

Habitat Use by Bats, *Myotis* spp., in Western Newfoundland

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Bat diversity and activity patterns were monitored using mist-nets and bat detectors, and roosting habitat was investigated using radio-telemetry in western Newfoundland during June–August 1995. Of the three species of bat known to occur in Newfoundland (*Lasiurus cinereus*, *Myotis lucifugus*, and *M. septentrionalis*), only the latter two were detected or captured. *Myotis* bats were recorded with detectors at 87% of the riparian sample sites, although at relatively low levels (mean of 19.4 commuting passes/hr). These detector results suggest that myotis bats are ubiquitous, yet not very abundant in western Newfoundland. Most captures were of *M. lucifugus* (66%, $n = 30$), yet *M. septentrionalis* appear to be more common than previously thought, representing 34% ($n = 15$) of the captures. *Myotis* bats roosted in holes ($n = 4$), in cracks ($n = 2$), and under loose bark ($n = 2$) of standing dead trees, generally close to cutblock edges and sources of water (presumably foraging sites). Compared to those trees available (based on random transects in cutblocks and forests), bats did not appear to select roost trees based on many of the characteristics I measured (% bark remaining, diameter at breast height, stand slope, or species group (deciduous or conifer)). However, bats tended to select roost trees of smaller height classes (0–5 and 11–15 m) and with greater numbers of cavities than those available. Because most roosts were located along edge habitat, forest harvesting may increase accessibility to roosts for some bats by creating corridors and openings through the forest. However, it is still unclear how habitat fragmentation and loss of forested areas may affect bat populations.

Key Words: Little Brown Bat, *Myotis lucifugus*, Northern Long-eared Bat, *Myotis septentrionalis*, habitat use, tree roosts, Newfoundland.

Typical of isolated islands, insular Newfoundland has relatively few native land mammals, of which a large proportion (21 %, 3 of 14 species) are represented by bats (Northcott 1974). However, little is known about the distribution, relative abundance, or habitat requirements of the three species of bats on Newfoundland (Northcott 1974; van Zyll de Jong 1985). The Little Brown Bat (*Myotis lucifugus*) has been observed over most of the island, and a maternity colony for this species has been monitored on the Avalon Peninsula (Ballam et al. 1993*). The Northern Long-eared Bat (*M. septentrionalis*) is thought to be less common (van Zyll de Jong 1985), and only a single occurrence of the Hoary Bat (*Lasiurus cinereus*) has been documented in Newfoundland (Maunder 1988).

Bats require suitable habitat in which to roost and forage. Forest harvesting alters natural bat roosting and foraging areas, which may in turn affect aspects of bat ecology. Research in the Pacific Northwest suggests that some bats are more dependent on older forest stands (Thomas 1988). Recent studies suggest that retaining certain tree species is necessary for suitable roost sites for some bats, whereas other species appear quite flexible in their roosting requirements (Barclay and Brigham 1996*). Conversely, openings and edge habitat are important

feeding sites for many bats (Fenton 1990), and these areas are created by forest harvesting (Brigham et al. 1997; Grindal and Brigham 1998). These and other investigations have led to the recognition that some bat species are sensitive to habitat modifications. Therefore, information on the diversity, distribution, and habitat requirements of bats is essential for the development of forest management practices that will preserve bats as a valuable component of Newfoundland's biodiversity.

The purpose of this study was to expand on a previous preliminary bat survey (Dennis 1994*), as well as further describe the roosting and foraging habitat use by bats in western Newfoundland. As no published information exists on habitat use by bats in Newfoundland, particularly in forest ecosystems, this study represents one of the few documentations of bat ecology in this province.

Methods

The study took place from June to August 1995 at two sites (Marten Pond: 48°38' N, 57°49' W; and Kennedy Lake: 49°16' N, 57°52' W) in the Western Newfoundland Model Forest, Newfoundland. These areas are found in the Western Newfoundland Ecoregion, with vegetation dominated by Balsam Fir, *Abies balsamea*, Black Spruce, *Picea mariana*, and White Birch, *Betula papyrifera* (Meades and Moores 1989). Elevation ranged from 210–350 m, and the landscape contained numerous lakes and creeks. The two study sites were located within active forest har-

*See Documents Cited section

TABLE 1. Age, sex, and reproductive classes of bats captured in western Newfoundland during 1995. NP = not pregnant, P = pregnant, L = lactating, PL = post-lactating.

	Adult Female				Adult Male	Juvenile Female	Juvenile Male	Total
	NP	P	L	PL				
<i>M. lucifugus</i>	5	2	0	12	3	6	2	30
<i>M. septentrionalis</i>	0	0	0	4	2	4	5	15
Total	5	2	0	16	5	10	7	45

vesting areas, resulting in a forest landscape mosaic of highly fragmented habitat from numerous years of harvesting (most occurring 5–20 y ago). In harvested areas, patches of non-commercial tree species were typically left standing in cutblocks.

Capture

Bats were captured in mist-nets set for a minimum of 2 h after dusk in potential bat flight corridors and foraging areas (e.g. near lake edges and over creeks). I identified bat species and recorded five variables (mass, forearm length, sex, reproductive condition, and age-class). Reproductive condition of the females was determined as either pregnant (estimated by palpation of the abdomen), non-pregnant (unswollen, furred nipples), lactating (swollen pink nipples), or post-lactating (unswollen, bare nipples; Racey 1988). Juveniles were determined by incomplete ossification of the third metacarpal-phalangeal joint (Anthony 1988).

Ultrasonic Detectors

I used Mini-2[®] ultrasonic bat detectors (Ultra Sound Advice, London, England) to monitor bat activity for 120 min after sunset. These instruments detect the high frequency sound that bats produce when traveling or searching for prey, and can be used to assess relative activity levels (Thomas 1988). Detectors were placed at ground level on lake edges, and orientated with microphones at a 45° angle directed over the water.

I differentiated bat species groups based on the pulse rate and frequency of echolocation calls. At each sample site, a pair of detectors was set at 20 kHz (to identify *L. cinereus*) and 45 kHz (to identify *M. lucifugus* or *M. septentrionalis*; Thomas and Laval 1988). Using Mini-2 bat detectors, it was not possible to distinguish between *M. lucifugus* and *M. septentrionalis* (Thomas et al. 1987).

Two activity types of bats were determined by the pulse rate of echolocation calls. Commuting passes were identified by a steady series of echolocation calls (two or more), produced when bats are traveling or searching for prey. Foraging attempts were identified by a rapid series of echolocation calls, produced when bats make a feeding attempt (Griffin 1958). Temperature at sunset was determined using alcohol thermometers placed 0.5–1 m above the ground.

Radio-telemetry

To locate and monitor roost sites, I affixed miniature radio transmitters (0.44 g, life of approximately 10 d; Holohil Systems Ltd., Woodlawn, Ontario) to the backs of captured bats using small amounts of Skin Bond[®] (Canadian Howmedica, Guelph, Ontario) surgical adhesive. On subsequent days, I tracked bats to their roosts in order to characterize roosting habitat.

The following roost habitat characteristics were recorded: cavity (type, height, aspect, number), tree (species, height, diameter at breast height (dbh), live/dead class, percent bark remaining, and emergent above/below canopy class), and forest stand (species composition, age-class, slope, and distance to nearest water source and cutblock). Heights and slopes were measured using a clinometer. Percent bark remaining on the tree was estimated visually. Stand age-classes were obtained from forest cover maps. I defined a water source as a body of water large enough for a bat to forage over, or drink from (e.g., lake or creek ≥ 2 m wide).

To assess the availability of potential roosting habitat, I measured trees within circular plots (10 m radius) established at 50 m intervals along 150 m transects. Transects were located in randomly chosen sites in two areas: cutblocks (0–20 y old) and undisturbed forest (81+ y, dominated by Balsam Fir). To eliminate edge effects, transects were located at least 100 m from edges within the two respective habitats. Within each plot, I recorded details of all potential roosts (number, species class as either conifer or deciduous, height class in 5 m increments, dbh, number of cavities, percent bark remaining). I defined a potential roost as a standing dead tree, with a height greater than 2 m and a dbh greater than 0.1 m. This definition was based on the characteristics of known roost trees documented during this study.

Once located by telemetry, roosts were verified by watching the tree for the emergence of bats. Observers (usually two) recorded the number of bats emerging until at least 30 min after sunset, or until too dark for viewing. Roost residency time was determined by the number of consecutive days that a bat remained in the same roost, not including the first roost located. Roost fidelity (the number of roosts used by an individual bat over time) was estimated by using only data in which individuals were

TABLE 2. Characteristics of known and potential roost trees in western Newfoundland in 1995. Mean (± 1 SE) values are presented when applicable. Statistical significance represented by: * ($p < 0.001$) or NS (not significant). Dashes represent irrelevant or uncollected data.

		Known Roosts	Potential Roosts		Significance
Characteristic			Forest	Cutblock	
Cavity	height (m)	4.2 (0.89)	-	-	-
	cavities (#)	4.0 (1.2)	0.18 (0.04)	0.17 (0.05)	*
Tree	height (m)	8.7 (1.2)	11-15	11-15	see Fig. 2
	conifer	5 ¹	228	53	NS
	deciduous	1 ¹	13	31	NS
	bark remaining (%)	55 (13.8)	52.9 (2.5)	43.9 (4.7)	NS
	dbh (cm)	29.1 (2.6)	23.6 (0.48)	25.9 (1.1)	NS
Stand	slope (%)	15 (2.4)	11.5 (0.37)	11.9 (0.64)	NS
	distance to cutblock (m)	10.6 (4.5)	-	-	-
	distance to water (m)	259 (107.5)	-	-	-
	# trees/ha	-	191.9	66.9	-
n		8	241	84	-

¹species (#) for known roosts: Balsam Fir (4); Black Spruce (1); White Birch (1); unidentified (2).

monitored for more than two days, and known to move between roosts. On topographical maps, linear distances were calculated between roost and foraging or capture sites, as well as distances between multiple roost sites for an individual bat.

I used t-tests to examine differences between characteristics of known and potential roosts (Zar 1984). Chi-square tests were used to examine differences between roost height classes and tree species type. I used a 0.05 rejection level in all cases.

Results

Capture

Mist-nets were set on 23 nights for a total of 143 mist-net hours (one mist-net hour = one 2 m $\times$ 6 m net set for one hour) at 15 different locations (e.g., lake edges, creeks). This resulted in the capture of 48 bats, three of which were recaptures (Table 1). *M. lucifugus* were captured more often (67%) than *M. septentrionalis* (33 %).

Sex and age-class structure was not equally distributed for captured bats. Adult females were captured more frequently than adult males (*M. lucifugus* — 6.3 females:1 male; *M. septentrionalis* — 2 females:1 male). Juveniles represented 27% and 60% of captures for *M. lucifugus* and *M. septentrionalis*, respectively (Table 1).

Ultrasonic Detection

Bat detectors were used on 24 nights for a total of 72 h at 36 sites, resulting in the detection of 1393 commuting passes and 271 foraging attempts. No passes were detected at 20 kHz (frequency setting to detect *L. cinereus*). Bat activity was recorded at 87 % of the sites sampled, although at relatively low levels (mean ± 1 SE): commuting passes/hour (19.4 ± 11.4); foraging attempts/hour: (3.8 ± 3.0). Bat

activity did not begin until at least 20 min after sunset, then generally peaked 45 min after sunset and declined over the remaining 75 min of observation time.

Mean (± 1 SE) temperature at sunset was 13.7°C (0.77) and ranged between 5 and 22°C, with most (87% of nights) temperatures above 10°C. In June, bat activity was regularly observed at cooler temperatures between 2 and 6°C later in the night.

Roosting Habitat

Radio transmitters were attached to 11 *M. lucifugus* (9 females, 4 males) and 4 *M. septentrionalis* (3 females, 1 male). Mean mass (g ± 1 SE) of *M. lucifugus* and *M. septentrionalis* carrying radio transmitters was 8.1 (0.2) and 7.7 (0.3), respectively. Of the 15 radio-tagged bats, eight different roosts were located from seven individual female bats (4 *M. lucifugus* and 3 *M. septentrionalis*; Table 2). Mountainous terrain and poor accessibility limited the success of monitoring radio-tagged bats. Because of the low number of roosts, both bat species were combined for the following analyses of roost characteristics.

Bats roosted in old woodpecker holes (n = 4), in cracks in tree trunks (n = 2), and under peeling bark (n = 2), all of which were located at least half of the tree height. Roost cavities faced SW (n = 4), SE (n = 2), or NE (n = 2). Four of the roosts were in Balsam Fir trees, and 83% of identifiable roost trees were coniferous. All roosts were located in dead standing trees in either forests greater than 81 y, or in cutblocks less than 20 y old. Most roosts (87.5 %, n = 7) were less than 15 m from cutblock/forest edges (Table 2). Although distance to water sources (lakes or creeks) varied greatly (Table 2), 75 % (n = 6) were less than 250 m from sources.

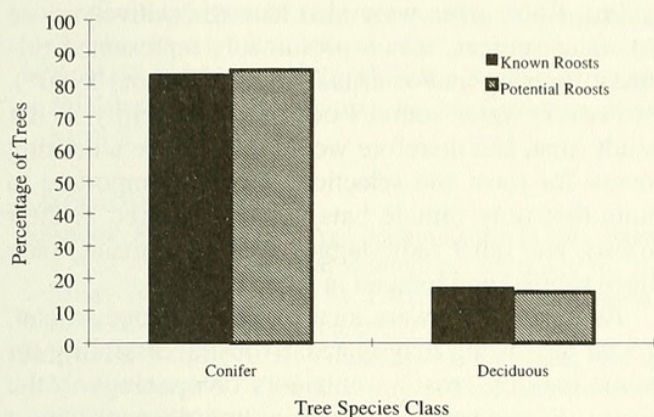


FIGURE 1. Species type composition of known ($n = 8$) and potential ($n = 325$) roost trees in western Newfoundland in 1995.

To assess the quantity and quality of potential roosts available to bats, ten transects were conducted in each of the forest and cutblock habitats for a total of 80 plots. The forest had almost three times the density of potential roosts than the cutblock (Table 2).

There were no significant differences between known and potential roosts for most comparable characteristics (% bark remaining, dbh, or stand slope; Table 2). Furthermore, roost tree species were used in approximately the same proportions as were available to bats (Figure 1, Table 2). However, smaller height classes (0–5 and 10–15 m) of roost trees were selected, compared to those available (0–5 m: $\chi^2 = 10.1$, $df = 2$, $p < 0.005$; 11–15 m: $\chi^2 = 9.28$, $df = 2$, $p < 0.005$; all other height classes $p > 0.05$; Figure 2), and only 50% of known roosts extended above the surrounding canopy height (Table 2). Known roosts had significantly greater numbers of cavities than potential roosts ($F = 102.3$, $df = 2$, $p < 0.001$).

Bats used numerous roosts and moved almost daily between roosts during the monitoring period. Mean number of roosts used by each bat was 0.79 roosts/day (SE = 0.09, $n = 5$ bats at 19 roosts). Mean residency time at the same roost for individual bats was 1.44 d (SE = 0.29, $n = 4$ bats at 9 roosts). Colony sizes were generally larger for *M. septentrionalis* (mean 21, SE = 13.1, $n = 3$ roosts) than *M. lucifugus* (mean 5.0, SE = 1.5, $n = 7$ roosts).

Bats which were monitored stayed close to foraging areas and other roost sites. Mean linear distance of roost to foraging or capture site was 560 m (SE = 153, $n = 8$). Mean linear distance between multiple roosts sites for the same individual was 410 m (SE = 48, $n = 7$). Note that in the above calculations (roost fidelity, roost residence time, and distances), different bats moved between, and used the same roosts.

Discussion

Diversity and Activity Patterns

Only *M. lucifugus* and *M. septentrionalis* were

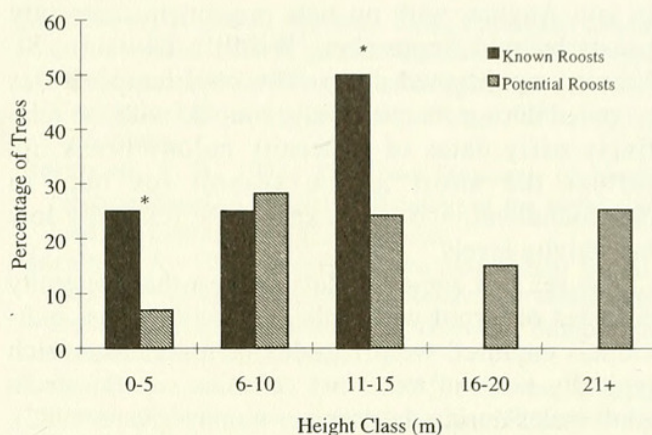


FIGURE 2. Height class distribution of known ($n = 8$) and potential (conifer or deciduous combined, $n = 325$) roost trees in western Newfoundland in 1995. * represents a significant difference ($p > 0.05$) within each height class.

captured or detected, supporting previously known bat diversity measures for Newfoundland. However, *M. septentrionalis* appear to be more abundant than previously thought, representing a third of captures in this study. The absence of *L. cinereus* from this survey suggests its occurrence is rare in western Newfoundland, or may simply be accidental, as represented by the single record in St. John's (Maunder 1988).

Bat activity was observed at most sample sites, but at relatively low levels, suggesting that myotis bats are well distributed in western Newfoundland, but at low abundance. For example, bat activity from this study is low when compared to myotis activity levels from other studies using similar sampling methodology in south west Ontario (80.4 passes/hr, Hickey and Neilson 1995), south west Alberta (approximately 60 passes/hour, von Frenkell and Barclay 1987), southern British Columbia (approximately 150 passes/hr, Grindal 1996*), and north east British Columbia (28.8–188 passes/hr, Crampton et al. 1997*).

The relatively low bat abundance measures inferred from detector data, and the foraging activity recorded at low temperatures, may be due to the relatively short summer season that bats experience in Newfoundland. Bat activity is generally thought to decrease dramatically at temperatures below 10 to 12° C, most likely due to low insect availability (Rachweld 1992; R. M. Brigham, personal communication). However, I regularly observed bats foraging in Newfoundland at low temperatures (2 – 6° C). Therefore, in this boreal ecoregion, bats may be forced to forage in extreme conditions (i.e., low temperatures, with presumably low levels of prey) to gain sufficient resources for growth, reproduction, and hibernation. For example, at Cochrane Lake in eastern Newfoundland, maternity colonies break up

in late August, with no bats present in maternity roosts by mid-September (Wildlife Division, St. John's, unpublished data). The cool temperatures recorded during June and July, coupled with the relatively early dates of maternity colony break up, reflect the short active season for bats in Newfoundland, and may explain the relatively low bat activity levels.

The sex and age-class data suggest that maternity colonies occurred within the study site. Most individuals captured were females or juveniles, which typically roost in maternity colonies separate from adult males during the summer months (Kunz 1982). Further, the high frequency of roost switching, together with the use of multiple roosts sites occupied by relatively few individuals, suggest that individuals may have been dispersing from maternity colonies. In addition, only females were monitored at roosts, suggesting that all known roosts were maternity colonies, or tertiary maternity colonies used during the break-up period. The timing of events interpreted from my data are consistent with those from eastern Newfoundland when juveniles become volant and leave the roost (late July), and maternity colonies are breaking up (late August: Wildlife Division, St. John's, unpublished data).

Roosting Habitat

Bats roosted exclusively in dead standing trees and did not select roosts based on tree species, as the known roost trees were in proportion to those species available. However, bats preferred roosts with greater numbers of cavities than those of potential roosts. These cavities, presumably created by woodpeckers and other primary cavity excavators, provide suitable sites for maternity colonies (Kunz 1982). The cavities tended to face south, which would result in passive thermal heating from direct solar radiation. These warm conditions facilitate embryo and juvenile development (Kunz 1982; Kurta et al. 1989; Racey and Swift 1981), and reduce energetic expenditures of adults through decreased thermoregulatory costs. Therefore, reproductive females may benefit energetically by selecting roosts that are heated by the sun.

The spatial distribution of roosts suggests that bats may select sites which are easy to access, and those which are close to alternate roost sites and foraging habitat. Bats may have difficulty flying to, and locating roosts in, interior forest stands due to the spatial complexity of a dense forest canopy and understorey (Brigham et al. 1997). In contrast, roosts located along edge habitat may be more easily located and accessed, explaining the close proximity of roosts to cutblock/forest edges observed in this study. Further, multiple roosts used by the same individuals were spaced relatively close together. Although the data are limited, this may indicate that groups of roosts, as opposed to single trees, were used by bats, as suggested by other studies (Kurta 1982; Vonhof and Barclay

1996). Roost trees were also located relatively close to water sources, which presumably represented primary foraging and/or drinking sites (Grindal 1996*). However, water sources occurred frequently in the study area, and therefore would unlikely be a limiting factor for roost site selection. It is also important to note that only female bats were monitored at their roosts, and other radio-tagged bats (e.g., males) may have roosted and foraged in larger areas.

As most roosts were located close to edge habitat, forest harvesting may increase roost accessibility for some bats by creating corridors or openings in the forest. Conversely, forest harvesting decreases roost availability by removing large blocks of older forest, which typically contain preferred roosting habitat (Grindal 1998). This loss of roosting habitat may be compensated somewhat by the harvesting practice in Newfoundland of leaving individual or groups of standing dead trees (typically non-commercial species) in cutblocks (SDG, personal observation). However, it is still unclear how habitat fragmentation and the overall loss of forested areas may affect bat populations (Grindal and Brigham 1998b).

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