The Influence of Logging Riparian Areas on Habitat Utilization by Bats in Western Oregon

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ABSTRACT

We monitored bat activity using Anabat II bat-detector systems in three riparian areas that had partially been clear-cut logged in western Oregon. Total bat activity averaged 4.1 to 7.7 times higher in wooded areas than in adjacent logged areas. Activity in wooded areas was almost exclusively *Myotis* species; non-*Myotis* species, especially *Lasionycteris noctivagans*, accounted for a substantial amount of the activity in logged habitats. Different levels of activity between the habitat types could be the result of differences in insect prey populations in the two habitats. More Lepidopterans, more large-bodied insects, and fewer small-bodied insects were captured in the wooded habitat than in the logged habitat. Differences in bat-community composition in the two habitats could be due to differences in the morphology and echolocation call structure of the bat species. Other hypotheses that might explain differences in activity include differences in risk of predation, competitive interactions, or behavioural or evolutionary constraints. Our findings indicate that forest-management activities in riparian areas can influence patterns of habitat use by bats.

INTRODUCTION

Many species of bats use riparian areas. The importance of riparian areas to bats, especially *Myotis* species, as foraging habitat has been documented in several studies (e.g., Brigham et al. 1992; Furlonger et al. 1987; Lunde and Harestad 1986; Thomas 1988; Thomas and West 1991). Bats also depend on riparian areas as a source of free water for drinking (Cross 1988). Despite the importance of riparian areas to bats, there is little information documenting the influence of alteration of riparian habitat on bat populations. Kurta and Teramino (1992) suggested that urbanization results in decreased activity of bats over riparian areas. There is almost no information available concerning the influence of forest-management activities in riparian areas on bats (Christy and West 1993).

In western Oregon, extensive management activities are being implemented or considered in forested riparian areas. Much of the focus of riparian-area management in the Pacific Northwest is ecological restoration aimed at enhancing or restoring anadromous fish habitat; anadromous fish may be keystone species in Pacific Northwest aquatic systems (Willson and Halupka 1995), and have declined or become extirpated in several stream systems (Frissell 1993). Following historic logging activities, many riparian areas in western Oregon were recolonized by red alder (*Alnus rubra*) that may be succeeded by shrub communities (Hibbs 1987). Neither alder- nor shrub-dominated riparian areas in western Oregon are likely to provide the long-term input of large woody debris into streams necessary to provide high-quality freshwater habitat for anadromous fish. In contrast, riparian areas with large conifers are likely to provide adequate inputs of woody debris to provide quality fish habitat. One of several proposed strategies to establish conifers in alder-dominated riparian areas is to clear-cut patches to the stream edge, and plant conifers in the clearcuts.

In this paper, we examine influences of logging in riparian areas on activity of bats in western Oregon.

METHODS

We selected three, third-order streams in western Oregon for study: Bark Creek (T11S R7W Sect. 30; 44° 35′N, 123° 35′W) and Buttermilk Creek (T10S R8W Sect. 31; 44° 40′N, 123° 42′W) in the Coast Range Mountains, and Ames Creek (T14S R1E Sect. 9, 10, and 15; 44° 38′N, 122° 41′W) in the western foothills of the Cascade mountains. Clear-cut logging was conducted at the study sites during spring and early summer 1993. At Bark and Buttermilk creeks, clearcutting was conducted along 90 m of the stream and in the adjacent upslope forest stand; at Ames Creek clearcutting was conducted along 180 m of the stream and in adjacent upslope forest stands. Overstorey vegetation in wooded portions of the riparian areas is dominated by red alder with scattered big-leaf maple (*Acer macrophyllum*) and occasional conifers.

At each study site, we established one station to monitor bat activity in wooded habitat and one in logged habitat. The two stations were equidistant from the forest-clearcut edge. We chose locations along the streams to maximize reception of bat echolocation calls, avoiding areas with sharp bends in the stream and areas with vegetation that might obstruct sound reception. Distances from the stations to the habitat edge varied from 40 to 75 m. Each monitoring station was situated within 3 m of the stream, with the detector microphone oriented along the major axis of the stream.

We monitored bat activity using an Anabat II bat-detector system according to methods described by Hayes and Hounihan (1994). With this system, bat echolocation calls, the time of night, and a calibration tone are recorded on audio tape as bats fly over or near a monitoring station. Bat detectors were set at a sensitivity of six to minimize stream and insect noises and to minimize detecting bats flying in adjacent habitats.

Because of substantial temporal variation in bat activity between nights, we paired activity by night in our comparisons. We eliminated nights when detectors at one or both stations malfunctioned and nights when rain or insect noise filled audio tapes at one or both monitoring stations before the end of the night. Bat activity was successfully monitored over both the logged and wooded sections of the stream for 12 nights between 9 August and 2 September 1993, and 9 nights between 9 May and 7 September 1994 at Bark Creek; for 15 nights between 28 July and 23 September 1993, and 13 nights between 9 May and 14 September 1994 at Buttermilk Creek; and for 6 nights between 30 August and 7 September 1994 at Ames Creek. Because of high levels of bat activity, audio tapes from the wooded area at Bark Creek were filled with bat calls by 2320 h on 10 May 1994 and by 0332 h on the night of 7 July 1994; we used data on bat activity for the portion of these nights when both detector systems were operational.

We randomly selected 10 nights from Bark Creek and 10 nights from Buttermilk Creek to assess taxon-specific responses in activity levels to habitat structure. We used the Anabat computer software program (version 4.2a) to examine time-frequency plots of echolocation pulses recorded on these nights to attempt to classify bat calls taxonomically. Due to considerable overlap in the characteristics of echolocation pulses emitted by species of bats in this geographical region (Hayes and Cross, unpublished data), we did not attempt to classify calls by species. We classified calls as *Myotis* or non-*Myotis* on the basis of the shape and frequency of echolocation pulses.

To supplement the echolocation data, we set mist nets at various locations for five nights at Bark Creek. We identified and released all captured bats at the site of capture.

We sampled insect populations using 10-watt, black-light traps (Bioquip, Santa Monica, California) powered by 12-volt gel cells. We set a 12-volt timer (Real Goods, Ukiah, California) so that the traps would operate for a three-hour period beginning 30 minutes after official sunset. Insects were collected in alcohol. We positioned traps in the forested and logged habitats approximately 10 m from the bat-monitoring stations, about 1.5 m off the ground. Insect populations were sampled between 10 August and 15 September 1994 for 9 nights at Bark Creek and for 7 nights at Buttermilk Creek. We identified the insects we collected by order and tallied them by body length into one of three size classes: 0 to 5 mm, 5 to 10 mm, and over 10 mm. Insects were oven-dried for at least 24 hours and weighed.

To account for temporal variability in insect data, we paired data by night. We performed a paired *t* test using PROC MEANS of the SAS statistical software package for personal computers (version 6; SAS Institute, Inc. 1985) to test whether the difference between the number or biomass of insects captured in the two habitat types was significantly different from zero. Because of small sample sizes, some size classes were combined for analysis.

RESULTS

Total Bat Activity

More echolocation calls were recorded in the forested habitat than in the logged habitat at each study site. The number of calls recorded in a night in the forested habitat averaged 7.7 times higher than those recorded in the logged habitat at Bark Creek (Figure 1a), 4.7 times higher at Buttermilk Creek (Figure 1b), and 4.1 times higher at Ames Creek (Figure 1c).

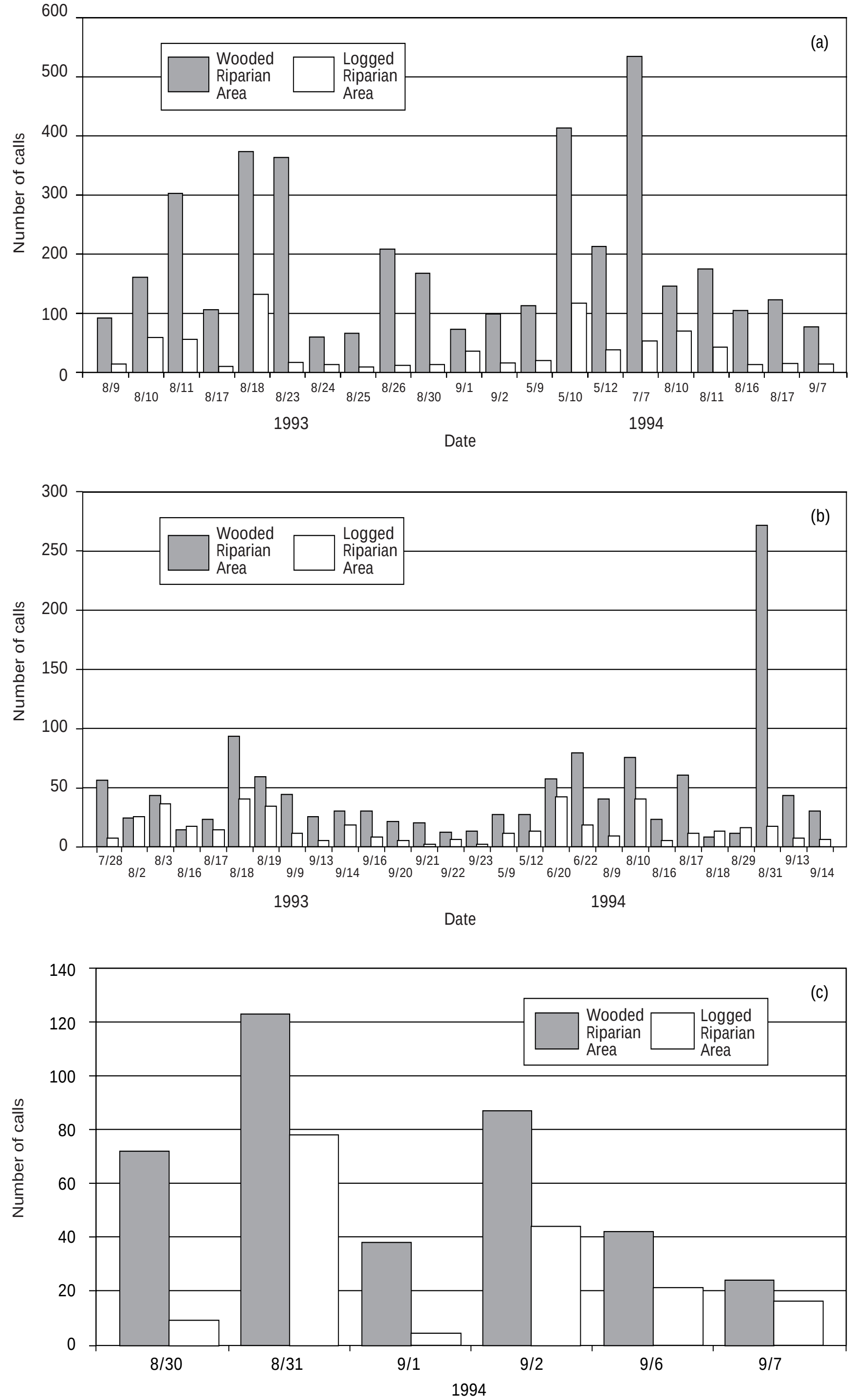

FIGURE 1 *Total number of bat calls recorded in wooded and logged habitat at (a) Bark Creek, (b) Buttermilk Creek, and (c) Ames Creek.*

The number of calls recorded in the wooded habitat exceeded those in the logged habitat during all nights at Bark Creek and Ames Creek, and during 24 of 28 nights at Buttermilk Creek. On each of the four nights for which greater number of calls were recorded in the logged habitat at Buttermilk Creek (2 and 16 August 1993, 18 and 29 August 1994), extremely low levels of activity were recorded in the wooded habitat, whereas numbers recorded in the logged habitat on those nights were more typical. Activity levels in the wooded habitat during two of these nights (18 and 29 August 1994) were the lowest ever recorded in wooded habitat during this study.

Levels of activity varied substantially between nights. Activity levels on consecutive nights in the wooded habitat varied by a factor of 6. For example, numbers of bat calls recorded on four consecutive nights (23 to 26 August 1993) in the wooded habitat at Bark Creek were 363, 59, 65, and 208. Relative differences in activity in the logged habitats were even greater, although the absolute differences were smaller. Activity levels on non-consecutive nights varied even more. The number of calls recorded in the wooded habitat varied from 7 to 270 at Buttermilk Creek and from 24 to 123 at Ames Creek. The minimum number of calls recorded in the wooded habitat at Bark Creek was 59; 413 calls were recorded by 2320 h on 10 May 1994, and 534 calls were recorded by 0332 h on 7 July 1994 when the tapes were filled at the wooded habitat at Bark Creek.

Although we did not collect detailed or quantitative data on behavioural patterns of bats using the wooded and logged habitats, anecdotal observations suggest that bats were functionally using the habitat types differently. Bats in the wooded habitat were frequently seen travelling in one or more circuitous routes through the wooded riparian area; an individual bat would repeatedly travel this pathway several times before leaving the immediate vicinity. In contrast, the bats that were occasionally seen in the logged habitat did not have a similar flight pattern. *Myotis* bats observed in the logged habitat apparently flew through the logged habitat *en route* from one wooded area to another. We did not observe a sufficient number of non-*Myotis* bats to comment on their behaviour patterns.

Species-Specific Responses

In the 10 nights at Bark Creek and 10 nights at Buttermilk Creek for which echolocation calls were classified as *Myotis* or non-*Myotis*, there were a total of 2,434 calls; 1,637 of these were of adequate quality to be taxonomically classified (Table 1). Of 1,263 identifiable calls in the wooded habitats, only 1 (< 0.1%) was identified as non-*Myotis*. This call was probably emitted by a *Lasionycteris noctivagans*. Non-*Myotis* calls were more prevalent in logged habitats; 6.2 and 29.4% of identifiable calls in the logged habitats at Buttermilk Creek and Bark Creek, respectively, were emitted by species other than *Myotis*. The majority of these calls appeared to be from *Lasionycteris*, but some may have been from *Eptesicus fuscus* or *Lasiurus cinereus*.

Mist Netting

We captured 18 bats during 5 nights of mist-netting on Bark Creek: 6 California *Myotis* (*Myotis californicus*), 5 Yuma *Myotis* (*M. yumanensis*), 3 little brown *Myotis* (*M. lucifugus*), 1 long-eared *Myotis* (*M. evotis*), 1 long-legged *Myotis* (*M. volans*), and 2 silver-haired bats (*Lasionycteris noctivagans*).

Insect Abundance

A total of 2,021 insects were captured in the light traps (Table 2). The number and biomass of insects we captured differed between the wooded and logged habitat for some orders and size classes. In general, insects with body lengths greater than 5 mm were more abundant in wooded habitats and those with body lengths less than 5 mm were more abundant in the logged habitats. Lepidopterans were more numerous and contributed more biomass in wooded habitats than in logged habitats, although the biomass for large Lepidopterans did not significantly differ among the habitats.

TABLE 1 *Number of bat calls classified as* Myotis, *non-*Myotis, *or unidentified, recorded during 10 nights at Bark Creek and 10 nights at Buttermilk Creek.*

Study site	Habitat	*Myotis*	non-*Myotis*	Unidentified	Total
Bark Creek	wooded	971	1	434	1406
Bark Creek	logged	161	67	101	329
Buttermilk Creek	wooded	291	0	182	473
Buttermilk Creek	logged	137	9	80	226

TABLE 2 *Number and biomass of insects captured in light traps at Bark and Buttermilk creeks.*

		Logged		Wooded	
Order	Size (mm)	Number	Biomass (g)	Number	Biomass (g)
Lepidoptera	< 10	34	0.100	77***	0.276**
	> 10	108	2.981	165**	4.036
Diptera	< 5	532	0.063	470	0.066
	> 5	21	0.045	17	0.047
Coleoptera	< 5	386**	0.132**	24	0.042
	> 5	4	0.370	9	0.463
Trichoptera	< 5	17*	0.016	2	0.005
	> 5	29	0.151	57*	0.352
Hymenoptera	< 10	7	0.015	7	0.001
	> 10	18**	0.559	3	0.174
Other[a]	all sizes	19	0.017	15	0.020
Total	< 5	959**	0.236***	516	0.126
	5–10	76	0.205	140**	0.414*
	> 10	140	4.011	190*	4.944

[a] Includes the orders Homoptera, Hemiptera, Ephemeroptera, Neuroptera, Collembola, and Psocoptera.
Asterisks next to a number denote that the value is significantly larger than the corresponding value from the other habitat type at $p < 0.10$ (*), $p < 0.05$ (**), or $p < 0.01$ (***).

Bat Response to Logging

Logging substantially reduced the total amount of bat activity in riparian areas. The magnitude of the influence that logging had on bat activity at these sites was unexpected for two reasons. First, the size of the disturbance (90 or 180 m of stream) is relatively small in relation to the distances that bats travel in the course of a night. Second, the species of bats using these riparian areas are widespread and use geographically and ecologically diverse habitats. The species at our study sites occur in more open habitats in other areas, including over large streams that have minimal cover from adjacent vegetation, and in very open areas, including deserts.

Decreased activity of *Myotis* species in the logged habitat might partially be explained by differences in insect populations. Observations of greater levels of foraging activity over riparian areas than in adjacent upslope areas (Lunde and Harestad 1986; Thomas 1988; Thomas and West 1991) has led to speculation that open water may be critical foraging habitat for some species of bats in Pacific Northwest forests (Christy and West 1993). Assessing insect availability is problematic, and any insect sampling method has biases (Kunz 1988; Whitaker 1994). Although sampling biases complicate interpretation of the insect data, our data suggest that insect populations differ between the two habitat types. In general, large insects appeared to be more abundant in the wooded habitat thanin the logged habitat. In addition, size classes of some insect taxa significantly differed between habitats. Large Trichopterans and Lepidopterans of all size classes were more abundant in the wooded habitat than in the logged habitat. Lepidopterans are a major component of the diet of all species of *Myotis* in our study area, and Trichoptera was identified as a component of the diet of *M. lucifugus* and *M. californicus* in western Oregon (Whitaker et al. 1977).

The differences in the proportions of *Myotis* and non-*Myotis* calls in the two habitat types indicate that the influence of habitat alterations differs among bat taxa. Activity levels of *Myotis* species are substantially reduced following clearcutting of alder-dominated riparian areas along small streams. In contrast, activity levels of non-*Myotis* species, primarily *Lasionycteris*, were considerably higher in the logged habitat than in the wooded habitat. The interaction between habitat structure and differences in the morphology and echolocation call structure of the bat species may partially explain differences in activity levels of different bat species in the wooded and logged habitats. The morphology and typical echolocation calls emitted by *Lasionycteris noctivagans* allows it to forage more effectively than *Lasiurus cinereus* for small prey over short distances (Barclay 1986), but *L. noctivagans* is probably a less effective forager in densely forested, highly cluttered riparian areas than are the smaller-bodied *Myotis* species using steep-frequency, modulated echolocation calls (Neuweiler 1989).

Other factors that may have influenced habitat-related differences in activity levels include competitive interactions among bat species, behavioural or evolutionary constraints, and relative risk of predation. Demonstrating specific causal effects would be difficult at best.

Bat populations responded to the habitat alterations relatively rapidly. We began monitoring bat activity at Bark Creek and Buttermilk Creek within two to three months of when logging was completed. Dramatic differences in activity levels between the two habitat types were evident from the onset of our monitoring, and the differences persisted for at least two years. Longer-term responses are not known. It is likely that differences in activity levels will persist for several years until trees in the logged habitat attain sufficient height to allow bats to fly beneath the tree canopies, but this remains speculative.

Scope and Limitations

Bat detectors are useful tools to assess activity levels of bats, but have limitations that must be understood to interpret the results. First, the number of bats using an area is not directly measured; the data provide only an index to activity. Second, the sensitivity of bat detectors differs among bat species because of species-specific differences in intensity and frequency of calls. Comparisons can be made between habitats within a taxon, but the data may provide only a poor estimate of relative activity levels between taxa. In addition, habitat structure may influence receptivity of bat detectors; highly cluttered environments may impede sound transmission resulting in relatively fewer detections for a given level of activity. The degree to which this influences comparisons of bat activity between habitats is not known. In our study, habitat-related differences in detector receptivity were probably of minor or no influence as the bat detectors were oriented towards relatively open areas over streams in both habitats. If habitat structure influenced detector receptivity in our study, receptivity would be greater in the less cluttered, logged habitats. Our estimates of differences in total activity and activity of *Myotis* species between habitat types would be conservative; differences in estimates of activity for non-*Myotis* species between habitat types could be inflated. Finally, temporal variation in bat activity along streams is high. We accounted for temporal variation in our study by pairing all comparisons by night.

Our ability to reliably classify bat echolocation calls by species is hampered by high variation in echolocation pulse characteristics emitted by bats within a species, and by considerable overlap in characteristics of pulses emitted by different species (Hayes and Cross, unpublished data). Intraspecific variation in calls may also result from differences in foraging habitat (Brigham et al. 1989); if substantially different call structures are used in the more open, logged habitat versus the more cluttered, wooded habitat, classification of echolocation calls would be confounded and could result in misclassification of some calls. Further taxonomic resolution could reveal additional patterns that have important management and conservation implications.

All of our work was conducted on third-order streams with alder-dominated riparian areas in the Oregon Coast Range. Results from larger streams, conifer-dominated riparian areas, or other geographic areas might be different. Although we have not formally studied other systems, anecdotal observations suggest that habitat alteration of larger streams and conifer-dominated riparian areas would influence bats differently than those we reported here. In comparison to the systems we examined, bats seem to use more strata in riparian areas dominated by conifers along larger streams, the physical structure in these streams do not impose the same limitations for large-bodied and fast-flying bats, and most of the activity along large streams appears to be in areas that are not covered by forest canopies. In the absence of research, it is difficult to speculate how bats would respond to habitat alterations in these systems.

Conservation and Management Implications

Our findings indicate that forest-management activities in riparian areas can have important consequences for patterns of habitat use by bats. The population-level consequences of decreased activity levels resulting from clear-cut logging of riparian areas are not clear. However, if the practice was widespread, it is likely that populations of some species of bats would be affected.

The influence of management activities on one resource, species, or community must be weighed against its influence on others. Riparian-area restoration activities may be an important component of plans to improve the long-term survival of anadromous fish runs in the Pacific Northwest. Benefits to one species or resource must be weighed against possible impacts on other species, including bats, in developing management strategies.

Future Research

Clear-cut logging represents one end of a spectrum of forest management activities being considered or implemented in riparian areas. We plan to begin additional research to examine the influence of other forest management activities, such as thinning riparian-area forests and maintenance of different sizes of uncut buffer strips along streams, on bat activity.

Finally, this work represents one piece of a host of studies we are conducting to examine the influence of forest management activities on bat populations in the Oregon Coast Range. Additional work on temporal variation in activity patterns, use of day and night roosts, foraging patterns of bats, and the influence of forest management on these activities are underway or planned for the near future.

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