Northern Long-Eared Bat (*Myotis septentrionalis*) in Minnesota

A Summary of Relevant Literature

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This literature review of Northern Long-eared Bat (NLEB, *Myotis septentrionalis*) focused selectively on literature pertaining to forested habitats in the northern United States, with an emphasis on the Midwest. Other literature was used if it added significant information on the distribution, behavior and habitat of the species. For a summary of literature on all aspects of NLEB, please see the US Fish and Wildlife Services summer field guidance, which presents a table comparing NLEB to Indiana Bat.[1]

1. Roosting/Foraging Ecology

Foster, R.W. and A. Kurta. 1999. Roosting ecology of the northern bat (*Myotis septentrionalis*) and comparisons with the endangered Indiana bat (*Myotis sodalis*). *Journal of Mammalogy* 80:659-672.

This study was conducted near Vermontville, Michigan in Eaton County, an area with wetland forests dominated by American elm, green ash, silver maple, and swamp white oak. The objective of the study was to describe the roosting niche of the Northern Long-Eared Bat (NLEB) during the mating period and various aspects of roosting behavior, including frequency and distance of movements. NLEBs are small (6-9g), insectivorous, and range from Canada to Florida. Previous studies determined that most NLEBs roost in trees during the summer, either in tree hollows or underneath the exfoliating bark of dead trees. In the winter, they have been found to hibernate in abandoned mines or caves.

[1] US Fish and Wildlife Service. 2014. Northern Long-eared Bat Interim Conference and Planning Guidance. http://www.fws.gov/northeast/virginiafield/pdf/NLEBinterimGuidance6Jan2014.pdf (Accessed 2014).

Researchers determined that all roost trees to which they tracked radio-tagged NLEBs were located in wetlands and the base of each trunk was submerged in water at some point during both study years, leading to the death of most trees. The 32 roost trees that NLEBs chose belonged to three species: 56% (n=18) was silver maple, 3% (n=1) was red maple, and 41% (n=13) was green ash. Of the roost trees, 17 were living and 15 were dead. In addition, even though elms possessing appropriate roosting characteristics made up 35% of the tree sample in the study area, NLEBs did not use American elms. Researchers found there were a large number of bats per roost early in the year, potentially relating to thermoregulatory needs, but large groupings may also facilitate the transfer of information among bats concerning the location of productive foraging areas and thereby increase foraging efficiency of all individuals.

Although NLEB roosts were mostly in maple, it is most likely that NLEBs are not dependent on any particular species of trees across their range. Rather, certain species of trees tend to develop suitable cavities or retain bark and will be used whenever they are present.

Jung, T.S., I.D. Thompson and R.D. Titman. 2004. Roost site selection by forest-dwelling male *Myotis* in central Ontario, Canada. *Forest Ecology and Management* 202:325-335.

The purpose of this study, conducted northwest of Sudbury, Ontario, Canada, was to investigate the roosting ecology of NLEB males. In general, snags are used as diurnal roost sites by many bats in northern forests and are an essential component in the life cycle of bats. They provide protection from poor weather and predators, as well as a location for thermoregulating and raising pups.

Researchers found that bats switched roosts on average every 3.1 days, and 26 of the 27 roosts identified were at snags, most being under exfoliating bark (n=22). Roost sites were evenly distributed among four main stand types: old-growth white pine (n=7), mature white pine (n=8), old aspen (n=7), and mature boreal mixed woods (n=4). NLEBs showed a strong preference for snags that were recently dead, with few branches and exfoliating bark (decay class 4). In addition, NLEBs preferred snags that were as tall as, or taller, than the forest canopy and appeared to avoid snags that were in the sub-canopy. Furthermore, they preferred snags that had a larger DBH (diameter at breast height) and less canopy closure around them than snags chosen randomly in the forest.

The selection of tall aspens and white pines in open areas may reflect active selection of locations with increased solar exposure, giving those locations a thermal advantage. Tall snags (especially those extending above the canopy) may also be easier for bats to relocate to when returning from foraging excursions. NLEBs prey on insects from foliage but rarely forage over water and therefore have no requirement to roost close to water bodies, other than to drink. Therefore, it is not surprising that in this study bats were not found to regularly roost near water bodies. Roost location may also have been influenced by the lower solar radiation potential for snags at low elevations, where shading by trees or landforms is more likely than higher on the landscape.

Consistent with other studies, there was a demonstrated association between foraging NLEBs and old-growth white pine stands, potentially because their structure enhances foraging success, rather than only providing snags for roosting.

Patriquin, K.J. and R.M.R. Barclay. 2003. Foraging by bats in cleared, thinned and unharvested boreal forest. *Journal of Applied Ecology* 40:646-657.

The purpose of this study was to determine the immediate response of bats to timber harvesting, by testing for differences in foraging by bats in different habitats available in a harvested forest. As found in previous studies, smaller bats can fly more slowly and maneuver more easily than larger bats, allowing them to exploit richer food sources in cluttered habitat. The study was conducted in the boreal forest north of Peace River, Alberta, Canada. The forest in the study area was conifer-dominated, with white spruce the most abundant tree species in the area.

The mean activity rate was higher in conifer forests than in deciduous and mixed forest, as indicated by feeding buzzes. *Myotis* bats may have been more active in conifer forests because such stands provide resources, such as roosts, in addition to foraging habitat. NLEBs did not forage in clear-cuts and were never detected flying through the center of these patches. This is partly due to NLEBs ability to glean insects from foliage, thus affording them more gleaning opportunities in intact or thinned forest than in clear-cuts. Furthermore, NLEBs likely were not present in clear cuts because roosting habitat is lost by clear-cutting.

Perry, R.W., R.E. Thill and D.M. Leslie, Jr. 2007. Selection of roosting habitat by forest bats in a diverse forested landscape. *Forest Ecology and Management* 238:156-166.

Because roost sites of bats play an important role in thermoregulation and protection from predators, roost-site characteristics influence bat fitness and survival. As seen in other studies, many tree-roosting bats prefer large-diameter trees and snags for roosting. This study was conducted in the Upper Lake Winona Basin in the Ouachita Mountains of central Arkansas. Most of the basin consisted of mixed shortleaf pine-hardwood forest, but the basin also contained oak-hickory forest.

The authors found that NLEBs preferred to roost in association with thinned mature, pine seed-tree stands and hardwood/mixed pine-hardwood stands ≥ 100 years old. Thinned mature forest habitat supported 49% of roosts, followed by mixed pine-hardwood of 50-99 years old (22.5%). In addition, 88% of NLEB roosts were in snags.

The authors speculated that bats preferred to roost in relatively open forest stands because of the ease of navigation due to reduced clutter, predator avoidance, facilitation of roost relocation, and thermal regulation. Many bat species are known to forage in partially open habitats, thus bats may have roosted in or near these stands to reduce travel time between roosting and foraging habitat. Reduced clutter around roosts could also help in detecting predators. Furthermore, open forest conditions allow more direct sunlight on tree trunks and canopies, which may have thermal benefits for developing young.

H.G. Broders, G.J. Forbes, S. Woodley and I.D. Thompson. 2006. Range extent and stand selection for roosting and foraging in forest-dwelling northern long-eared bats and little brown bats in the Greater Fundy Ecosystem, New Brunswick. *The Journal of Wildlife Management* 70:1174-1184.

Bat hibernation at northern latitudes lasts 6-8 months and over-winter survival is dependent on whether sufficient nutritional reserves have been accumulated. In addition, copulation for NLEBs is thought to occur at hibernacula. This study, conducted in and around Fundy National Park in New Brunswick, Canada, sought to characterize the structure of local bat populations and to assess inter-gender variation in the use of space for roosting and foraging and in the selection of foraging sites.

Male NLEBs had the smallest minimum roosting area and minimum foraging area and appeared to forage within and adjacent to their minimum roosting area. The minimum roosting area and minimum foraging area for female NLEBs were over 6 and over 3 times larger, respectively, than those of males. Males roosted alone in trees and at sites that were abundant and likely used episodes of torpor to maximize energy efficiency with less consequence for fitness than females. Females roosted communally, presumably to reduce thermoregulation costs. The authors hypothesized that females may have traveled twice as far as males between roosting and foraging sites because suitable maternity-colony roosts were more limiting than male roosts.

Relative to other forest-roosting female *Myotis* species in North America, female NLEBs traveled greater distances between roosts, but had comparable roosting-area sizes and traveled similar distances between roosts and foraging areas as congeners and conspecifics. Furthermore, the results suggest that female NLEBs may be more energetically burdened than local males. Finally, it appears that mature forests with an abundance of trees having cavities seem to be a requisite for productive populations of NLEB.

Carter, T.C. and G.A. Feldhamer. 2005. Roost tree use by maternity colonies of Indiana bats and northern long-eared bats in southern Illinois. *Forest Ecology and Management* 219:259-268.

This study was conducted within the greater Mississippi River floodplain at two locations in southern Illinois. It aimed to quantify habitat characteristics of maternity roosts. Roosting bats primarily used a swamp with high densities of snags at its edges. Prior studies showed that NLEBs use the forest during the summer and hibernate in caves and mines in the winter. NLEBs used five species of trees for roosting under bark, in cavities, and in crevices: 9 in swamp pin oak, 5 in elm, 2 in unidentified snags, and 1 each in sweetgum, oak, and hawthorn. The average roost height for NLEBs was 9m and they roosted in areas with higher canopy closure than in random plots. NLEBs also switched roosts frequently, likely due to temperature, precipitation, predator pressure, and the ephemeral nature of roost sites.

Broders H.G. and G.J. Forbes. 2004. Interspecific and intersexual variation in roost-site selection of northern long-eared and little brown bats in the Greater Fundy National Park Ecosystem. *The Journal of Wildlife Management* 68:602-610.

The objectives of this study were to describe the forest characteristics associated with roost sites of NLEBs to determine which characteristics best differentiated roost trees from available trees, and to examine how criteria for roost selection differed between sexes. Many forest-dwelling bats roost under exfoliating bark or in crevices or cavities of dead or dying trees. Such tree types (snags and dying trees) are most often associated with old forests.

Females typically roosted in large cracks or crevices of shade-tolerant deciduous trees either alone (n=1) or in colonies (n=12). The most common species for NLEB roosts in mature shade-tolerant deciduous tree stands were sugar maple and yellow birch. Males roosted primarily in coniferous trees (mostly red spruce) in coniferous stands or conifer-dominated mixed-wood stands. Males also roosted alone. In contrast, female NLEBs formed maternity colonies in mature, shade-tolerant deciduous stands.

Shade-tolerant, deciduous tree species, such as sugar maple and yellow birch, may be valuable as maternity sites because they are susceptible to the heart rot that creates internal openings in trunks, and limb breakage often allows access to the interior. In addition, because shade-tolerant deciduous stands tend to be located in upland areas, solar radiation on the trunks was probably higher. This may have led to high temperatures which could decrease the energy required for females to maintain body temperatures and may have aided fetal growth. The authors hypothesized that roost sites were near many other potential roost trees because access to multiple sites, each providing different microclimates, may have benefits for thermoregulation on any particular day, based on ambient conditions.

Perry, R.W. and R.E. Thill. 2007. Roost selection by male and female northern long-eared bats in a pine-dominated landscape. *Forest Ecology and Management* 247:220-226.

This study was conducted in the Ouachita Mountains of western Arkansas and eastern Oklahoma, a pine dominated area. Females roosted alone (31%) and in colonies (69%), with colonies ranging from 2 to 51 bats. Snags provided 90% of roosts, with roosts located under loose bark, in cavities, and in crevices, while 10% of roosts were in live trees. Shortleaf pine was the most used tree species (71% of all roosts) and 67% of roosts were in shortleaf pine snags. When comparing male and female roosting habits, females tended to roost in more open conditions and in snags that were greater in diameter than males. This may be because roost trees located in more open habitats may receive greater solar radiation, which may speed the development of young. Both female and male NLEBs preferred to roost in or in close proximity to thinned mature (>50 years old) stands of mixed pine-hardwood.

Garroway, C.J. and H.G. Broders. 2008. Day roost characteristics of northern long-eared bats (*Myotis septentrionalis*) in relation to female reproductive status. *Ecoscience* 15:89-93.

Beginning in late spring and continuing through early autumn, females of most temperate bat species aggregate in roosting groups ranging from a few to several hundred individuals. Roost sites are critical for population persistence as they provide a microclimate suitable for offspring development and they act as a center of the local population. The fieldwork for this study was conducted in Nova Scotia, Canada between June and August. Tree species used for roosting included red maple (n=20), eastern hemlock (n=15), yellow birch (n=4), red spruce (n=2), sugar maple (n=2), and white birch (n=1). All of the trees used for roosting were either snags (n=17) or living with defects (n=27). During the lactation period, bats were more likely to roost in taller trees with a higher dominant canopy and a greater distance between the roost and the canopy and in areas with a lower density of coniferous trees and total number of trees in general, relative to pre- and post-lactation periods.

Menzel, M.A., S.F. Owen, W.M. Ford, J.W. Edwards, P.B. Wood, B. R. Chapman and K.V. Miller. 2002. Roost tree selection by northern long-eared bat (*Myotis septentrionalis*) maternity colonies in an industrial forest of the central Appalachian Mountains. *Forest Ecology and Management* 155:107–114.

The main objectives of this study were to estimate the richness and relative abundance of bat species present in the study site, an industrial forest landscape located in the central Appalachians. In addition, researchers aimed to determine the abundance and the preferred roost habitat for NLEB maternity colonies in intensively managed forest stands. The authors used the Westvaco Ecosystem Research Forest (WERF) as the study site. The forest cover within the

WERF was primarily of an Allegheny hardwood-northern hardwood type dominated by beech, yellow birch, sugar maple, red maple, black cherry, and Fraser magnolia. Black locust was also a common tree species throughout the study area and usually found in canopy gaps within stands that have experienced heavy selection cutting and also in stands regenerated by clear-cutting.

To determine NLEB roost sites, researchers attached radio-transmitters to the backs of bats. In addition to lactating NLEBs that the authors used to find roost trees, they also netted 132 bats from seven species: big brown bat, eastern red bat, hoary bat, silver-haired bat, little brown bat, NLEB, and eastern pipistrelle (now tricolored bat). Of the bats that were netted, NLEB, eastern red bat, big brown bat, and little brown bat were the most common species captured. Following their capture, researchers attached radio-transmitters to seven lactating NLEBs and subsequently located 12 roost trees used by NLEBs. The tree species used by NLEBs included: one red maple, one northern red oak, one sassafras, one American basswood, two Fraser magnolias, two black cherries, and four black locusts. Of these 12 roosts, 11 were located in cavities and the remaining roost was located under a large piece of exfoliating bark.

The roost trees that were chosen had little or no remaining bark, a broken top, and a firm trunk with few or no limbs present. Data analysis indicated that roost tree size and level of decay did not influence roost tree selection, although snag longevity may have influenced roost tree selection. Black locusts, in particular, have a high level of decay resistance so they are likely to have a greater longevity than snags of most other tree species in the region. NLEB preference for black locust as a roost site appears to support this idea, although the authors did not make a firm statement regarding black locusts serving as roost sites. This discovery has implications for forest managers. They may wish to retain black locust snags during harvest in order to provide potential roost sites for bats in newly regenerating stands.

Krusic, R. A., M. Yamasaki, C. D. Neefus and P. J. Pekins. 1996. Bat habitat use in White Mountain National Forest. *Journal of Wildlife Management* 60:625-631.

The purpose of this study was to indentify bat species in the White Mountain National Forest and determine their patterns of habitat use. This study was conducted in the White Mountain National Forest, located in north-central New Hampshire and southwestern Maine. The area is 97% forested and dominated by northern hardwood tree species, including maple, beech, yellow birch, and red spruce. Researchers captured 84 bats from six species. Adult, male little brown bats made up 56% of the trapped bats. Bat flight and feeding activity were highly concentrated along trails and water bodies relative to the forest interior. Within the forest, greater flight activity was recorded by detectors in the mid-upper canopy than the subcanopy. In contrast to prior studies, researchers found a decrease in bat activity with increasing forest age in softwood areas. Furthermore, the lack of bat activity in two survey sites in virgin stands of spruce-fir forest suggests that bats prefer hardwood forests for foraging and roosting. In addition, flight activity was recorded most frequently in over-mature hardwood forests, but feeding activity here was low, suggesting that such areas are primarily used as roost sites by foliage and tree-roosting bat species. Finally, this study determined that still water is an important resource for bats and it attracted bats from a wide area, providing drinking and gleaning opportunities.

Owen, S.F., M.A. a, W.M. Ford, J.W. Edwards, B.R. Chapman, K.V. Miller, P.B. Wood. 2002. Roost tree selection by maternal colonies of northern long-eared myotis in an intensively managed forest. United States Department of Agriculture Forest Service General Technical Report NE-292:1-6.

The objectives of this study, conducted on the WERF in the central Appalachians, were to determine if and where NLEB maternity colonies roosted in intensively managed forest stands. The authors also wanted to compare roost trees (and the surrounding habitat) with potential roost trees to identify important roost habitat characteristics. Researchers captured 168 bats belonging to the following species: big brown bat (23), silver-haired bat (3), eastern red bat (25), hoary bat (12), little brown bat (27), NLEB (61), Indiana bat (1), and eastern pipistrelle (16). By tracking the NLEBs that they captured, the authors were able to locate 43 roost trees used by the NLEBs. On one day of the study, they observed 88 NLEBs leaving a cavity in a live black cherry. In addition, they found 15 roosts under exfoliating bark and 28 roosts in natural cavities. The roosts were located in 11 tree species, with the most abundant being 13 roosts (30%) in black locust, and 9 roosts (21%) in black cherry. Both of these tree species were used more than expected based on their abundance relative to the population of all trees.

The authors speculated that based on their observation of 88 NLEBs leaving a single roost site, the intensively managed forests in the central Appalachian mountains provide adequate habitat for NLEBs. In this study, finding roost sites in black locust was a novel discovery and their use as roost sites was likely due to the rapid growth of black locust and their place in the forest ecosystem. Black locust grows extremely fast but is overtopped and suppressed by other tree species. Fortunately, black locust is very rot-resistant and can remain intact as a snag for years. Based on the rot resistance of black locust and black cherry, and the use of these trees as roost sites, the authors hypothesized that snag longevity was an important factor influencing roost tree selection.

2. Hibernation and Breeding

Knowles, B. 1992. Bat hibernacula on Lake Superior's North Shore, Minnesota. *Canadian Field-Naturalist* 106:252-254.

NLEBs normally winter below-ground in caves, mines, or storm sewers. Since hibernating bats require high humidity, minimal disturbance, and low, stable, above-freezing temperatures, natural hibernacula are rare. In Minnesota, suitable natural locations are restricted largely to sedimentary-strata solution caves in the state's southeastern quarter. Two caves were found at Palisade Head, a large rhyolite mass fronting 1 km along Lake Superior, about 130 km northeast of Duluth. On 30 June 1990, no bats were found occupying either cave, with both caves having wet, actively dripping ceilings, presenting unattractive environments for daytime roosting. On 9 September 1990, no bats were present, but by 23 September, one cave was occupied at midday by 93 torpid bats, a mixture of little brown bats and NLEBs. Cave bats are common summer residents in northern Minnesota and these bats can be expected to use nearby hibernacula if available, thus avoiding unnecessary dangers and the energy costs of migration.

Krochmal, A.R. and D.W. Sparks. 2007. Timing of birth and estimation of age of juvenile *Myotis septentrionalis* and *Myotis lucifugus* in west-central Indiana. *Journal of Mammalogy* 88:649-656.

The NLEB colony examined in this study roosted in an unused 1,100 m^2 barn in Vermillion County, Indiana. Researchers examined bats at roosts from 31 May to 22 July 2000. They detected newborn NLEBs in the roost on 5-10 June, with the modal birth date being 6 June. All adults observed with young tended only a single juvenile, supporting earlier observations that twinning does not commonly occur in NLEBs. Flight availability developed rapidly, with juveniles developing a flapping response by 15 days and full flight capability by 21 days. All bats in the colony were born within a narrow 6-day window, establishing NLEB as a species that exhibits synchronous birthing.

Whitaker, J.O. and L.J. Rissler. 1992. Winter activity of bats at a mine entrance in Vermillion County, Indiana. *American Midland Naturalist* 127:52-59.

In this study, conducted at the Copperhead Cave in east-central Vermillion County, Indiana, researchers monitored/banded 283 NLEBs, 565 little brown bats, 82 pipistrelles (tricolored bats), and 4 big brown bats (934 total) from 19 September to 15 November. The objectives of the study were to determine flight activity at the mine entrance between mid-November and mid-March and the relationship of activity to temperature. They tested the assumption that little or no winter bat activity occurred by placing a trap at the entrance to the mine on 21 November 1989.

The trap was checked once per day and researchers found 1-6 bats in the trap at every date except for two between 22 November and 1 December. The trap was left continuously in place until 11 March 1990. NLEB was the most active bat during winter, with 148 males and 61 females taken. Researchers determined that although most could not be seen, NLEBs hibernated there in large numbers as indicated by the number of bats that entered the trap in the winter from inside the mine. There was less bat activity in December, January, and February, than in November or March. Activity was significantly greater in March than in January. Although the sample sizes are small, data from periods when the trap was tended show significantly increased activity of bats with increased temperature. Preliminary data also indicated that bats were not feeding during the winter. Hibernating bats awaken periodically during winter, although arousal frequency is not directly associated with any variable. Ambient temperature, however, does have a substantial impact upon arousal. During arousal, bats may fly about within their hibernacula and occasionally outside, or change hibernacula. Hibernation reportedly may begin as early as August but NLEBs became active in mid-March.

3. General Behavior

Henderson, L.E. and H.G. Broders. 2008. Movements and resource selection of the northern long-eared myotis (*Myotis septentrionalis*) in a forest-agriculture landscape. *Journal of Mammalogy* 89:952-963.

This study, conducted at two sites on Prince Edward Island, Canada, investigated movement patterns and resource selection of forest-dependent NLEBs in a fragmented forest-agricultural landscape. NLEBs are forest dependent because they generally rely on forest features for both roosting and foraging. The study area's historical forest cover was 98% but had been reduced to 45% by the time of the study due to clearing for farming and timber production. Forests in the study area were characterized by broadleaf deciduous and boreal conifer species, including sugar maple, yellow birch, red spruce, and balsam fir.

Researchers followed 21 female bats over 45 tracking nights and found that females roosted almost exclusively in maple trees. At one of the sites, females roosted in a storage barn from late June through mid-August and used trees in early June and in late August. Pregnant/lactating females likely varied in their roost selection because of the different energetic costs associated with maintaining high body temperatures for fetal growth and lactation. Foraging areas in both sites were concentrated along forest-covered creeks and included deciduous-dominated and mixed-wood stands. The minimum foraging areas were approximately six times larger than minimum roosting areas. At both sites, open areas were used less and forested areas were used more than expected given the availability of each. In addition, foraging plots had more structural clutter from higher tree densities and contained a larger proportion of coniferous trees relative to roosting plots. In sum, the preference by female NLEBs for deciduous roost trees in deciduous-dominated stands on Prince Edward Island was consistent with previous studies of roost tree selection in relatively intact forested landscapes. The movements of females under forest cover indicated a strong preference for foraging and commuting within forested landscapes.

Owen, S.F., M.A. Menzel, W.M. Ford, B.R. Chapman, K.V. Miller, J.W. Edwards and P.B. Wood. 2003. Home-range size and habitat used by the northern myotis (*Myotis septentrionalis*). *American Midland Naturalist* 150:352-359.

This study was conducted in a forest in Randolph County, West Virginia in an area dominated by black cherry, sugar maple, red maple, yellow birch, American beech, and northern red oak. Researchers radio-tagged 20 pregnant or lactating (7 and 13, respectively) NLEBs and found that the mean maternal 95% adaptive kernel home range was 65 ha.

NLEBs are gleaners and forage mainly on forested hillsides and ridges rather than among riparian or floodplain-forests. This study was consistent with that general observation, as individuals allocated most of their time to the upland diameter-limit harvests, intact forests, and road corridors. In addition, bat distribution and abundance are affected by insect abundance and availability. Open areas following recent clear-cutting or deferment cut stands provided little feeding substrate, whereas thinned areas contain better habitat for insects. The small canopy gaps created by diameter-limit harvests also increased solar radiation within forest stands, thus creating a warmer environment conducive to insect abundance and activity. This combines the beneficial environmental attributes of closed forests with more open conditions used by NLEBs.

Titchenell, M.A., R.A. Williams and S.D. Gehrt. 2011. Bat response to shelterwood harvests and forest structure in oak-hickory forests. *Forest Ecology and Management* 262:980–988.

This study, conducted in southern Ohio, focused on bats' response to varying degrees of forest management using the shelterwood method of timber harvesting, used to regenerate oaks in eastern deciduous forests. The conceptual basis for this study was that areas of low structural volume are often associated with high levels of bat activity. Harvesting changes the total amount of volume within a stand and also the vertical structure of the stand, often resulting in decreased volume in the understory to mid-story.

The primary objectives of this study were to assess bat activity within the shelterwood harvested and control sites. Researchers aimed to quantify the effects of shelterwood harvesting on forest structure and to use the amount of structural volume within the harvested and control sites to explain variations in bat activity. The authors predicted that due to the reduction in volume, shelterwood harvest sites would support higher levels of overall bat activity than control sites. The forests used as study sites were dominated by upland oak-hickory forest species: white oak, chestnut oak, Scarlet oak, pignut hickory, shellbark hickory, and mockernut hickory. These species accounted for 88.2% of the total basal area, with the remainder consisting of the upland hardwood species red maple, yellow poplar, and black gum.

Within each forest study area, researchers established one control forest (unharvested), one 50% of full stocking (full stocking = 100% cover) forest, and one 70% of full stocking forest, each comprising 10 ha. The authors grouped the bats observed into three species groups: LABO (*Lasiurus borealis*), EPLA (*Eptesicus fuscus, Lasionycteris noctivagans*), MYPE (*Myotis lucifugus*, *M. septentrionalis*, *M. sodalis, Perimyotis subflavus*). Of the 11,560 bat passes recorded by the AnaBat II system, only a small portion (6.8%) of the passes were attributed to the three species groups mentioned above. Among those passes attributed to the species in question, 45% (358) were LABO, 40% (351) were EPLA, and 15% (117) were MYPE.

Bat activity was highest within harvested sites, with a total of 5487 (47.5%) passes recorded within the 50% shelterwood harvest sites and 5327 (46.1%) passes recorded within the 70% shelterwood harvest sites. A total of 746 passes were recorded within the control sites, comprising 6.4% of the total passes recorded. Activity levels for species within MYPE were higher within the harvested sites than in the control sites. In the 70% shelterwood harvest sites 57 passes were recorded, in 50% shelterwood harvest sites 47 passes were recorded, and in control sites only 13 passes were recorded.

The authors' prediction that overall bat activity would be greater in the shelterwood harvest sites than in the control sites was supported by significantly higher numbers of passes in both harvest levels compared to the control sites. In addition, overall bat activity was relatively low in the control sites, corroborating prior studies that identified low levels of bat activity in upland, closed-canopy sites. The authors expected the MYPE species group to be associated with higher levels of structural volume but this prediction was not fully supported because this species group was present in all stands. This is consistent with previous studies, which classified small-bodied bats (including *P. subflavus* and *M. lucifugus*) as habitat generalists that can use habitats of both high and low structural volumes. (Whether this is true of *M. septentrionalis* was not discussed.)

The results of this study suggest that shelterwood harvests may provide quality foraging habitat for bats, particularly *L. borealis*, *E. fuscus*, and *L. noctivagans*. The authors hypothesized that these species are likely responding to the decreased structural volume in the understory and the mid-canopy, which can make foraging more energy-efficient.

4. Relevant Studies on Other Species in Genus *Myotis*

Jung, T.S., I.D. Thompson, R.D. Titman and A.P. Applejohn. 1999. Habitat selection by forest bats in relation to mixed-wood stand types and structure in central Ontario. *Journal of Wildlife Management* 63:1306-1319.

This study documented the species composition of bats and their use of forest habitats in a contiguous forest landscape located between the boreal forest and the Great Lakes-St. Lawrence forest biomes in central Ontario. The most common stand type in the study area included white pine-dominated mixed-wood and white pine-and red pine-dominated mixed-wood. The mixed-wood types contained sugar maple, white birch, trembling aspen, and balsam fir. Conifer stems provided 25-75% of total stem density.

Detection rates of both *Myotis* species (NLEB and little brown bat) were 2.7-14 times greater in old-growth white pine stands than in other stand types. In addition, detection rates for *Myotis* species were positively associated with higher basal area of trees, greater tree density, greater canopy closure, and smaller tree height. *Myotis* species were detected (and therefore foraged) less in the sub-canopy than in the canopy or in canopy gaps, suggesting that either the subcanopy provided lower quality habitat or these bats may have been excluded from the subcanopy by ecomorphological constraints. Bats may have preferred old-growth white pine forests because of the complexity of their canopy (and super-canopy) and their open understory. One major limitation of this study, however, was that the authors did not distinguish between NLEB and little brown bat because NLEB's low-intensity calls were less detectable than little brown bat calls.

Kalcounis, M.C., K.A. Hobson, R.M. Brigham and K.R. Hecker. 1999. Bat activity in the boreal forest: importance of stand type and vertical strata. *Journal of Mammalogy* 80:673-682.

The purpose of this study, conducted during the summer in the southern boreal ecoregion of Saskatchewan, Canada, was to evaluate bat activity measured from the ground in old and mature stands to determine if activity differed among forest types. More specifically, researchers wanted to measure the vertical distribution of bat activity in three forest types to determine if bat activity differed below, within, and above the canopy, and if that activity varied temporally. Prior studies on bats in high-latitude temperate forests found that foraging activity was most intense in mature stands and bats roosted exclusively in old stands.

During 16 sampling nights, scientists recorded 3,621 bat passes. 76% were recorded in aspen-white spruce mixed-wood forest, whereas 22% and 2% were recorded in aspen and jack pine forest, respectively. The mean number of calls per night of *Myotis* was higher within and above the canopy than below the canopy at the 33m tower placed in aspen. There were no elevational differences in the other two forest types.

The results of this study indicated that bats discriminate among types of mature forest, with significantly more activity in aspen-white spruce mixed-wood forest than in monotypic aspen or jack pine forest stands. Furthermore, the increased activity in mixed-wood stands suggests that mixed-wood stands provide both roost sites and foraging opportunities.

It is also assumed that maneuverable species tend to use cluttered areas, which are more likely to support higher densities of prey. Thus, it is not surprising that the smaller *Myotis* were detected commonly within and below canopy although the authors reported a relatively high level of activity by *Myotis* throughout the night above the canopy. A major limitation of this study, however, was that the authors did not distinguish between little brown bat and NLEB due to the overlap in the call structure of these species.

Psyllakis, J.M. and R.M. Brigham. 2006. Characteristics of diurnal roosts used by female *Myotis* bats in sub-boreal forests. *Forest Ecology and Management* 223:93-102.

The objectives of this study were to describe the characteristics of roost trees used by female bats in the *Myotis* genus, and to examine selection in the sub-boreal spruce forests of Prince George, British Columbia, Canada. Of the 37 confirmed roost trees identified by the authors, 19 were coniferous. In addition, the conifer trees used as roosts were typically dead and in the middle stages of decay, with bark and limbs remaining. Furthermore, 86.5% of the 37 roosts found were in forest stands between 120 and 250 years old. The remaining 13.5% were in remnant snags in stands between 40 and 80 years old. The remaining roosts in deciduous trees were primarily in long vertical cracks in trembling aspen (n=13) or black cottonwood (n=1), and under exfoliating bark of trembling aspen (n=4).

Grindal, S.D., J.L. Morissette and R.M. Brigham. 1999. Concentration of bat activity in riparian habitats over an elevational gradient. *Canadian Journal of Zoology* 77:972-977.

It is generally assumed that riparian areas support high concentrations of insect prey that are attractive to, and therefore support, high densities of foraging bats. The purpose of the current study was to compare the relative activity levels (using bat detectors) of a community of temperate zone bat species between riparian and upland habitats over an elevational gradient. The study was conducted in the southern interior of British Columbia, Canada, during the summers of 1993-1995. The low and mid-elevation zones were composed of mixed conifer forests dominated by western red cedar and western hemlock. Commuting and foraging activity levels were significantly greater in riparian areas than in upland areas, 10.8 and 40.2 times greater respectively. While NLEB was not found, other *Myotis* species were observed.