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Use by Bats of Patches of Residual Trees in Logged Areas of the Boreal Forest

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Abstract.—Previous studies have shown that bat activity is greater along forest-clearcut edges than in the center of clearcuts or in the forest interior. Residual patches of trees in logged areas may also provide habitat for bats. To investigate this, we monitored bat activity at three locations within cutblocks: along the outside edge of the forest cutblock, in the center of the clearcut portion of the cutblock and along the outside edge of the residual patches of trees, at the EMEND (Ecosystem Management by Emulating Natural Disturbance) study site in northern Alberta, during the summer of 2000. Our results indicate that small maneuverable species such as *Myotis lucifugus* and *M. septentrionalis* were equally active along the edge of residual patches and the forest edge of cutblocks and least active in the center of cutblocks. Larger species, such as *Lasionycteris noctivagans*, showed no preference. Thus, patches of residual trees provide commuting habitat, and potentially foraging habitat, for bats.

Introduction

Forest harvesting, primarily through clearcutting, continues to clear large tracts of Canada's boreal forests, fragmenting them into smaller tracts of contiguous forest and altering the quantity and quality of habitat available for many forest animals (Bayne and Hobson, 1997). Some forestry operations leave residual patches of trees in clearcuts to mimic the natural disturbance regime of boreal forests (*e.g.*, fire). By definition, the presence of residual patches means these harvested areas are "cutblocks," as opposed to clearcuts in which every tree within the defined area is removed. Residual patches are intended to mimic natural areas skipped by fire and act as forested habitat patches between contiguous tracts of forest separated by clearcuts. The use of residual patches of trees by birds and small mammals has been studied extensively (Nupp and Swihart, 1996; Bayne and Hobson, 1997; Eng, 1998; Merrill *et al.*, 1998; von Sacken, 1998). Remnant patches can increase the use of cutblocks by birds, but their effectiveness as forested habitat patches for other species, including bats, has not been determined (Merrill *et al.*, 1998). Bats, as the primary nocturnal predators of insects, may be important in forest habitats and should, therefore, be considered in forest management decisions in order to maintain biodiversity and natural ecological processes (Crampton and Barclay, 1998).

The creation of forest-edge habitat, the transitional habitat formed between the harvested forest and the unharvested forest, by forestry activities may positively affect bats (Ekman and de Jong, 1996; Grindal and Brigham, 1999; Verboom and Spoelstra, 1999). Many insectivorous bats prefer to commute and/or forage along edge habitats, such as riverbanks, tree lines, forest edges and edges created by logging, rather than in open nonforested areas or within the forest interior. This suggests that there are environmental conditions that make forest-edge habitats attractive to bats (Ekman and de Jong, 1996; Grindal, 1996; Grindal and Brigham, 1999; Verboom and Spoelstra, 1999).

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Insect abundance and diversity may be greater along forest edges than in open areas or within forest interior, allowing bats to maximize their rate of energy intake (Verboom and Huitema, 1997; Voller, 1998; Grindal and Brigham, 1999). However, in cases where insect abundance is greater in the forest interior than at the forest edge, bats often still stay near the edge, suggesting that there are advantages of forest-edge habitat besides food availability (Grindal and Brigham, 1999). Forest edge and open habitats consist of less clutter (trees, branches and shrubs) for bats to maneuver around, allowing easier and less costly flight than in the forest interior. Forest edges may also provide navigational references for orientation during flight, protection from wind and protection from predators, such as owls (Verboom and Huitema, 1997).

The objective of our study was to assess the effectiveness of patches of residual trees in cutblocks as bat commuting and foraging habitat. We compared bat activity at the forest edge of cutblocks, at the edge of residual tree patches and in the center of the clearcut portion of cutblocks. If residual tree patches constitute effective habitat, bats should travel and forage along their edges as they do along the forest edges of cutblocks.

The size, wing morphology and echolocation abilities of bat species influence their use of forest-edge habitat. Small, slow, more maneuverable species with short broad wings, and higher frequency, shorter-range echolocation, tend to stay close to forest edges and are observed less frequently in open areas, although they are not restricted to edges (Fenton, 1990). Larger, less maneuverable, fast flying species with long narrow wings, and lower frequency, longer-range, echolocation abilities are observed along forest edges less frequently than smaller species and more frequently in open areas (Fenton, 1990; Ekman and de Jong, 1996; Grindal, 1996). In open areas, larger species can minimize the energetic cost of flight by flying faster than they could in the clutter of interior forest or forest edge habitat (Ekman and de Jong, 1996; Verboom and Huitema, 1997). We predicted that smaller more maneuverable bat species would forage along the patch edge at the same rate as they do along the cutblock-forest edge and more than they do in the center of cutblocks, whereas larger less maneuverable species would show no preference for cutblock-forest edges or patch edges over the center of cutblocks.

METHODS

We conducted this study at the EMEND (Ecosystem Management by Emulating Natural Disturbance) study area, located in the boreal mixedwood forest north of Peace River, Alberta (57°N; 118°W). This forest is dominated by white spruce (*Picea glauca*), black spruce (*P. mariana*), balsam poplar (*Populus balsamifera*) and aspen (*P. tremuloides*). EMEND is an experimentally designed and manipulated forest area, intended to permit the study of ecological effects of various forest harvesting and regeneration techniques, such as clearcutting and selective harvesting. The site is designed to account for the influences of stand composition on the effects of harvest and regeneration techniques. Three stand types were involved in this study: conifer-dominated stands (CDOM) approximately 100 to 120-y-old; deciduous-dominated stands (DDOM) 80-y-old; and mixed stands (Mixed) 90 to 100-y-old. Stand type was identified before harvest, which occurred during the winter of 1998/1999. Therefore, the cutblocks that we studied were 1.5-y-old. We used three replicates of each stand type. Further information on this study area is available on the EMEND website (http://www.biology.ualberta.ca/emend).

From 1 June to 21 July 2000, we sampled nine cutblocks, each 8 to 10 ha. The precise size and shape of each cutblock varied owing to various environmental and experimental constraints, such as the presence of water bodies, roads, the size and shape of natural tree stands and the need to maintain buffers between adjoining treatments. Two oval residual patches of trees, 0.46 ha (90 × 60 m) and 0.20 ha (60 × 40 m), were left within each cutblock to mimic natural fire skips. The patches were located to maximize the distance between each other and between the patches and the forest edges of the cutblock. Although the degree of isolation of patches may influence bat activity along their edges (Swystun *et al.*, 2001), patches in our study did not vary in isolation. We sampled bat activity along the edge of the large residual patches.

We measured bat activity at three locations in each cutblock: along the forest edge of the cutblock; along the outside edge of the large residual patch; and in the center of the cutblock, a minimum of 10 m, but usually 30 m, away from the residual patches or the cutblock forest edges, with the detectors pointing into the center of the cutblock. At each location we counted bat echolocation passes as a measure of activity. We monitored for bat species known or expected to be in the area because they had either been netted or detected by echolocation analysis (Patriquin, 2001). We used a Pettersson Ultrasound Detector D100, set at 25 kHz, to count passes by the larger, faster flying bat species in the area: big brown bats (*Eptesicus fuscus*; 15–20 g), hoary bats (*Lasiurus cinereus*; 25–30 g) and silver-haired bats (*Lasionycteris noctivagans*; 10–15 g), and a Mini-2 Bat Detector (Ultrasound Advice) set at 40 kHz to count passes by the smaller more maneuverable bats species: little brown bats (*Myotis lucifugus*; 8–10 g) and northern long-eared bats (*M. septentrionalis*; 6–8 g) (van Zyll de Jong, 1985). These are the only species of bats in our study area. Big brown bats have not been caught by mist netting in the study area, but their distribution is predicted to extend into it (van Zyll de Jong, 1985). A passing bat may not always be foraging, but may be commuting. However, bats increase their rate of echolocation pulses as they attack a prey item, resulting in a characteristic feeding buzz (Fenton and Bell, 1979). Therefore we also compared the frequency of foraging "buzzes" at the three locations.

We sampled one cutblock each night, randomizing the sampling order of the cutblocks. We started monitoring for bat activity 30 min after sunset and continued for 2.5 h. We monitored for 15 min each at the cutblock-forest edge, patch edge and center of the clearcut portion of the cutblock. After monitoring each location once, we returned to the first location so that, during the 2.5 h period, we sampled two of the locations three times each and one location twice. Due to this asymmetry in the sampling, we varied the starting location within a cutblock among the sampling nights so that the same location was not always left out of the third rotation of detection. We measured ambient temperature with a mercury thermometer at sunset.

To sample as much cutblock forest edge and patch edge as possible, when feasible, we walked along the edges as we monitored, with the detector oriented parallel to the edge. However, because of abundant debris on the ground this was not always possible, as the bat detectors detected the noise from walking, making it difficult to detect bat activity. In this case, we stood in one spot for 1 to 2 min, took a few steps and continued monitoring. To detect bat activity in the center of a cutblock, we stood in one spot and slowly, but continuously, turned to sample as much of the cutblock as possible without pointing the detector towards forest or patch edges that were within 50 m.

There were many nights when no bat activity was detected at one or more of the locations in a cutblock, resulting in non-normal distributions of data. We used a chi-square test to determine if the presence or absence of bats was influenced by location. If it was not, we then analyzed whether activity level varied by removing all zeros and log-transforming the remaining values to normalize the data. To determine if the number of bat passes per hour varied among the different locations or stand types, we performed an analysis of covariance (ANCOVA), with ambient temperature as the covariate. When the sample size was insufficient to perform an ANCOVA, we used a chi-square test.

We detected few feeding buzzes and used a chi-square test to compare the number of feeding buzzes detected at each location over the entire study period to the number of buzzes expected if bats foraged at the same rate at all locations. We calculated the expected number of feeding buzzes at each location based on the proportion of passes that occurred at each location throughout the summer.

For ease of interpretation, we present back-transformed (anti-logged) means instead of log-transformed means used during analysis. Back transforming the standard error values results in asymmetrical standard error values (Sokal and Rohlf, 1995). We used a Type I error rate of 0.05 for all statistical tests and present means ± 1 standard error.

RESULTS

We monitored bat activity on 27 nights, for a total of 52 h, and detected 173 passes and 22 buzzes. The presence or absence of bats did not differ significantly among locations within the cutblocks ($\chi^2 = 1.34$, df = 2, $P > 0.05$). We performed an ANCOVA with all passes combined (25 and 40 kHz passes) and one with 40 kHz passes only. Because we detected few 25 kHz passes (31), we could not conduct an ANCOVA on these data alone. When bats were present, the mean number of total bat passes per hour did not differ significantly among location in the cutblocks, although the trend indicated more passes at the forest edge of the cutblock than at the patch edge or center of the cutblock ($F = 3.03$, df = 2, 41, $P = 0.059$; Table 1). For 40 kHz passes alone, there were significantly more passes at the forest edge of the cutblock and the edge of the patch than in the center of the cutblock ($F = 6.66$, df = 2, 34, $P < 0.005$; Table 1). Activity did not differ between the forest edge of the cutblock and the edge of the patch. The 25 kHz passes were evenly distributed among the three locations, indicating that location did not significantly affect the activity of the larger bat species ($\chi^2 = 0.45$, df = 2, $P > 0.05$) although our sample size was small. The observed number of bat passes significantly increased with temperature for all species combined ($F = 12.58$, df = 1, 41, $P < 0.005$) and for *Myotis* species (40 kHz) alone ($F = 4.41$, df = 2, 34, $P < 0.05$). Stand type (CDOM, DDOM, MIXED) did not significantly affect bat activity (Total: $F = 2.80$, df = 2, 41, $P > 0.05$; 40kHz: $F = 1.84$, df = 2, 34, $P > 0.1$).

Foraging activity of 40 kHz bats did not differ significantly with location ($\chi^2 = 3.91$, df = 2, $P > 0.05$). However, there was a trend for higher foraging rates at the cutblock forest edge than in the center of the cutblock or at the edge of the patch. There were not enough 25 kHz feeding buzzes for statistical analysis.

DISCUSSION

Within cutblocks, a bat's choice of location for traveling and foraging is influenced by its morphology and echolocation abilities. Smaller more maneuverable bats, such as *Myotis lucifugus* and *M. septentrionalis*, that use relatively high frequency echolocation calls, are better adapted to fly through cluttered environments (Fenton, 1990; Kalcounis and Brigham, 1995) and, as predicted, showed a preference for traveling along the forested edges of the cutblocks and residual patches rather than in the center of the cutblock. These bats traveled and fed along the edges of the residual tree patches as frequently as along the forest edges of cutblocks. Therefore, cutblocks that incorporate remnant patches do provide additional habitat for bats compared to clearcuts although we cannot assess foraging activity due to the low numbers of feeding buzzes we detected.

TABLE 1.—Bat passes/hour (mean ± SE) at three locations within cutblocks, when bats were present. Results are presented for all bat species combined, and for Myotis species alone. On several nights, only non-*Myotis* species were detected. Thus, mean *Myotis* passes may be greater than the mean for all bats, because mean *Myotis* passes were calculated only using nights when *Myotis* were detected

	Cutblock center	Forest edge	Patch edge
All bats	2.62 + 0.5/−0.42	4.75 + 1.23/−0.95	4.01 + 0.84/−0.7
Myotis species	1.95 + 0.28/−0.24	5.08 + 1.63/−1.23	4.06 + 0.91/−0.75

Although we could not distinguish between the two *Myotis* species, another study carried out at the same time and study site, but using different detectors (ANABAT), could identify some *Myotis* passes as either *M. septentrionalis* or *M. lucifugus* based on call characteristics (Patriquin, 2001). *Myotis septentrionalis* was never detected in the center of cutblocks, suggesting a strong preference for edge habitat (Patriquin, 2001). This species feeds on flying insects, but also gleans insects from surfaces (Faure *et al.*, 1993; Caceres and Barclay, 2000). Therefore, these bats may prefer edges because they present a broader array of prey than available in open habitats. These bats may also prefer edges because of the protection provided from predators and wind (Verboom and Huitema, 1997; Grindal and Brigham, 1998). *Myotis lucifugus* showed a somewhat weaker preference for edge habitat, as it was observed in the center of the cutblocks, but significantly more often at edges (Patriquin, 2001).

That bat activity was significantly influenced by location when the 40 kHz passes were analyzed separately, but not when all species were analyzed together (*see also* Swystun *et al.*, 2001), likely resulted because larger bats, detected at 25 kHz, showed no preference for location. Larger, faster flying, less maneuverable species that use relatively low frequency echolocation, such as *Eptesicus fuscus*, *Lasionycteris noctivagans* and *Lasiurus cinereus*, negotiate clutter poorly and are more apt to fly in open habitats (Fenton, 1990). These larger bats showed no preference for traveling or foraging at any location within cutblocks, contrary to our prediction that they would prefer the center. The larger species may have used both edge and open habitats, although our sample size is too small to make any conclusions other than that the distribution of the two groups of bats differed. *Lasionycteris noctivagans* has been observed foraging along forest edges (Barclay, 1985).

Our results indicate that when *Myotis* bats were present, they foraged at the same rate regardless of location. This suggests that prey density may not have differed at the three locations, but we detected few feeding buzzes and there was a trend for greater feeding rates along the cutblock edge. Previous studies have found greater insect densities along forest edges than in the center of cutblocks (Grindal, 1996; Burford *et al.*, 1999). However, the cutblocks at our study site were small (averaging 10 ha) and insect populations in the forest surrounding the cutblocks and in the remnant tree patches may thus have maintained insect densities within the cutblock.

The provision of habitat by patches of remnant trees in cutblocks may mitigate the impact of forestry on bats. However, the low activity and foraging rate in all cutblock locations suggests that other habitats, such as riparian zones, may be more important foraging areas, as has been documented elsewhere (Grindal *et al.*, 1999). Foraging is only one aspect of a bat's use of forest habitat; harvesting trees reduces the availability of appropriate roosting sites (Grindal, 1996; Jung *et al.*, 1999). The value of remnant patches to bats would be greater if they are used for both roosting and foraging.

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