly more abundant at distances further from riparian transects ($P < 0.001$)(Figure 2).

Z. trinotatus was the only rodent species with significant seasonal variation in captures on the riparian and upland transects. It was captured more often in the cool-wet season than the hot-dry season ($P < 0.01$) along the riparian and upland transects (Figure 3). In addition, *Z. trinotatus* was 4.7 X more abundant along the riparian versus upland transects in the cool-wet season, but only 2.7 X more abundant along the riparian transect in the hot-dry season.

Discussion

There are a multitude of factors affecting activity and dispersion of small mammals, and animal densities alone may not always be an accurate means of measuring habitat quality of a species (Van Horne 1983). Our study does not measure the complexity of the landscape or vertebrate community; nevertheless we feel the strength in capture patterns gives validity to the results. We use these results to make important interpretations and suggest forest management implications for some species.

P. longicaudus and *C. californicus* were significantly more abundant in the old-growth and large saw timber seral stages than in the other seral stages in this study, and captures of *N. gibbsii* were progressively lower from old-growth to the younger conifer seral stages. Similarly, Carey and Johnson (1995) and Aubrey et al. (1991) found *N. gibbsii* more abundant in old-growth than in managed conifer stands. However, captures of *N. gibbsii* were even higher in the deciduous stands

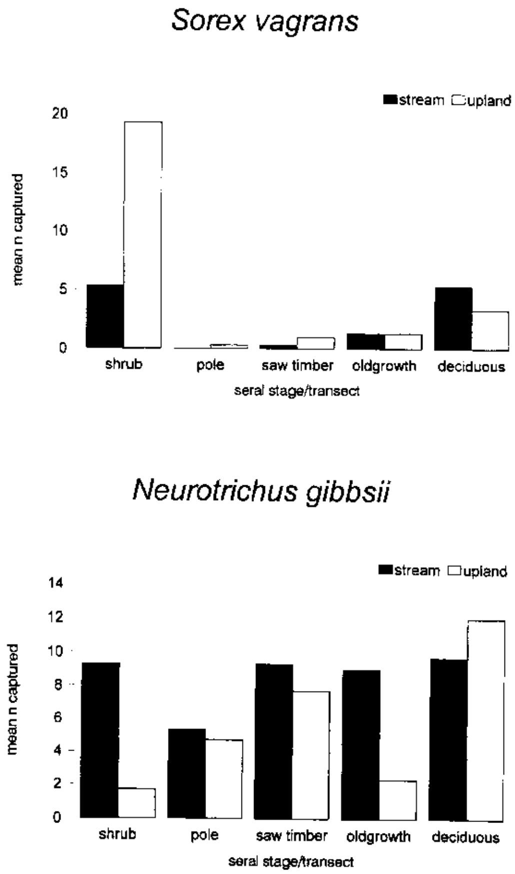

Figure 1. Mean number of *S. vagrans* and *N. gibbsii* captured among five forest types along riparian (n=3) and upland (n=3) transects in the Oregon Coast Ranges, 1989-90.

than in the mature conifer seral stages in this study, and we suggest that they might prefer the cool moist microclimates associated with mature deciduous and coniferous forests. Our results are also consistent with Corn and Bury (1986 and 1991) and Aubrey et al. (1991) for *P. longicaudus* and with Macnab and Dirks (1941), Maser et al. (1981) and Cross (1985) for *C. californicus*.

S. vagrans, S. townsendii, P. maniculatus, M. oregoni, Z. trinotatus were significantly more abundant in the shrub habitats than in other seral stages of this study. *S. vagrans* was found in a variety of habitats including lowland grasses, open brush, woods, moist meadows, headland shrub and prairie, tideland river habitats and dry uplands by others (Bailey 1936, Maser et al. 1981, Christenson and Larrison 1982). Corn and Bury (1991) found *S. vagrans* more abundant in mature (80-120 years) than young (40-75 years) and old-growth stands (150-525 years), but with the exception of the old-growth replicates, the stands they compared were of a different age and structure than those in this study. Some have suggested that *S. townsendii* occupies open habitats, mostly in wet pasture lands and agricultural fields of lowland valleys (Bailey 1936, Maser et al. 1981, Christenson and Larrison 1982). These habitat preferences might have resulted in limited numbers of captures in this study, although Maser et al. (1981) suggested that this species is sometimes found in headland prairie and shrub habitats. The fossorial habits of moles may limit the captures of this group even when drift fences are used with pitfalls (Briese and Smith 1974).

Riparian Associates

S. pacificus, S. bendirii, M. longicaudus, M. townsendii, P. albipes and Z. trinotatus were more abundant along riparian than upland transects, and they are likely to depend on small perennial streams for at least part of their life requirements on the Oregon Coast Range. *S. pacificus, S. bendirii* and *Z. trinotatus* had a strong association with riparian habitat; all were more abundant closer to the riparian areas along inter-riparian transects. The association of *S. bendirii* with riparian habitat was particularly strong: it should be considered an obligate species of riparian habitat and require riparian areas for survival on the Central Oregon Coast. The results from our study are similar to that of McComb et al. (1993), who found that *S. pacificus, S. bendirii* and *Z. trinotatus* were more abundant closer to riparian areas along inter-riparian transects, and *S. bendirii, Z. trinotatus, Microtus longicaudus and P. albipes* were more abundant along riparian than upland transects in their study. In addition, they found *P. maniculatus* and *N. gibbsii* were more abundant closer to the riparian area along inter-riparian transects. Maser et al. (1981) also suggested an association with riparian habitat for *S. pacificus, S. bendirii, M. longicaudus, M. townsendii, P. albipes* and *Z. trinotatus* on the Oregon Coast. Our results compare well with Bailey (1936), and Christenson and Larrison (1982) for *S. pacificus, S. bendirii*, and *M. townsendii*; with Ingles (1965) for *Microtus longicaudus*; and with Maser and Johnson (1967) for *P. albipes*. Doyle (1990) also found *Z. trinotatus* to be more abundant along the riparian

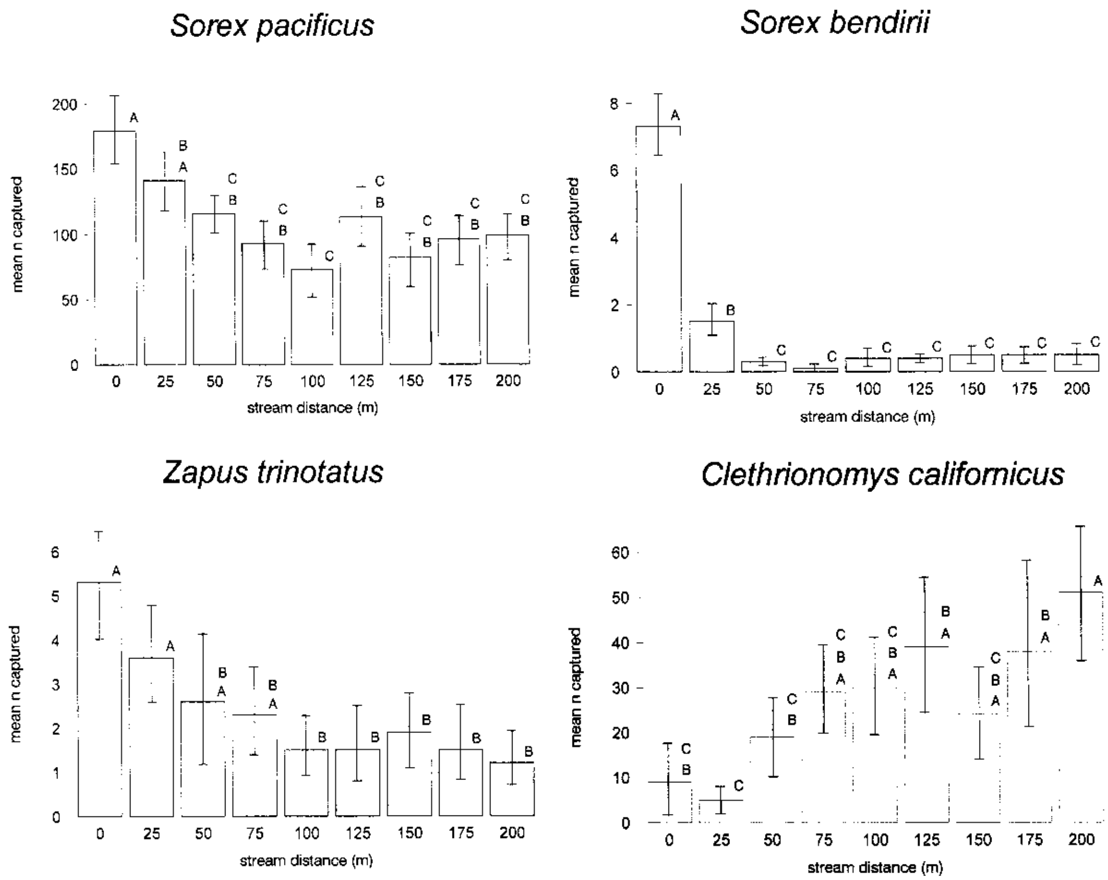

Figure 2. Mean number of *S. pacificus*, *S. bendirii*, *Z. trinotatus*, and *C. californicus* captured (±standard error) along inter-riparian transects (n=15) in the Oregon Coast Ranges, 1989-90. Letters (A and B) are used to distinguish between means with significant differences. Significantly different means will not share the same letter.

areas than upland and Cross (1985) found them almost entirely in the riparian areas of forests, but even more frequently in the riparian areas of clear-cuts. In addition, Ingles (1965) found them affiliated more with grassy, moist meadows located in coniferous forests. Our data suggest *Z. trinotatus* has an association with herbaceous vegetation with greater abundances in riparian areas of all the seral stages except shrub stands. In contrast, *S. bendirii* showed an affinity to all riparian areas and to the large saw timber seral stage where canopy closure was the greatest.

We conclude that small riparian systems are important habitat for small mammals and should be considered in management plans. The effect of dramatic habitat alterations on small mammal populations can be devastating particularly because many small mammal species have limited geographic ranges. Although it was ubiquitous among the seral stages in this study, *P. albipes* is one species which is naturally rare and considered sensitive in Oregon. They have been captured infrequently in a variety of habitats and have been captured most often in alder-dominated riparian areas (McComb et al. 1993 and in this study). However, this finding might be more a result of the emphasis in recent years on study and management of riparian areas, and instead *P. albipes* might be more dependent on deciduous vegetation often found in, but certainly not restricted to riparian areas. This would support Voth et al. (1983) who considered *P. albipes* to be closely associated with habitats dominated by deciduous trees and shrubs.

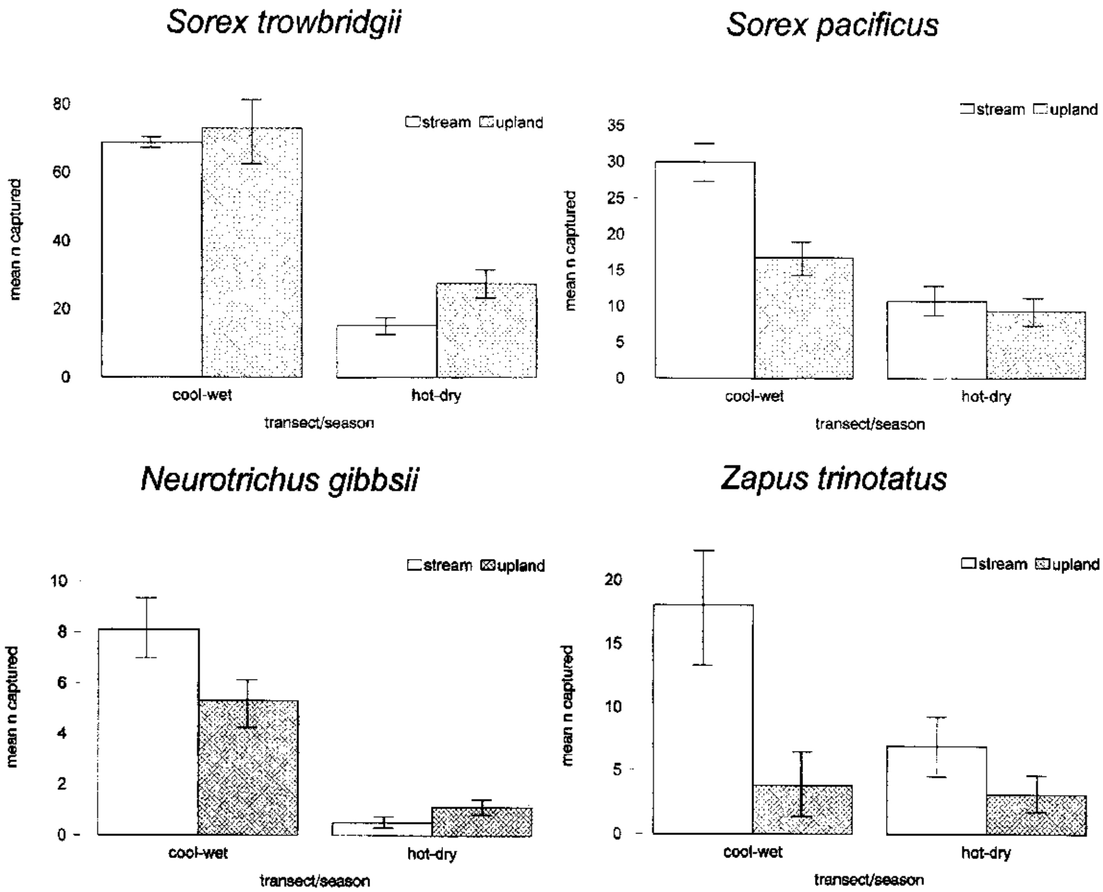

Figure 3. Mean number of *S. trowbridgii*, *S. pacificus*, *N. gibbsii*, and *Z. trinotatus* captured (±standard error) in riparian (n=15) and upland (n=15) areas during different seasons in the Oregon Coast Ranges, 1989-90.

Capture frequencies along inter-riparian transects for *S. bendirii*, *S. pacificus* and *Z. trinotatus* allow us to suggest zones along riparian areas for management of riparian associates. There was a significant decline in captures of these species at distances of 50-100 m from riparian transects. Consequently, riparian management zones should be at least 75-100 m on each side of perennial streams to include riparian habitat features and areas of highest abundance of all riparian associated small mammals, and to allow a buffer area which might help reduce the impact of a disturbance. These recommendations exceed current guidelines established under the Oregon Forest Practices Act, which maintain riparian management areas only on fish-bearing streams, within an average of three times the stream width, or a maximum of 30.3-m wide. Without proper forest management of riparian habitat, the status of many species' populations might be affected, functional riparian communities lost and the overall biotic potential of the riparian ecosystem limited (Kauffman 1988). Rochelle et al. (1988) suggested that specific wildlife goals for riparian areas include the maintenance or enhancement of critical riparian species, maintenance of important habitat features (down logs, snags, etc.), enhancement of cover conditions, and optimum species diversity.

P. longicaudus and *C. californicus* were significantly more abundant in the old-growth and large saw timber seral stages than in the other seral stages in this study; and *C. californicus* was significantly more abundant in the upland than in the riparian habitat (Doyle 1990) and at distances farther from riparian areas in this study and McComb et al. (1993). Management for upland/old forest associates

(*C. californicus* and *P. longicaudus*) may be equally as important as for riparian species. Management for these species should include maintenance of mature forest structural components and include upland habitat corridors. Our results are in agreement with McComb et al.; they suggest riparian buffers in mature forests of Western Oregon may not provide sufficient habitat for western red-backed voles unless they are substantially wider than necessary for riparian associates, to include linkages to upland forest patches. Whether it is management for riparian or upland associates, the approach taken should be tailored to meet the specific requirements of each species in a given area. A comprehensive approach to stream side management should include the transition and upland areas as well as the riparian zones.

The optimal size of the riparian management area for small mammals may vary geographically and temporally. Therefore, we recommend guidelines be incorporated into timber harvest plans that test the adequacy of our prescribed riparian buffer zone to meet the needs of all riparian associated small mammals within a given geographic area.

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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.

Aubrey, K. B., M. J. Crites, and S. D. West. 1991. Regional patterns in small mammal abundance and community composition in Oregon and Washington. *In* L. F. Ruggiero, K. B. Aubrey, A. B. Carey, and M. H. Huff, technical coordinators. Wildlife and vegetation of unmanaged Douglas-fir forests. United States Forest Service General Technical Report PNW-285. Pp. 285-294.

Bailey, V. 1936. The mammals of life zones of Oregon. North American Fauna 55:1-416.

Briese L. A., and M. H. Smith. 1974. Seasonal abundance and movement of nine species of small mammals. Journal of Mammalogy 55:615-629.

Campbell A. G. and J. F. Franklin. 1979. Riparian vegetation in Oregon's Western Cascade Mountains: Composition, biomass, and autumn phenology. Bulletin number 14. Coniferous Forest Biome Ecosystem Analysis Studies. Seattle, Washington. 90pp.

Carey, A. B. and M. L. Johnson. 1995. Small mammals in managed, naturally young, and old-growth forests. Ecological Applications 5(2):336-352.

Christenson, J. R., and E. J. Larrison. 1982. Mammals of the Pacific Northwest. A pictorial introduction. Univ. Press of Idaho, Moscow. 166 pp.

Corn, P. S., and R. B. Bury. 1991. Small mammal communities in the Oregon Coast Range. *In* L. F. Ruggiero, K. B. Aubrey, A. B. Carey, and M. H. Huff, technical coordinators. Wildlife and vegetation of unmanaged Douglas-fir forests. United States Forest Service General Technical Report PNW-285. Pp. 241-256.

Corn, P. S., and R. B. Bury. 1986. Habitat use and terrestrial activity by red tree voles (*Arborimus longicaudus*) in Oregon. Journal of Mammalogy 67:404-406.

Cross, S. P. 1985. Responses of small mammals to forest riparian perturbations. *In* Proc. Conf. on Riparian ecosystems and their management. United States Forest Service General Technical Report RM-120. Pp. 269-275 .

Cross, R. B. 1988. Riparian Systems and Small Mammals and Bats. *In* K. Raedeke (ed.) Streamside management: riparian wildlife and forestry interactions. Symposium proceedings, Univ. of Washington, Seattle. Pp. 93-112.

Devore, J. L., and R. L. Peck. 1986. Statistics, the exploration and analysis of data. West Publishing Company. St. Paul, MN 699 pp.

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

Franklin J. F., and C. T. Dyrness. 1973. Vegetation of Oregon and Washington. United States Forest Service General Technical Report PNW-80. 417pp.

Hair, J. D. 1988. Riparian habitat: Love it and leave it. *In* K. Raedeke (ed.) Streamside management: riparian wildlife and forestry interactions. Symposium proceedings, Univ. of Washington, Seattle. Pp. 1-4.

Hall, F.C., L. W. Brewer, J. F. Franklin, and R. L. Werner. 1985. Plant communities and stand conditions. *In* E. R. Brown (ed.) Management of wildlife and fish habitats in forests of Western Oregon and Washington. United States Department of Agriculture Forest Service Publication R6-F & WL-192-1985. Pp. 17-31.

Hall, F. C. 1988. Characterization of riparian systems. *In* K. Raedeke (ed.) Streamside management: riparian wildlife and forestry interactions. Symposium proceedings, Univ. of Washington, Seattle. Pp. 7-12.

Hirsch, A. and C. A. Segelquist. 1978. Protection and management of riparian ecosystems: Activities and views of the U.S. Fish and Wildlife Service. *In* R. R. Johnson and J. R. McCormick (tech. coords.) Strategies for protection and management of floodplain wetlands and other riparian ecosystems. United States Forest Service General Technical Report WO-12. Pp. 228-235.

Ingles, L. G. 1965. Mammals of the Pacific States. Stanford Univ. Press, Stanford, Calif. 506 pp.

Kauffman, J. B. 1988. The status of riparian habitats in Pacific Northwest forests. *In* K. Raedeke (ed.) Streamside management: riparian wildlife and forestry interactions. Symposium proceedings, Univ. of Washington, Seattle. Pp. 45-55.

Knopf, F. L., R. R. Johnson, T. Rich, F. B. Samson and R. C. Szaro. 1988. Conservation of riparian ecosystems in United States. Wilson Bulletin 100:272-284.

Maser, C., and M. L. Johnson. 1967. Notes on the white-footed vole (*Phenacomys albipes*). Murrelet 48:24-27.

Maser, C., B. R. Mate, J. F. Franklin, and C. T. Dyrness. 1981. Natural history of Oregon coast mammals. United States Forest Service General Technical Report PNW-133.

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 Science 67:7-15.

Macnab, J. A., and J. C. Dirks. 1941. The California red-backed mouse in the Oregon Coast Ranges. Journal of Mammalogy 22:174-180.

Meehan, W. R., F. J. Swanson, and J. R. Sedell. 1977. Influence of riparian vegetation on aquatic ecosystems with particular reference to salmonid fishes and their food supply. *In* R.R. Johnson and D. A. Jones (tech. coords.) Importance, Preservation and Management of Riparian Habitat: A Symposium. United States Forest Service General Technical Report RM-43. Pp. 137-145.

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Oakley, A. L., J. A. Collins, L. B. Everson, D. A. Heller, J. C. Howerton and R. E. Vincent. 1985. Riparian zones and freshwater wetlands. *In* E. R. Brown (tech ed.) Management of wildlife and fish habitats in forests of Western Oregon and Washington. United States Department of Agriculture Forest Service Publication R6-F & WL-192-1985. Pp. 57-80.

Rochelle J. A., K. J. Raedeke, L. L. Hicks. 1988. Introduction: Management opportunities for wildlife in riparian areas. *In* K. Raedeke (ed.) Streamside management: riparian wildlife and forestry interactions. Symposium proceedings, Univ. of Washington, Seattle. Pp. 135-138.

SAS Institute. 1987. SAS Procedures Guide For Personal Computers, Version 6 ed. Cary, NC: 373 pp.

Sedell, J. R., F. H. Everest, and E. J. Swanson. 1982. Fish habitat and streamside management: past and present. *In* Increasing Forest Productivity: Proc. Soc. Am. For. Conf., Soc. Am. For. Publ: #82-01, Washington D.C. Pp. 244-255.

Simons, L. H. 1985. Small mammal community structure in old-growth and logged riparian habitat. *In* Proc. Sympos. Riparian ecosystems and their management. United States Forest Service General Technical Report RM-120. Pp. 505-506.

Thomas, J. W., C. Maser, and J. E. Rodick. 1979. Riparian zones. *In* Thomas, J. W. (tech. ed.) Wildlife habitats in managed forests: The Blue Mountains of Oregon and Washington, p. 40-47. United States Department of Agriculture Forest Service, Agriculture Handbook 553. Washington D.C.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47: 893-901.

Voth, E. H., C. Maser, and M. L. Johnson. 1983. Food habits of *Arborimus albipes*, the white-footed vole, in Oregon. Northwest Science, 57: 1-7.