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Riparian and Upland Small Mammals on the East Slope of the Cascade Range, Washington

Abstract

Differences in small mammal diversity and abundance between riparian and upland areas have not been consistently shown in the Pacific Northwest, and the issue is expected to be complex along the east slope of the Cascade Range with its complex biogeography and forest landscape structure. The information is important for evaluating buffer zone management and the potential impacts of fuel reduction projects. We quantified small mammal species' abundances, diversity, and indicator species in riparian and upland forest along three third-order streams. Each location had a set of four 5 x 6 pitfall kill-trapping grids with 15 m spacing and the first grid row 5 m from the water. One site had an additional set of four grids. We trapped for two weeks during late June and early July during 1997 and 1998 for a total trap effort of 13,411 trap nights. We captured 1,104 individuals of 14 species. Insectivores were 69% and rodents 31% of the captures. *Sorex trowbridgii* was the most abundant species (54% of all captures). *Peromyscus keeni* and *P. maniculatus* combined dominated the rodent community with 43% of rodent captures. Species richness and individuals captured generally were highest within 20-35 m of the stream. *Sorex palustris*, *P. keeni*, *Microtus longicaudus*, *S. vagrans*, and *Zapus princeps* showed strong affinities to the immediate riparian zone (≤ 5 m from the stream). No species were indicators or most abundant in the upland forest away from the riparian areas. Refuge and corridor functions for small mammals in riparian areas would be maintained by current buffer-width standards of 60-100 m.

Introduction

Riparian areas are recognized as important habitat for small mammals in the Pacific Northwest (PNW) (Kauffman et al. 2001, Anthony et al. 2003). Research has mostly been in wet and mesic closed-canopy forests west of the Cascade Range (Cross 1985, Anthony et al. 1987, Doyle 1990, McComb et al. 1993, Gomez and Anthony 1998), but one study has occurred in somewhat drier closed-canopy Rocky Mountain forests of northeastern Washington (Hallett and O'Connell 1997). Despite similar biogeography and environment, differences in diversity and abundance between riparian and upland areas have not been consistently shown because of highly variable local conditions (e.g., vegetation composition and structure, disturbance processes) across the region and temporal patterns of abundance (Anthony et al. 2003). Local context has the same confound-

ing effect on bird diversity in forested riparian areas vs. upland forests in the PNW (Lehmkuhl et al. 2007).

If riparian small mammal ecology varies highly in closed-canopy forests of the PNW, then small mammal riparian habitat relationships are expected to be even more complex along the eastern slope of the Cascade Range. The composition and structure of eastside forests varies strongly along environmental gradients determined largely by aspect and elevation (Franklin and Dyrness 1973). At middle and low elevations, southerly aspects historically supported open-canopy dry forests dominated by ponderosa pine (*Pinus ponderosa*), whereas northerly aspects supported closed-canopy forests of mixed ponderosa pine, Douglas-fir (*Pseudotsuga menziesii*), and grand fir (*Abies grandis*). Varied fire regimes also have played a role in creating patchy forest landscapes. Fire disturbance regimes historically varied from low-intensity, high-frequency fires in low-elevation dry forest to high-intensity, low-frequency fire regimes at high elevations, with local variation along moisture gradients (Agee 1991, Agee 1993).

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Small mammal biogeography in the eastern Cascades adds more complexity to the issue. The eastern Cascade Range is a biogeographic ecotone for species typical of wet forests of western Washington, for species of the dry shrub-steppe of eastern Washington, and for species with primary distributions in forests of the Rocky Mountain region (Johnson and Cassidy 1997). As such, species occurrences and abundances in the eastern Cascade Range vary along temperature-moisture environmental gradients that affect vegetation pattern in a regional east-west direction and locally by topography (Lehmkuhl 2008). For example, presence and abundance of species typical of wet western Washington forests decline in an easterly direction from the Cascade crest as the environment becomes increasingly dryer, but species may occur locally at low elevations on cool-moist northerly aspects. The distribution of shrub-steppe species follows an opposite pattern for warm-dry conditions. The complexity of the environment and the fact that most species occur at the edge of their range, where they may be less well adapted than at the core of their ranges (Brown and Lomolino 1998), makes predicting species occurrence, abundance, and response to management actions difficult.

The importance of riparian areas for biodiversity is at a critical stage in the eastern Cascades dry forests. Fire has been suppressed or excluded for nearly a century in these interior dry forests and fire regimes have shifted from low- to high-intensity (Hann et al. 1997, Agee 2003). Management has become focused on restoration of stable fire regimes by thinning and prescribed burning to change composition from relatively dense mixed-conifer forest to open stands dominated by ponderosa pine (Graham et al. 2004). Changing current upland disturbance regimes and management will have consequences for maintaining the integrity of adjacent riparian systems, in which fire regimes can have high continuity with upland fire regimes (Camp et al. 1997, Everett et al. 2003).

Riparian habitat conservation usually involves the creation of uniform-distance riparian buffer zones to conserve the patterns of riparian vegetation and the interacting disturbance processes in channels and uplands (FEMAT 1993, Macdonald et al. 2004, Hickey and Doran 2004). Buffer zones are intended to preserve unique riparian habitats and wildlife, serve as movement corridors for upland species, or be refugia for species isolated

by upland disturbance (FEMAT 1993, Washington Department of Fish and Wildlife 1996). Yet, few local data exist to list species that are associated with riparian areas, that might use those areas as movement corridors or refugia, or determine how well riparian systems function as refugia in disturbed landscapes (Anthony et al. 2003). Managers need information on species assemblages, characteristic species, and species habitat associations in riparian and adjacent upland habitats to evaluate the potential impacts of dry forest management (Schmoldt et al. 1999, Altman 2000).

We studied small mammals to quantify species' abundances, diversity, and characteristic species in a gradient from riparian to upland forest along third-order streams on the east slope of the Cascade Range. We hypothesized that riparian small mammals assemblages would be richer, more abundant, and unique in composition relative to adjacent uplands because of high habitat diversity and a refuge effect for species primarily associated with mesic west-side Cascades forests. We hypothesized that riparian small mammal habitat relationships in the eastern Cascades would be transitional between western and eastern Washington.

Study Area

We studied small mammals in the riparian and adjacent upland zones of three third-order streams in dry mixed-conifer forest on the east slope of the Cascade Range in north central Washington. The streams were chosen opportunistically from the small pool of candidate streams in the Swauk Sandstone land type, the predominant dry forest land type in the central Washington Cascades, that had little to no timber harvest or roads in the riparian area. Hence, our scope of inference is limited to these streams. We located eight trapping grids in Devil's Gulch (West Fork Mission Creek) approximately 16 km south of the town of Cashmere, Washington. Grids were located 1.5-3 km up the Devils Gulch Trail #1220 on an easterly flowing stream segment (T22N, R19E, S19 & 30). Four grids sampled the riparian zone and adjacent dry southerly aspects (north side of the creek) and four grids sampled the riparian zone and adjacent mesic northerly aspects (south side). Elevations ranged from 600-720 m. Ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) were the dominant tree species. We located another four grids each on the south banks (northerly aspects) of Jack Creek (T21N, R16E,

N $\frac{1}{2}$ S2) and Stafford Creek (T21N, R16E, SE $\frac{1}{4}$ S27 and S33) in the Teanaway River drainage 32 km west of Mission Creek. Elevations ranged from 840–1185 m. The dominant tree species were Douglas-fir and grand fir (*Abies grandis*), with interspersed ponderosa pine, lodgepole pine (*Pinus contorta*), and western white pine (*P. monticola*).

Peffer (2001) found the riparian (valley bottom from the stream to the toe of the slope) and upland zones of the study areas distinctively different. Riparian areas were characterized by: 1) taller, larger, and less dispersed shrubs; 2) more deciduous trees of all size classes and, consequently, more deciduous litter; 3) greater herb and shrub ground cover; and 4) more large (≥ 25 cm diameter) well-decayed logs than upland areas. In contrast, upland areas had: 1) more conifer trees and small to medium-sized (11–25 cm dbh) snags; 2) higher percentage of grass, lichen, and moss ground cover; and 3) more small and medium (< 25 cm dbh), less-decayed logs than riparian areas. Vegetation differences along the riparian-to-upland gradient were most pronounced < 20 m of the stream.

At each of the four blocks of four grids, we subjectively located half of the grids at sites with narrow (< 20 m) valley bottoms and half with wide valley bottoms. Valley bottom was defined as the area extending from the stream banks to the toe of the hill slope. Channel types were Rosgen (1994) B-type channels (Thomas Robison, Okanogan-Wenatchee National Forest, personal communication) with moderate gradients of 5%, moderate entrenchment with low sinuosity, and steep (45%) adjacent slopes. Valley bottom width was mostly ≤ 50 m.

Methods

We sampled small mammals by pitfall kill-trapping on 5 x 6 grids with 15 m spacing. The first row of the grid paralleled the stream 5 m from the water and had five traps. The next six rows of traps extended up the hill at 15-m intervals. Traps were two #10 tin cans taped together and buried to ground level. We filled cans with 6–8 cm water and shaded them with 20 x 20 cm plywood squares placed 4–5 cm above each trap. We placed traps within a 2-m radius of the grid point adjacent to a log, stump, live tree, rock or slope break that acted as a natural drift fence. The 16 grids had a total of 480 traps, with 149 in valley bottom and 331 in upland zones.

We trapped for two weeks in 1997 (July 7 – 22) and in 1998 (June 22nd – July 7) for a total 13,411 trap nights. Although the timing of the second trapping period during 1998 was two weeks earlier than in 1997, plant phenology during both years was in similar stages of development due to a late spring in 1997. We checked traps and collected animals every other day. Each animal was measured, weighed, identified to species on the day of capture, and then frozen for specimen preparation and definitive identification. The Institutional Animal Care and Use Committee of Eastern Washington University approved the project. Mammal taxonomy and nomenclature follows Baker et al. (2003).

We initially considered each of the four locations (Devil's Gulch dry, Devil's Gulch mesic, Jack Cr., Stafford Cr.) as separate sample units each with an identical 4-block experiment (Cochran and Cox 1957) testing distance-from-stream effects. The four trapping grids at each location were the replicate blocks. We considered the rows of traps that paralleled the stream at 5, 20, 35, 50, 65, and 80 m from the stream as "treatment" units within blocks (i.e., the grids) (Timothy Max, Chief Statistician, PNW Research Station, Portland, Oregon, personal communication). We considered the five traps in each row as subsamples; so, we used total captures from all traps within a row as the dependent variable. We later grouped the two Devil's Gulch blocks and the two Jack Cr. and Stafford Cr. blocks for some analyses into two biogeographic groups based on the initial work by Peffer (2002) and our analysis that showed similar small mammal species compositions within the two blocks (see similarity analysis below). We compared results from the two groups qualitatively or graphically to describe distance-from-stream effects and how they varied by location.

We estimated species richness as the sum of species captured in each sample unit. We used the number of individuals captured for each species as an index of abundance in the sample unit. It was not feasible to estimate density for each sample unit (4 locations x 4 grids/location x 6 distance samples (rows)/grid = 96 units) because the number of animals captured at each unit were too few to effectively model with mark-recapture removal models. We excluded animals with < 10 total captures, which yielded 11 species to analyze. To ensure the reliability of simply analyzing the number of animals captured, we tested the as-

sumption of equal capture probabilities among sites and distances (White 2005) by estimating capture probabilities with a Huggins behavior model (M_h) (White et al. 1982) with Program MARK (White and Burnham 1999). We evaluated models with and without location and distance, both as a categorical grouping variable and a continuous covariate, with AIC criteria (Burnham and Anderson 2002) in MARK for five species with sufficient total captures ($n > 60$) for reliable model estimation (Appendix).

We concluded that the number of individuals captured was a reliable index of abundance for the five most abundant species tested. Models with invariant capture probabilities, i.e., no location or distance from the stream effects, were best supported by the data (Appendix). Capture probabilities averaged about $p(c) \approx 0.3$, and some apparent variation with distance from the stream was belied by large confidence intervals that suggested little real variation across distance categories (Figure 1). Estimated population sizes for the five species at individual trapping grids (i.e., all row data pooled) averaged 30% higher than the total number of individuals captured, which was a very good predictor of true abundance ($R^2 > 0.91$) for all five species.

We examined compositional similarity in small mammal assemblages among the two biogeographic groups and among distance-to-stream classes within group, and identified small mammal indicator species for distance-to-stream classes with two non-parametric multivariate analyses of community structure, as implemented in PCORD software (McCune and Mefford 1999). We used Multi-Response Permutation Procedures (MRPP) to test the hypothesis of no difference in species composition (i.e., species frequencies and relative abundances combined) among locations and distance-to-stream classes within locations (Zimmerman et al. 1985, Biondini et al. 1988). We analyzed differences among distance classes for each location as a blocked MRPP, with the four grids designated as blocks. An A statistic measured the grouping effect size, or the distinctiveness of groups, typically on a scale of 0-1, with $A < 0$ where composition is less heterogeneous than random expectation. Values of $A > 0.3$ are considered fairly high (McCune and Grace 2002). Monte Carlo permutations calculated probabilities for differences between types. We compared those probabilities to a Bonferroni-adjusted $P < 0.10$

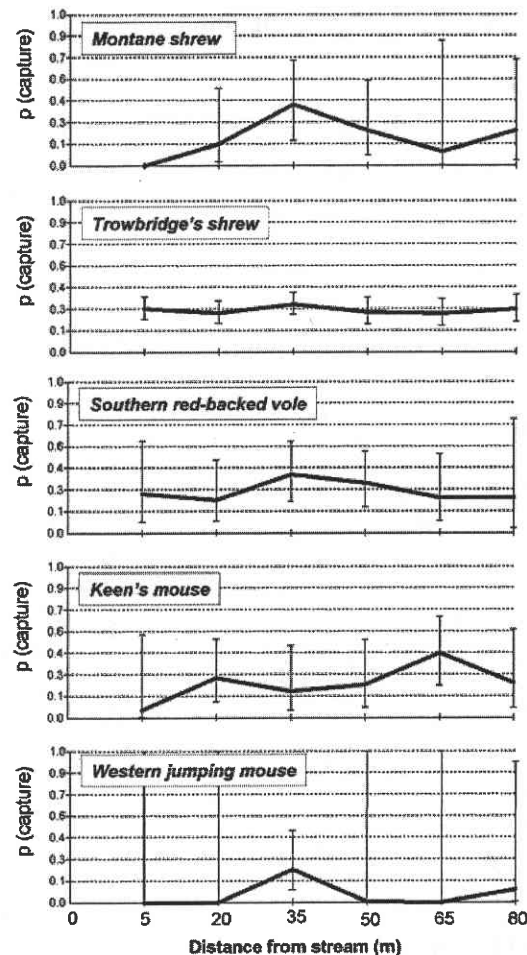


Figure 1. Removal capture probabilities with distance from stream as estimated by mark-recapture behavior model M_h in Program MARK for select small mammal species in dry forest of the eastern Washington Cascade Range. Only species with total captures (>62) sufficient for modeling are shown.

for multiple comparisons among locations or distance classes.

We used Indicator Species Analysis (ISA) to estimate the indicator value of species for distance-to-stream classes and to identify indicator species, i.e. characteristic species found mostly in a single type and present in the majority of the sites belonging to that type (Dufrene and Legendre 1997). ISA combines information on both species relative abundance and constancy to estimate indicator values for each species in each group. The maximum indicator value of a species among cover types was tested for statistical

significance against the random expectation calculated by Monte Carlo permutation. We used $P < 0.10$ as the significance level for strong indicator species, and $P < 0.25$ for weak indicator species. The modifiers "strong" and "weak" refer to the strength of statistical inference, indicated by the P -value, as an index of the ecological association. Our indicator, or characteristic, species based on frequency and abundance in habitats should not be confused with the different concepts of ecological indicator species that represent ecological guilds or communities (*sensu* Landres et al. 1988) or with focal species (Lambeck 1997) for monitoring specific limiting habitat factors in those vegetation types. We used orthogonal difference contrasts in ANOVA (SPSS 2001) to test for differences in species' total captures with distance from the stream (5, 20, 35, 50, 65, and 80 m) in each biogeographic group. Differences contrasts compared the value at each distance category to the mean of previous distances.

We accepted a probability of Type I error $P = 0.10$ for hypothesis testing. Although less conservative than $P = 0.05$, particularly with the relatively small sample size in this study ($n = 6$ stream reaches), we considered $P = 0.10$ to be an acceptable chance of error for ecological

field studies, well within the bounds of statistical convention, and conservative in committing Type II errors (Zar 1999). We evaluated multiple comparisons among locations or distance classes with Bonferroni-adjusted P -values that we estimated by dividing the overall $P = 0.10$ by the number of comparisons. A significant difference is implied where a difference among means is reported; but, we reported exact P -values in the text to allow readers to assess the probability of error relative to their own standard of significance (Zar 1999).

Results

We captured 1,104 small mammals from 14 species (Table 1), plus a few incidental captures of snowshoe hare (*Lepus americanus*), yellow-pine chipmunk (*Neotamias amoenus*), coast mole (*Scapanus orarius*), and northern pocket gopher (*Thomomys talpoides*), which are not well sampled by pitfall traps. We excluded those incidental species from further analyses. Insectivores accounted for 69% and rodents 31% of the captures, but four insectivores and four rodents dominated the catch. Trowbridge's shrew (*Sorex trowbridgii*), montane shrew (*S. monticolus*), vagrant shrew (*S. vagrans*), shrew-mole

TABLE 1. Numbers of small mammals captured with pitfall traps during the early summer in riparian and adjacent upland forest along three streams in dry forest of the eastern Cascade Range, Washington.

Common name	Scientific name	Devil's Gulch N ^a		Devil's Gulch S ^b		Jack Creek		Stafford Creek		Total
		1997	1998	1997	1998	1997	1998	1997	1998	
Insectivores										
shrew-mole	<i>Neurotrichus gibbsii</i>	0	3	1	2	2	7	2	7	24
marsh shrew	<i>Sorex bendirii</i>	0	0	0	0	1	0	1	2	4
dusky shrew	<i>S. cinereus</i>	0	0	0	0	1	2	1	1	5
montane shrew ^c	<i>S. monticolus</i>	5	2	5	6	7	26	7	4	62
water shrew	<i>S. palustris</i>	0	6	0	6	2	2	0	2	18
vagrant shrew	<i>S. vagrans</i>	3	7	0	6	10	12	6	11	55
Trowbridge's shrew ^c	<i>S. trowbridgii</i>	75	94	51	99	48	101	46	85	599
Rodents										
southern red-backed vole ^c	<i>Myodes gapperi</i>	0	3	0	1	7	26	7	27	71
long-tailed vole	<i>Microtus longicaudus</i>	0	3	0	1	0	9	1	2	16
montane vole	<i>M. montanus</i>	0	0	0	0	2	0	0	0	2
creeping vole	<i>M. oregoni</i>	1	2	0	4	3	3	0	5	18
deer mouse	<i>Peromyscus maniculatus</i>	10	11	8	10	0	0	1	4	44
Keen's mouse ^c	<i>P. keeni</i>	0	7	1	2	18	19	23	31	101
western jumping mouse ^c	<i>Zapus princeps</i>	2	1	0	1	31	33	12	5	85
	Total	96	139	66	138	132	240	107	186	1104

^a Devil's Gulch sites with north-facing aspects similar to those in Jack and Stafford Creeks.

^b Devil's Gulch sites with south-facing aspects unique to Devil's Gulch.

^c Species with sufficient captures for estimating capture probabilities by location and distance from stream.

(*Neurotrichus gibbsii*), Keen's mouse (*Peromyscus keeni*), western jumping mouse (*Zapus princeps*), deer mouse (*P. maniculatus*), and the southern red-backed vole (*Myodes gapperi*) comprised 93% of all captures. Trowbridge's shrew was by far the most abundant species (54% of all captures). The two *Peromyscus* species combined dominated the rodent community with 43% of rodent captures, followed by western jumping mouse (23%) and southern red-backed vole (21%).

Mammal assemblages differed overall among the four locations (MRPP $A = 0.053$, $P < 0.001$) (Table 1), but each location was not unique. Two biogeographic groups were evident: Devil's Gulch (dry and mesic grids together) and Jack and Stafford Creeks. Mammals in the dry and mesic grids of Devil's Gulch were similar ($A = -0.003$, $P = 0.481$), as were mammal assemblages in the mesic Jack Creek and Stafford Creek grids ($A = 0.007$, $P < 0.146$). Fewer animals were captured in Devil's Gulch and the composition of the catch differed in that group of grids compared to grids in Jack and Stafford Creeks ($A = 0.052$, $P < 0.0013$). Trowbridge's shrew was by far the dominant species at all sites, but more so in Devil's Gulch (74% of captures) than in the more abundant and richer small mammal communities of Jack and Stafford Creeks (42% of captures) (Figure 2). *Peromyscus* spp. were the second most abundant species at all locations; but, captures on Jack and Stafford Creeks were mostly Keen's mouse, whereas those at Devil's Gulch were predominantly deer mice. Southern red-backed voles and western jumping mice were relatively abundant in the westerly Jack and Stafford Creek areas, but were uncommon in the dryer Devil's Gulch sites. Montane and vagrant

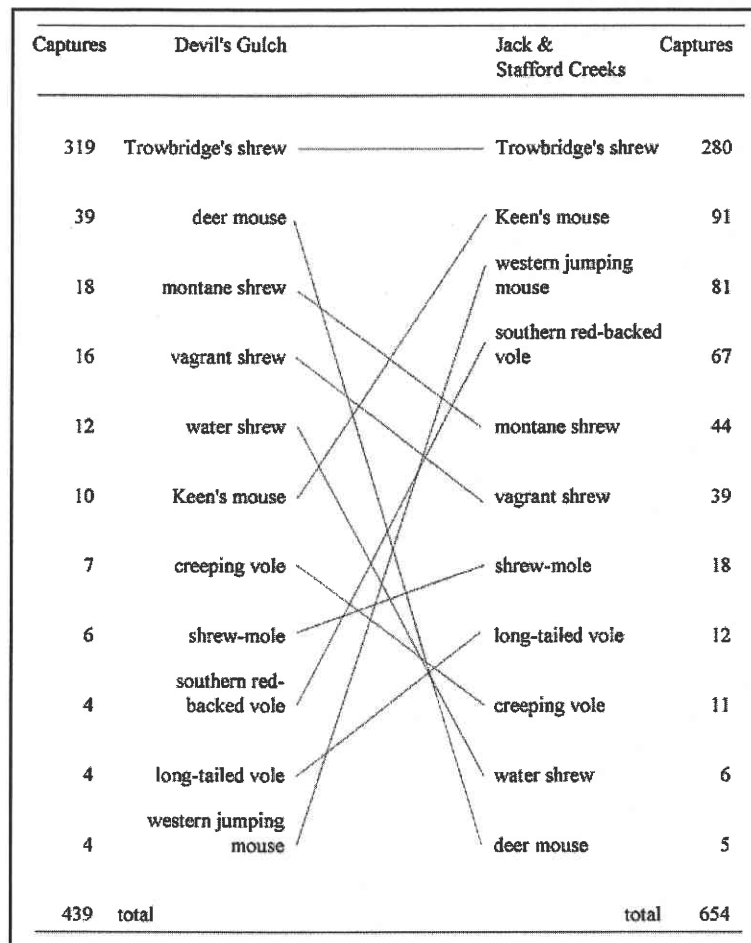


Figure 2. Rank abundance of small mammal species and total individuals captured with pit-fall traps during the early summer in riparian and upland forest (within 90 m) along three streams in dry forest on the east slope of the Cascade Range, Washington.

shrews, the other two relatively abundant shrews, were ranked moderately important at all locations, but were more abundant in the westerly Jack and Stafford Creeks (Figure 2).

Across the four locations the number of species and total number of individuals captured generally were higher within 20-35 m of the stream compared to further distances (Table 2). Species richness was highest within 20 m of streams in 3 of the four locations ($P < 0.05$), with greater richness in Jack and Stafford Creeks than in Devil's Gulch. Total captures likewise were highest within 20-35 m of the stream in mesic Jack and Stafford Creeks grids ($P < 0.10$) and the dry Devil's Gulch grids ($P = 0.11$).

TABLE 2. Species richness of small mammals and total individuals captured with pit-fall traps during the early summer by distance to stream along three stream reaches in dry forest on the east slope of the Cascade Range, Washington.

Distance to stream (m)							
Stream	5	20	35	50	65	80	P-value ^a
<u>Species richness</u>							
Devil's Gulch north	4.5 A ^b	3.3 A	2.3 A	2.3 A	2.8 A	2.0 A	0.133
Devil's Gulch south	4.3 A	3.3 A	2.0 B	3.3 B	1.5 C	2.0 C	0.030
Jack Creek	7.5 A	6.3 A	4.5 B	3.8 C	4.8 C	3.0 D	0.005
Stafford Creek	6.0 A	5.0 A	3.6 B	3.0 C	3.6 CD	3.2 D	0.049
Mean	5.6	4.4	3.1	3.1	3.2	2.6	
<u>Total captures</u>							
Devil's Gulch north	13.8 A	13.8 AB	9.5 B	7.8 C	8.3 C	5.8 D	0.110
Devil's Gulch south	11.3 A	8.3 A	8.0 A	12.0 A	5.8 A	6.0 A	0.211
Jack Creek	24.0 A	17.0 AB	19.3 B	11.8 C	10.5 D	9.0 E	0.096
Stafford Creek	18.5 A	16.8 A	11.0 B	5.2 CD	10.0 D	7.4 E	<0.001
Mean	16.9	13.9	11.9	8.9	8.7	7.1	

^a P-values from one-way analysis of variance blocked by 4 trapping grids in each location.

^b Values with similar letters are not different from the adjacent values from difference contrasts.

The composition of mammal assemblages changed with distance from stream at the combined Jack and Stafford Creek ($A = 0.062$, $P = 0.002$) grids, but not in the combined Devil's Gulch (MRPP $A = 0.007$, $P = 0.358$) sites. At Jack and Stafford Creeks, mammal composition was similar within 35 m of the stream ($P > 0.31$ for comparisons 5 m = 20 m, 5 m = 35 m, 20 m = 35 m), then changed at 50 m from the stream compared to closer distances (5 m $\neq$ 50 m, $P = 0.007$; 20 m = 50 m, $P = 0.03$; 35 m $\neq$ 50 m, $P = 0.006$). Mammal composition did not change beyond 50 m (50 m = 65 m and 65 m = 80 m, $P > 0.36$). (Bonferroni adjusted $P \leq 0.013$ for eight pairwise distance comparisons).

Five of the 11 species showed strong ($P \leq 0.10$) associations with the immediate riparian zone (≤ 5 m from the stream) based on indicator species analysis (Figure 3) and changes in abundance along the distance-from-stream gradient (Figure 4). Keen's mouse and long-tailed vole were strong indicators and most abundant ($P \leq 0.10$) in the immediate riparian areas of both Devil's Gulch and Jack-Stafford Creek. The water shrew likewise was a strong indicator and most abundant ($P \leq 0.10$) in the immediate riparian area, but only in Devil's Gulch. Although few water shrews were captured in the Jack-Stafford Cr. area, their abundance was highest ($P \leq 0.10$) within 35 m of the stream. Vagrant shrews were indicators and most abundant in a broader riparian zone within 20 m of the stream ($P \leq 0.10$), compared to the immediate streamside zone, of

Jack-Stafford Cr. area. Western jumping mouse likewise was an indicator of the immediate riparian area in Jack-Stafford Cr., but abundance did not appear to significantly differ within 35 m of the stream. The creeping vole was a weak ($P = 0.14$) indicator and most abundant ($P \leq 0.10$) in the immediate riparian area in the Jack-Stafford Cr. Trowbridge's shrew showed a trend of greater abundance within 50 m of streams. No species were indicators or most abundant in the upland forest away from the riparian areas.

Discussion

We found riparian corridors along small streams in the eastern Washington Cascades to be important habitat for many small mammal species. Our data supported the hypothesis that riparian small mammal assemblages would be richer, more abundant, and unique in composition relative to adjacent uplands. Although composition closely resembled that of western Washington forests, greater richness and overall abundance in riparian vs. upland habitats more closely resembled that of northeastern Washington forests (Hallett and O'Connell 1997). Richness was higher ≤ 20 m of the stream, and abundance was higher ≤ 35 m of the stream at three of the four locations. In the Jack-Stafford Cr. area, species composition ≤ 35 m from the stream also was different than at greater distances from the stream. Diverse small mammal communities in the riparian area are likely a result of more diverse forest-floor habitats and

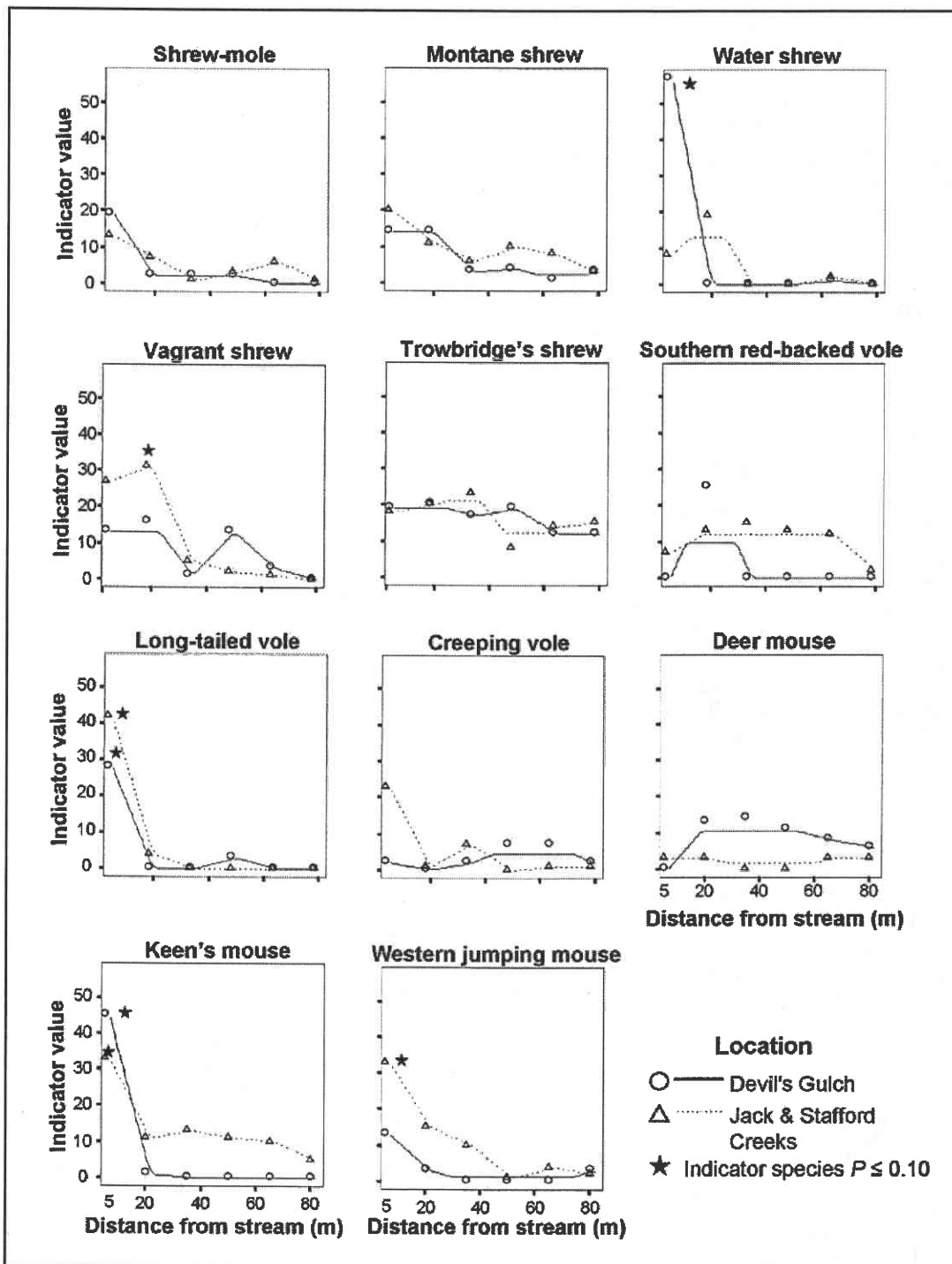


Figure 3. Indicator species values for small mammal species relative to distance to stream at three stream locations in dry forest of the eastern Washington Cascade Range. Indicator value was a function of species abundance and frequency of occurrence (Dufrene and Legendre 1997) on grid rows at various distances from streams. Significance of the maximum value was estimated by Monte Carlo permutations.

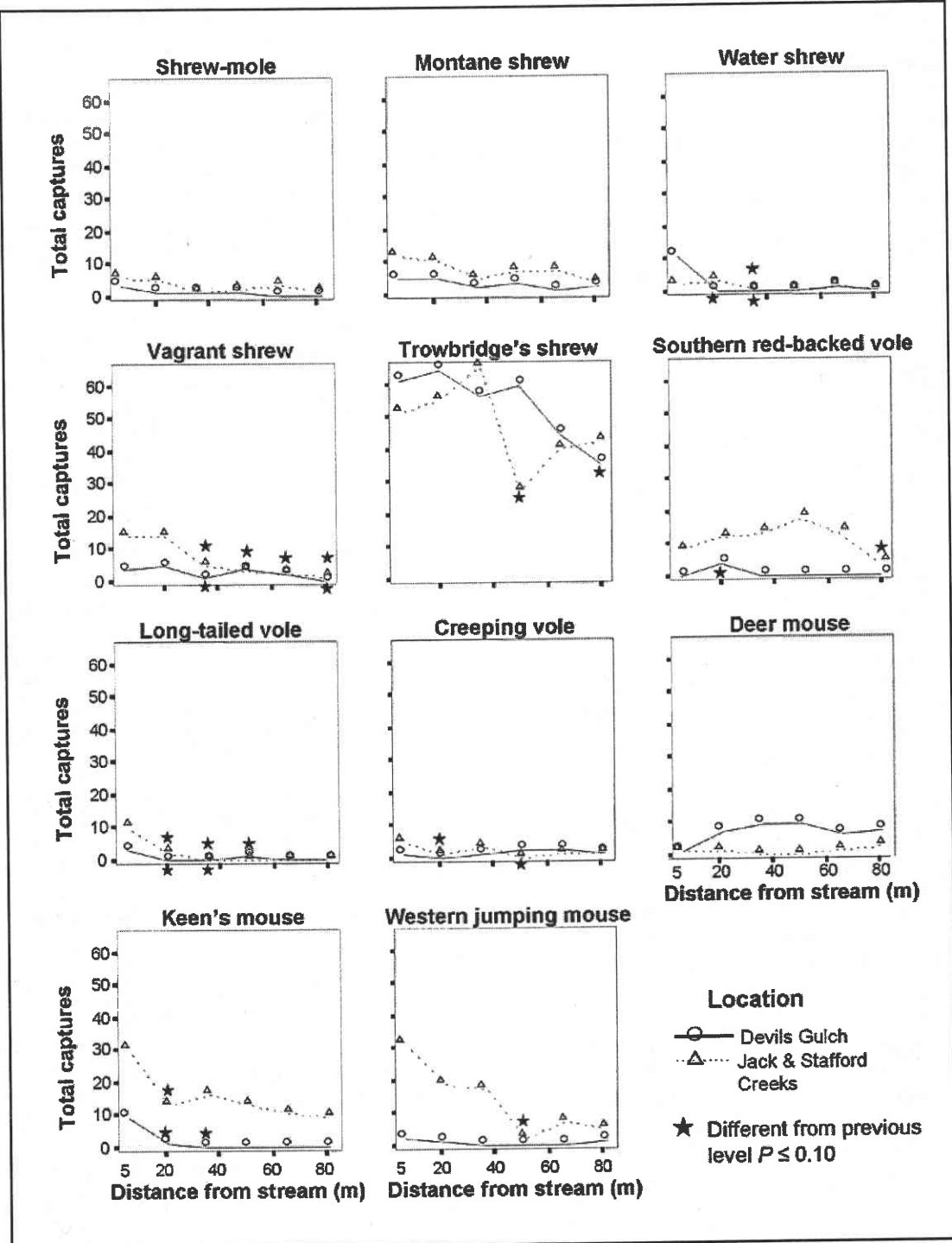


Figure 4. Individuals of small mammal species captured with pitfall traps during the early summer in riparian and adjacent upland forest by distance to stream along three streams in dry forest of the eastern Cascade Range, Washington. Sampling effort was 560 trap nights per distance category on eight grids per location.

associated food resources and cover in the riparian zone than in the uplands. Riparian areas had more herbaceous plants, shrubs, deciduous trees, ground cover of deciduous leaves, and larger logs in older decay classes than in uplands; whereas, uplands were dominated by conifers and grasses (Peffer 2001). Our results are consistent with conclusions by Anthony et al. (2003) that most PNW small mammal species are found in both riparian and upland areas, but that some species are more abundant in riparian areas, and that the presence of a few obligate species in riparian areas often results in higher species richness.

Our results for 11 species support our hypothesis about the transitional nature of our east-slope Cascades forests. Our results both confirm and conflict with conclusions by Anthony et al. (2003) in their review of regional PNW riparian habitat relationships for small mammals, and are supported by studies on the west side of the Cascade Mountains (Anthony et al. 1987, Doyle 1990, McComb et al. 1993, Gomez and Anthony 1998) and northeastern Washington (Hallett and O'Connell 1997). Among species distributed across the region (i.e., both west and east of the Cascade Range), our results support Anthony et al.'s conclusions for several species. The water shrew is a riparian obligate species (Anthony et al. 1987, O'Connell et al. 2000) on both sides of the Cascades. Their dependence on freshwater invertebrates can explain why nearly all captures of water shrews were within 5 m of a stream. The vagrant shrew is a widespread early-seral species associated with forested riparian areas (Verts and Carraway 1998, O'Connell et al. 2000). The deer mouse is a generalist species that uses both riparian and upland habitats similarly and is not associated with riparian or upland habitats in western or northeastern Washington forests (Anthony et al. 1987, Hallett and O'Connell 1997).

Our results disagree with the conclusions of Anthony et al. (2003) for some regionally-distributed species. We found riparian habitat relationships in the eastern Cascades for some species were more similar to western locations (i.e. west of the Cascade crest) than for reported eastern locations, which included the eastern Cascades (vs. as a transitional area) in their review. Similar to western locations, we found the southern red-backed vole to be a generalist species in the eastern Cascades, not a riparian-associated species (i.e., higher abundance in riparian vs. uplands)

as reported for northeastern Washington (Hallett and O'Connell 1997). Likewise, the long-tailed vole was a strong riparian associate in the eastern Cascades, not a generalist as reported for eastern locations. Long-tailed voles occupy a variety of habitats in the Pacific Northwest (Verts and Carraway 1998) and are often equally abundant in riparian and upland habitats (e.g., O'Connell et al. 2000). However, in the forests of western Washington and Oregon, as in our study, this species is more abundant in riparian than upland habitats (McComb et al. 1993), and has been considered a riparian obligate (Kelsey and West 1998).

Apparent patterns (i.e., not significant at the nominal *P*-value) of occurrence for the regionally-distributed montane shrew suggest it is a riparian-associated species in the eastern Cascades, as in western locations, not a generalist as reported for eastern locations based on a study in northeastern Washington (Hallett and O'Connell 1997). Johnson and Cassidy (1997) report that montane shrews are found in all coniferous forest zones, but are much less common in dry ponderosa pine forests of the east slopes of the Cascades than in mesic forests. Montane shrews were caught primarily in the mesic mixed-conifer forests of Jack and Stafford Creeks, and as predicted by Johnson and Cassidy (1997), their abundance diminished markedly in the ponderosa-pine dominated forests of Devil's Gulch.

Riparian habitat relationships of species with primarily western Washington ranges reported in Anthony et al. (2003) were mostly similar in the eastern Cascades. We confirmed the creeping vole as an early-seral species closely associated with riparian areas. Apparent trends of abundance for the shrew-mole supports its status as a riparian-associated species (Gomez and Anthony 1998, Verts and Carraway 1998). That relationship seemed most strong in the driest Devil's Gulch sites where the contrast between riparian and upland was strongest. Trowbridge's shrew is a habitat generalist throughout its range (Johnson and Cassidy 1997), but did show a weak pattern of high abundance within 50 m of streams. Whitaker and Maser (1976) suggested that Trowbridge's shrew can adapt to a wide variety of environments because they eat a wider variety of foods than other shrews in the region, but noted that it particularly feeds on invertebrates found in woody debris. The greater abundance of large well-decayed woody debris in our riparian than upland habitats (Peffer

2001) might explain the relatively high abundance of this shrew in riparian vs. upland habitats in these transitional forests.

In contrast to its' generalist designation in western locations, Keen's mouse was a strong riparian associate at the edge of its' range in the eastern Cascades. Keen's mouse is not strongly associated with riparian habitats in the mesic forests of western Washington (Anthony et al. 1987, O'Connell et al. 2000), but was associated with riparian habitat within 5 m of our streams in these transitional forests. Keen's mouse occurs on the east slopes of the Cascades in closed-canopy forests with water or wetlands, but is less common as forests become drier (Johnson and Cassidy 1997). We found it abundant in the riparian habitats of Jack and Stafford Creeks but less abundant in the uplands. Its abundance dropped markedly in both habitats of the drier forests of Mission Creek. The contrasting habitat associations of the two *Peromyscus* species in these transitional forests suggests a potential role of interspecific interactions in shaping their distributions.

The western jumping mouse, the only wholly eastern species in our study, was confirmed as an early-seral species with a strong association with riparian areas in the eastern Cascades and eastern Washington in general. The related Pacific jumping mouse, *Zapus trinotatus*, similarly has been associated with riparian areas in western Oregon (Cross 1985, Doyle 1990, Gomez and Anthony 1998). Contrary to range predictions in Johnson and Cassidy (1997), all jumping mice identified in this study were *Z. princeps*, not *Z. trinotatus*.

Our data show that riparian buffer zones created under current standards or guidelines for these types of streams would act as refuges and corridors to maintain small mammal assemblages characteristic of the narrow riparian zone and the adjacent uplands. Riparian buffer standards for National Forest lands under the Northwest Forest Plan (U.S. Department of Agriculture and U.S. Department of Interior 1994) are 100 m on either side of the stream. Recommended buffers for other forested areas within Washington State are 61 m wide on each side of the stream (Washington Department of Fish and Wildlife 1996). Those buffer widths would include a substantial area of upland forest, in many cases $\geq 50\%$ of the buffer width on these third and fourth order streams, so

a corridor function would not be solely dependent on inclusion of upland forests. The narrow riparian belt of primarily deciduous vegetation would not likely benefit by conifer thinning or other fuel-reduction treatments.

Our density data and indicator (i.e., characteristic) species will help forest managers assess and monitor the wildlife impacts on riparian species of dry forest thinning or prescribed fire projects that aim to reduce ground and canopy fuels and re-establish natural fire regimes (Graham et al. 1999, Agee and Skinner 2005). Monitoring with pitfall kill traps as we used them may be problematic in the future for a variety of perceived humane or ecological reasons (Sullivan et al. 2003). The method, however, is not proscribed by the American Society of Mammalogists (Gannon and Sikes 2007) and is more effective for capturing shrews in our area than snap traps (Lehmkuhl 2008). Live-trapping with Sherman, or similar live traps, can be effective for sampling the full diversity of small mammals (e.g. Carey et al. 2001), but live-trapping capture probabilities and consequent species' relative abundances will differ from our results. Each trapping method has pros and cons relative to efficient and unbiased capture of each species, so managers should evaluate capture probabilities and derive model estimates of true abundance to properly assess monitoring data (Williams et al. 2002).

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APPENDIX

Results of Program MARK removal modeling of small mammal capture probabilities as a function of distance from stream and study location in three dry forest drainages of the eastern Washington Cascade Range. Only species with sufficient captures for reliable model estimation are listed. Each species has two groups of models that differed in how distance was modeled as a covariate: as a categorical variable (first group of models) or as a continuous variable (second group of models). Models are sorted by lowest AIC_c value within each group.

Species	N ^a	Model ^b	AIC _c	Delta AIC _c	AIC _c Weight	Model Likelihood	N Par.
<i>Myodes gapperi</i>	71	M _b p(.)	254.2	0.0	0.99	1.00	1
		M _b p(distance category)	262.6	8.4	0.01	0.02	6
		M _b p(.)	242.8	0.0	0.45	1.00	1
		M _b p(locations)	243.8	1.0	0.27	0.61	2
		M _b p(., distance)	244.8	1.9	0.17	0.38	2
		M _b p(locations, distance)	245.7	2.8	0.11	0.24	3
<i>Peromyscus keeni</i>	101	M _b p(.)	381.0	0.0	0.80	1.00	1
		M _b p(distance category)	383.7	2.7	0.20	0.26	6
		M _b p(., distance)	341.2	0.0	0.47	1.00	2
		M _b p(locations, distance)	342.1	0.9	0.29	0.63	3
		M _b p(.)	343.3	2.1	0.17	0.36	1
		M _b p(locations)	344.9	3.7	0.07	0.16	2
<i>Sorex monticola</i>	62	M _b p(.)	237.4	0.0	0.92	1.00	1
		M _b p(distance category)	242.4	5.0	0.08	0.08	6
		M _b p(.)	237.4	0.0	0.41	1.00	1
		M _b p(., distance)	238.5	1.1	0.24	0.59	2
		M _b p(locations, distance)	238.8	1.4	0.21	0.50	5
		M _b p(locations)	239.7	2.2	0.14	0.33	4
<i>S. trowbridgii</i>	599	M _b p(.)	2109.3	0.0	0.98	1.00	1
		M _b p(distance category)	2117.5	8.2	0.02	0.02	6
		M _b p(locations)	2105.2	0.0	0.65	1.00	4
		M _b p(locations, distance)	2107.2	2.0	0.24	0.37	5
		M _b p(.)	2109.3	4.1	0.08	0.13	1
		M _b p(., distance)	2111.2	6.1	0.03	0.05	2
		M _b p(.)	332.8	0.0	0.84	1.00	1
		M _b p(distance category)	338.9	6.1	0.04	0.05	6
<i>Zapus princeps</i>	85	M _b p(.)	317.2	0.0	0.51	1.00	1
		M _b p(., distance)	319.0	1.8	0.21	0.41	2
		M _b p(locations)	319.2	2.0	0.19	0.38	2
		M _b p(locations, distance)	320.9	3.6	0.08	0.16	3

^a Total number of individuals captured.

^b Capture probability *p* from removal sampling modeled as a behavior model (M_b) with recapture probability *c* = 0. Notation "(.)" indicates no distance or location effect in model.