# Northern Long-eared Bat
# Habitat Requirements – Literature Review and Annotated Bibliography

## Wild Meadows Wind Project
## Grafton and Merrimack Counties, New Hampshire

Prepared for

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## Introduction

At the request of New Hampshire Fish and Game Department (NHFGD) at a consultation meeting in Concord, New Hampshire on March 31, 2011, Atlantic Wind LLC (a subsidiary of Iberdrola Renewables LLC) contracted Stantec Consulting Services Inc. (Stantec) to prepare a literature review, habitat assessment, and annotated bibliography of the habitat requirements for northern long-eared bats (*Myotis septentrionalis*) for the Wild Meadows Wind Project (Figure 1).

## Literature Review

Northern long-eared bats are a forest interior species that require adequate canopy closure for both roost and foraging habitat (Lausen 2009). Roosting and foraging activities tend to occur within closed, intact forest stands (Sasse and Pekins 1996, Foster and Kurta 1999, Lacki and Schwierjohann 2001, Owen et al 2002). Wing morphology of the northern long-eared bat makes them ideally suited for the high maneuverability required for gleaning-type foraging within a cluttered forest interior (Amelon and Burhans 2006, Owen et al. 2003, Henderson and Broders 2008). Bat distribution and abundance are affected by availability of insect prey, which for northern long-eared bats consists primarily of beetles and moths (Brack and Whitaker 2001, Carter et al. 2003). Abundance of these prey items is typically higher in more closed forest stands than in openings, which supports studies which have found northern long-eared bats to avoid open habitats (Owen et al. 2003). Small canopy gaps may be used, as they will increase solar radiation for maternity roost trees as well as support a warmer environment conducive to insect abundance and activity (Owen et al. 2003). Although they are a predominantly forest interior species, northern long-eared bats will use riparian areas for foraging and seem to prefer streams protected by canopy closure (Yates and Muzika 2006, Henderson and Broders 2008). However, researchers reported capturing more little brown bats (*Myotis lucifugus*) over open water habitat than northern long-eared bats (Broders et al. 2006). During the lactation period, proximity to aquatic habitat may be an important variable in roost tree selection (Sasse and Pekins 1996).

Several studies have documented northern long-eared bats use of edge habitat (Hogberg et al. 2002, Henderson and Broders 2008). Henderson and Broders (2008) found that northern long-eared bats did not travel more than 78 meters (m) from the edge of intact forest structure. Average home range size for female northern long-eared bats in West Virginia was 65 hectares (ha; measured using 95% adaptive kernels; Owen et al. 2003). One study documented foraging in areas of forest patch size between 46 ha and 65 ha (Owen et al. 2003). Lacki et al. (2009) reviewed relative elevation data from eight projects studying northern long-eared bat roost characteristics and found more than half of the northern long-eared bats roost trees were located at higher points in the landscape, along midslopes and upperslopes than lower habitats.

In the eastern United States, maternity roost tree species included beech (*Fagus grandifolia*), silver maple (*Acer saccharinum*), red maple (*A. rubrum*), black cherry (*Prunus serotina*), green ash (*Fraxinus pennsylvanica*), black locust (*Robinia pseudoacacia*), elm (*Ulmus spp*.) and artificial roosts (Foster and Kurta 1999, Grindal and Brigham 1999, Owen et al. 2002, Thompson 2006, Lacki et al. 2009, Lausen 2009). In New Brunswick, Canada, northern long-eared bat maternity roost trees were 24 times more likely to be found in deciduous trees than conifers (Broder and Forbes 2004, Thompson 2006), although preferred tree species seems to vary throughout the species range (Thompson 2006). Forest stands with a more diverse stocking of tree species recorded a higher abundance of northern long-eared bats (Lacki and Schwierjohann 2001).

Yamasaki (2004) documented a mean diameter at breast height (dbh) for New Hampshire roost trees to be 30 cm. However, Lacki et al. (2009) found the dbh range varied across the species known range, and northern long-eared bats appeared to be less selective about roost diameter than Indiana bats (*Myotis sodalis*). Canopy surrounding maternity roosts is relatively open and maternity roosts were located in areas with low stem density (Garroway and Broders 2008). Although difficult to determine with accuracy, roosts tend to be placed high in roost trees (Lacki et al. 2009). Roost structures include flaking or

sloughing bark, crevices, and holes (Carter and Feldhamer 2005, Lacki and Schwierjohann 2001, Park 2010). If a suitable roost structure is available, bats will use both live and dead trees and tend towards mid-aged snags as opposed to recently dead and very old snags with little to no bark or structural integrity remaining (Lacki and Schwierjohann 2001).

The availability of mid-decay snags is an important feature in the forest structure for northern long-eared bats (Yamasaki 2004, Broder and Forbes 2004). Although not exclusive to snag trees, one study of northern long-eared bats documented 100 percent of the population used snag trees during some portion of the maternity roost season (Lacki et al. 2009). Snags that have shed their branches with sloughing bark seem to offer desirable conditions (Lacki et al. 2001), although other features such as canopy closure, proximity to water and limited open spaces seem to be equally as important for roost tree selection (Yamasaki 2004, Carter and Feldhammer 2005). Lacki et al. (2009) documented a snag density of 37.8 +/- 3.6 snags/ha. However, some studies suggest snag density is likely not the most important variable for roost tree selection by northern long-eared bats (Jung et al. 1999).

Males generally roost individually while females form maternity colonies (Broders and Forbes 2004, Henderson and Broders 2008). Maternity colonies are typically less than 100 individuals with a mean colony size of 11 bats documented at 1 project in New Hampshire (Sasse and Pekins 1996). As the maternity season progresses, the size of maternity colonies decrease (Lacki et al. 2009). During the lactation period, females will switch roosts every two to five days (Foster and Kurta 1999).

In 1996, a study conducted in the White Mountain National Forest in New Hampshire tracked 26 northern long-eared bats to roosts and found a strong preference for American beech and maple species (Sasse 1995, Sasse and Pekins 1996). Two-thirds (66%) of identified roost trees were snags. Roost tree species identified included beech (n = 14, 30%), sugar maple (*Acer saccharum*; n = 13, 28%), yellow birch (*Betula alleghaniensis*; n = 8, 17%), red maple (n = 6, 13%), and big-tooth aspen (*Populus grandidentata*; n = 2, 4%). A single black cherry, hemlock (*Tsuga canadensis*), paper birch (*Betula papyrifera*), and white ash (*Fraxinus americana*) made up the remaining four roost trees (8%). Roost snags had larger diameters (mean dbh = 41 cm), more remaining bark (mean percent remaining = 78%), lower snag-class values, and were taller (mean height = 14.8 m), than available snags. Live snags had larger diameters (mean dbh = 31 cm) than surrounding live trees. Both snag and live roosts were surrounded by higher live-tree diameters, indicating stands of older age. Mean canopy closure was 78%, and most roost trees were located in stands with greater than 75% canopy cover. Common characteristics with other studies included large diameter roost trees (Park 2010), the use of both live trees and snags (Lacki et al. 2009), and proximity to interior forests with a high canopy (Garroway and Broders 2008). Mist net sites were located between 280 and 622 m elevation in Grafton, Carroll, and Coos Counties, New Hampshire. Forty percent of captured northern long-eared bats were male. One in five captured northern long-eared bats was juvenile. Average distance between capture site and roost tree was 602 m (range 60 – 1,719 m), which may be considered the minimum distance between roosting and foraging areas.

Male northern long-eared bats are solitary roosters and appear to have much greater flexibility in roost habitat (Broders and Forbes 2004). Several studies have documented males roosting in conifer species and mixed conifer and deciduous forest stands (Broders and Forbes 2004, Jung et al. 2004). In West Virginia, male northern long-eared bats showed a preference for both live and snag black locusts (Ford et al. 2006), likely due to the prevalence of this tree species in the study area. In Ontario, Canada, males used primarily white pine (*Pinus strobus*) and trembling aspen (*Populus tremuloides*) snags, which were two of the tallest tree species in the area (Jung et al. 2004). In New Brunswick, as a forest stand increased proportionately in conifer species, the likelihood of capturing a male versus a female increased (Broders and Forbes 2004).

**Habitat Assessment**

The literature review suggests that the most probable areas of northern long-eared bat habitat will be in hardwood or mixed forests with primarily closed canopies and mid-decay stage, large-diameter snags. At this time, select portions of the Project area have been mapped. Hardwood and mixed forest stands occur throughout mapped portions of the Project (Figure 1); however, much of this area has been logged in the recent past. Unlogged hardwood or mixed forest stands that have suitable corridors for mist nets will be targeted for mist net survey locations (Figure 1).

Tinkham Hill and Braley Hill both have ample trails and corridors on them that will provide suitable mist net sites and both contain a number of large diameter American beech snags which could provide suitable roosting habitat. On top of the Tinkham Hill ridge there are only a few roost tree options to the east of the summit. Large diameter snags were not observed often on Melvin Mountain, although this ridge does have some smaller diameter snags across the summit. Mapping indicates that Forbes Mountain has unlogged hardwood stands on the upper slopes of the ridge, and unlogged hardwood and mixed stands on the lower elevations. However, much of the Forbes Mountain portion of the project has been actively logged in recent years and unlogged stands are generally restricted to inaccessible areas (i.e., steep slopes or ledge). As of 2013, Melvin Mountain and Crane Mountain are now outside, but in the vicinity of, the proposed Project area. However, mist net surveys at Melvin Mountain and Crane Mountain still provide valuable data documenting bat species presence near the Project area.

**Species Status**

The U.S. Fish and Wildlife Service issued a proposed ruling on October 2, 2013, to list the northern long-eared bat as federally endangered throughout the species' range (USFWS 2013). The decision to list the species was based primarily on the widespread and drastic population declines as a result of WNS, which has "led to dramatic and rapid population declines in northern long-eared bats of up to 100 percent from pre-WNS levels in some areas" (USFWS 2013). The USFWS is soliciting public comment (Due December 2, 2013) and peer review regarding the listing. Public hearings may be held if requested before November 15, 2013 and will be announced in the Federal Register 15 days prior to the time the hearing is scheduled.

**Annotated Bibliography**

Amelon, S., and D. Burhans. 2006. Conservation Assessment: *Myotis septentrionalis* (Northern long-eared bat) in the Eastern United States. In USDA Forest Service General Technical Report NC-260: Conservation Assessments for Five Forest Bat Species in the Eastern United States.

*Abstract*: The primary goals of this assessment are to consolidate and synthesize existing information on the status, distribution, conservation, and management considerations for five species of forest bats on national forests in Region 9: *Pipistrellus subflavus* (eastern pipistrelle), *Nycticeius humeralis* (evening bat), *Myotis austroriparius* (southeastern myotis), *M. leibii* (eastern small-footed myotis), and *M. septentrionalis* (northern long-eared bat).

Brack, V., Jr., and J.O. Whitaker. 2001. Foods of the northern Myotis, *Myotis septentrionalis*, from Missouri and Indiana, with notes on foraging.

*Abstract*: This paper presents information on foods eaten by the northern myotis, *Myotis septentrionalis*, from four different localities in the states of Missouri and Indiana, USA. Based on fecal and stomach content analyses, we found that *M. septentrionalis* feeds heavily on Lepidoptera (10.4-94.0% of the volume), and to a lesser extent on Coleoptera (0.4-64.0), Trichoptera (0.0-54.5), and Diptera (0.0-15.3). Non-flying prey items, such as spiders and lepidopterous larvae, made up 12.7% of food in 63 stomachs from Copperhead Cave, Indiana, which is a clear indication of the gleaning behavior of this species. Foraging was concentrated in the understory of non-riparian habitat, which may be a further reflection of a gleaning strategy. No significant differences were found in the overall diet of *M. septentrionalis* between evening and morning feeding periods, although there were some differences in consumption of particular orders.

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. Journal of Wildlife Management 68: 602-610.

*Abstract*: The structure of echolocation calls, and the distance over which bats perceive their environment, varies with the amount of structural clutter through which they are flying. Clutter and species had significant effects on the frequency-time characteristics of search-phase echolocation calls of northern long-eared (*Myotis septentrionalis*) and little brown bats (*M. lucifugus*). We tested an a priori derived model that predicted the pattern of differences in echolocation call variable values among clutter categories would provide insight into the relative maximum distances that bat species could perceive using echolocation. Specifically, the model predicted that species adapted to flying and foraging in cluttered habitats would have a shorter maximum perceptual distance than species adapted to flying and foraging in uncluttered habitats. The results supported this model and suggest the clutter-adapted *M. septentrionalis* had a shorter maximum perceptual distance than *M. lucifugus*, a species known to forage in a variety of habitats but mainly in uncluttered areas (i.e., over water). Using calls as the sampling unit, a neural network correctly classified .94% of the echolocation calls to species in high clutter. In medium and low clutter, .82% of the calls were correctly classified to species; however .90% correct classification was achieved by leaving 30% of calls unclassified. Researchers should develop clutter-specific call libraries to improve species classification accuracy for echolocation calls.

Broders, H.G., 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. Journal of Wildlife Management 70:1174-1184.

*Abstract*: To understand bat biology and appreciate their dependence on and role within forested ecosystems, the biological resolution at which studies are directed must elucidate species and gender patterns. We studied species- and gender-specific aspects of summer range extent and stand selection in northern long-eared bats (*Myotis septentrionalis*) and little brown bats (*M. lucifugus*) in the Greater Fundy Ecosystem, New Brunswick, Canada, using trapping, radiotelemetry, and ultrasonic monitoring. Our results suggested that this 2-species system is comprised of 4 ecologically distinct groups with respect to site selection and range extent for roosting and foraging. All bats exhibited an affinity to specific roosting areas. *Myotis septentrionalis* roosted and foraged in the forest interior. The roosting and foraging areas for females were 6.1 times and 3.4 times larger, respectively, than for males. Both genders foraged in site types in proportion to their availability. *Myotis lucifugus* females roosted in buildings outside the core study area, and those captured in the forested landscape were transients. Compared to male and female *M. septentrionalis*, male *M.lucifugus* had intermediate-sized roosting areas but the largest foraging areas. Water sites were selected during foraging more than expected. Bat foraging activity, measured acoustically at 8 site types, was greatest at lakes and least above the forest canopy. Male *M. lucifugus* activity levels were positively associated with temperature and the amount of mature coniferous forest and water within 1 km of the sampling site, and they were negatively associated with the amount of mature deciduous forest within 1 km of the site. Our results suggested that understanding gender effects is crucial for accurate characterization of forest bat habitats. Studies of bats that combine data for genders, species, or guilds may produce spurious results and may be of minimal value for, or actually hinder, bat conservation and management programs.

Carter, T.C., M.A. Menzel, S.F. Owen, J.W. Edwards, J.M. Menzel, and W.M. Ford. 2003. Food habits of seven species of bats in the Allegheny plateau and ridge and valley of West Virginia. Northeastern Naturalist 10:83-88.

We captured 159 bats in the Allegheny Plateau and Ridge and Valley physiographic provinces of West Virginia during summer 1998, including the northern long-eared myotis (*Myotis septentrionalis*; n = 40), little brown myotis (*M. lucifugus*; n = 34), big brown bat (*Eptesicus fuscus*; n = 29), eastern pipistrelle (*Pipistrellus subflavus*; n = 27), eastern red bat (*Lasiurus borealis*; n = 22), hoary bat (*L. cinereus*; n = 5), and silver-haired bat (*Lasionycteris noctivagans*; n = 2). We analyzed fecal pellets of each bat to determine food habits. Diets of northern long-eared myotis and eastern red bats were dominated by Coleoptera (42.3 and 24.5%, respectively) and Lepidoptera (31.1 and 47.0%, respectively). Diet of big brown bats primarily consisted of Coleoptera (67.5%). Diet of hoary bats was dominated by Lepidoptera (98%). Diet of silver-haired bats was moderately diverse, but primarily composed of Lepidoptera (47.5%) and Diptera (20.0%). Diets of little brown myotis and eastern pipistrelles were highly diverse, consuming an even proportion of six orders of insects including Coleoptera, Hemiptera, Lepidoptera, Homoptera, Diptera, Hymenoptera, and Tricoptera. Diets of these seven species of bats did not differ notably from diet of each species reported from other regions of the eastern United States. Our results provide information about food habits of bats that are common throughout the central Appalachian Mountains.

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.

*Abstract*: Roost trees used by female Indiana bats (*Myotis sodalis*), a federally endangered species, and sympatric northern long-eared bats (*Myotis septentrionalis*) at two locations in southern Illinois greatly impacted by past flooding were located using radiotelemetry. For 30 Indiana bats, we located 49 roosts in 7 species of trees. Green ash snags (*Fraxinus pennsylvanica*) and pin oak snags (*Quercus palustris*) were used more than expected and sweetgum snags (*Liquidambar styraciflua*) less than expected based on availability. Ten adult female northern long-eared bats were tracked to 19 different trees of 5 species. We used logistic regression to predict use of roost versus random trees for both species, and to compare roosts of Indiana bats versus northern long-

eared bats. Indiana bats typically roosted in areas of low vegetative obstruction (clutter) on the forest edge (x2 = 10.28, d.f. = 2, P = 0.006). Compared to random trees, roosts of northern long-eared bats were within intact forests (x2 = 10.56, d.f. = 1, P = 0.001). Amount of obstruction and decay differed; roosts of *M. sodalis* typically were less cluttered and more decayed than those of *M. septentrionalis* (x2 = 38.63, d.f. = 2, P < 0.001). Indiana bats roosted almost exclusively under exfoliating bark of bottomland snags, whereas northern long-eared bats also made extensive use of cavities and crevices. Indiana bats cannot be expected to remain in an area indefinitely if snag creation is not sustained, and natural forest succession should be considered in long-term management of this endangered species.

Ford, W.M, S.F. Owen, J.W. Edwards, and J.L. Rodrigue. 2006. *Robinia pseudoacacia* (black locust) as day-roosts of male *Myotis septentrionalis* (northern bats) on the Fernow Experimental Forest, West Virginia. Northeastern Naturalist 13:12-24.

*Abstract*: During the summer of 2003, we captured and radiotagged ten male *Myotis septentrionalis* (northern bats) on the Fernow Experimental Forest (FEF) in the Allegheny Mountains of West Virginia to investigate day-roost selection. Of 16 roosts that were located, 13 were in *Robinia pseudoacacia* (black locusts), five in snags and eight in live trees. The other three roosts occurred in a *Sassafras albidum* (sassafras) snag and two live *Acer saccharum* (sugar maples). All live trees used as roosts were medium to large, canopy-dominant trees with considerable amounts of exfoliating bark and numerous broken limbs and cavities. Snags used as roosts were smaller than trees and other snags in surrounding stands, whereas live trees used as roosts were larger than other trees and snags in surrounding stands. Similar to previous research on female northern bats in the Allegheny Mountains, we observed a strong preference for both live and snag black locust as roosts over other available species. The high abundance of black locust as an important component on the FEF has been a relatively recent development dating to the early 1900s. Use of live canopy-dominant black locust with characteristics of mature forest trees lends support that older forests with decadent conditions provide important day-roost habitat, whereas use of both canopy dominant live trees and long-lasting black locust snags may support the ecological concept of roosting "areas" for northern bats.

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

*Abstract*: During 1993 and 1994, we radiotracked 11 adult female and juvenile northern bats (*Myotis septentrionalis*) to 32 roost trees: 18 silver maples (*Acer saccharinum*), 1 red maple *(A. rubrum*), and 13 green ashes (*Fraxinus pennsylvanica*). Fifty-three percent of the trees were living; 52% of the roosts were in crevices or hollows, and the rest were under exfoliating bark. Northern bats did not use American elms (*Ulmus americana*) in proportion to their abundance, but in general, characteristics of roost trees were similar to a random sample of apparently suitable trees. Northern bats changed roosts every 2 days, and distance between roosts varied from 6 to 2,000 m. As many as 60 adults were found in a single tree, making this the largest summer aggregation ever reported for the species. Compared with Indiana bats (*M. sodalis*) separately studied at the same site, northern bats moved greater distances between roosts and roosted more often in maples, cavities, living trees, and areas with high canopy cover.

Garroway, C.J., and H.G. Broders. 2007. Nonrandom association patterns at northern long-eared bat maternity roosts. Canadian Journal of Zoology 85:956-964.

*Abstract*: Bats are among the most ecologically diverse mammalian orders. Most species live in groups for at least a portion of their life cycle and behavioural evidence suggests that individuals of many species live within complex nonrandomly assorting societies. However, rigorous quantitative characterizations of bat societies have been rare because of the difficulties inherent in studying these highly mobile, small, nocturnal animals. Here we use an automated monitoring system (PIT tags), telemetry, and recently developed analytical techniques to investigate the social organization (size, sexual composition, and spatiotemporal cohesion) and social structure (pattern of social interactions and relationships among individuals) of a colony of free-living northern long-eared bats, *Myotis septentrionalis* (Trouessart, 1897). Cluster analysis of HWI (half-weight association index) for all pairs and permutation tests indicate that colonies consist of multiple, nonrandomly assorting subgroups. A plot of the temporal persistence of relationships (standardized lagged association rate) showed that roosting groups dissociate over periods of approximately 10 days after which subsets of individuals remain associated throughout the summer roosting season. A model representing a two-levelled social structure of long-term (whole summer) and short-term (up to 10 days) acquaintances best fit the lagged association rate. Subgroups were most cohesive during the lactation period, but we found no evidence for the effects of minimum nightly temperature on subgroup cohesion.

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.

*Abstract*: In summer, females of most temperate bat species aggregate at maternity roosts, during which time females gestate, give birth, and wean offspring. These activities make the presence of suitable roosts critical for population persistence. Many studies have identified important roost tree characteristics by comparing roost trees to random trees. However, if bats select trees that facilitate either torpor use or maintenance of normothermic body temperatures relative to the energetic demands of reproduction, then it follows that roost tree characteristics may vary similarly. We compared variation in roost tree and site selection by lactating northern long-eared bats to the pre- and post-lactation periods. Scores from 2 principal components were the best predictors of the variation in roost selection. Relative to pre- and post-lactation periods lactating bat roost sites had a high and relatively open

dominant canopy with low tree density (both coniferous and deciduous) and roost sites were situated high in tall trees. Our result demonstrates that when managing for bat roost trees, within-season variation in roost tree use should be considered.

Grindal, S.D. and R.M. Brigham. 1999. Impacts of forest harvesting on habitat use by foraging insectivorous bats at different spatial scales. Ecoscience 6:25–34.

*Abstract*: Riparian areas are generally assumed to represent important foraging areas for insectivorous bats, but this contention has rarely been formally quantified. To test this assumption, we used bat detectors to compare the relative activity levels of a community of temperate-zone bat species between riparian (lake) and upland (cutblock) habitats at three different elevations (ranging from 540 to 1800 m) in a forested area of southern British Columbia. In addition, we also investigated the sex and age class distributions of bats (based on mist-net captures) between riparian and upland habitats among the elevational zones. Bat activity levels were significantly greater in riparian than upland areas (10 and 40 times greater for foraging and commuting activity, respectively). Capture rates were greater in riparian areas and biased towards females, suggesting that female bats may preferentially select riparian areas, probably because of the abundant prey resources typically associated with this habitat. Captures of females also predominated at lower elevations, whereas males were captured more often in higher elevation zones. Our data support the assumption that riparian habitats represent important foraging and probably drinking areas for bats. The sex bias and differences in capture rates and activity levels need to be considered when designing bat surveys in different habitat types or over elevational gradients.

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.

*Abstract*: The fragmentation of forests by the expansion of agriculture is recognized as an important factor influencing worldwide declines of forest-dependent species. Species that are forest dependent may be especially vulnerable to fragmentation because they have specialized resource requirements and may exhibit lower mobility in an agricultural matrix. We investigated movement patterns and resource selection of forest-dependent northern long-eared myotis (*Myotis septentrionalis*) in a forest–agricultural landscape on Prince Edward Island, Canada. Radiotelemetry was used to locate day-roosts and to estimate locations of female bats during nightly foraging bouts. Day-roost locations and foraging areas were mapped using a geographic information system to generally characterize the forest cover of foraging and roosting areas. Vegetative structure and insect prey availability were measured in the field and compared between foraging and roosting areas to describe resource selection at these sites. Movements of female northern long-eared myotis were constrained to forest features and foraging areas were concentrated along forest-covered creeks with bats roosting predominantly in deciduous trees within the same forest fragment, although bats at 1 site seemed to exclusively use a barn during late pregnancy and lactation. Differences in prey availability did not explain the spatial segregation of roosting and foraging areas. Relative to roost areas foraging sites were more likely to be close to forested creeks and densely forested areas, whereas roost sites were characterized by the availability of potentially suitable roosts. This study demonstrates the importance of investigating movements and resource selection of individuals in fragmented landscapes because a specialization on forest resources can highly restrict the vagility of forest-dependent species to a local environment.

Hogberg, L.K., K.J. Patriquin, and R.M.R. Barclay. 2002. Use by bats of patches of residual trees in logged areas of Boreal Forest. American Midland Naturalist 148: 282-288.

*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 Lasioncteris noctivagans*, showed no preference. Thus, patches of residual trees provide commuting habitat, and potentially foraging habitat, for bats.

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

*Abstract*: Recent studies have suggested old-growth forests may be important habitat for some species of bats, but the proximate factors related to greater bat activity in older forests are not well understood. To assess relative habitat use by bats, we used ultrasonic detectors and mist nets to sample bat activities among old-growth pine (*Pinus strobes*), mixed woods, mature white pine mixed woods, boreal-type mixed woods, and selectively logged white pine mixed woods in central Ontario. We quantified 15 structural characteristics in the 21 stands sampled for bat activity. Detection rates of *Myotis* species, silver-haired bats (*Lasionycteris noctivagans*), and hoary bats (*Lasiurus cinereus*) were 2.7-14.0 times greater in old-growth white pine mixed wood stands than in other stand types ($Ps < 0.05$). Multivariate habitat models suggested that, between logged and uncut stands, the availability of potential roost sites may be an important determinant of bat activity for *Myotis* species and silver-haired bats. Among uncut stands, our habitat models suggested that snag availability was not an important variable affecting habitat selection by bats. Rather, bat detection rates in uncut forests were correlated with canopy and subcanopy structure. Little brown bats (*Myotis*

*lucifugus*) and northern long-eared bats (*M. septentrionalis*) may spatially separate for feeding. To maintain habitats for bats, forest managers should implement timber harvest strategies that retain old-growth white pine stands in the landscape, preserve snags and large live trees in selectively logged forests, and promote regeneration of second-growth white pine stands to old age rather than truncating age classes at younger ages.

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.

We used radiotelemetry and random exit counts to determine roost site selection by male northern long-eared bats (*Myotis septentrionalis*) and unidentified *Myotis*, either northern long-eared or little brown bats (*M. lucifugus*) in a conifer-dominated, mixedwood forest landscape in central Ontario, Canada. We compared the characteristics of snags used as roosts (n = 26), with randomly located snags and random points (n = 52 and 50, respectively), at three spatial scales: focal tree, surrounding forest, and landscape. Snags used as roost sites by these bats differed from random snags for 19 of the 23 variables measured ($P<0.05$). Logistic regression models were derived which suggested that the bats selected large snags, in open canopies, of intermediate stages of decay, that were located in upland areas, but away from water bodies. Bats may have selected roost sites for their thermal advantage in the mornings, as most used cavities or bark on the south and east sides of snags. To ensure that snags of appropriate characteristics persist for these two species of *Myotis*, forest managers in the northern Great Lakes forest region should retain, and manage for, large white pine (*Pinus strobus*) and trembling aspen (*Populus tremuloides*) snags at sites in forests that meet these criteria. Such a regime is possible under a selection harvest that is normally practiced in these mixedwood forest types.

Lacki, M.J., and J. Schwierjohann. 2001. Day roost characteristics of northern bats in mixed mesophytic forest. Journal of Wildlife Management 65: 482-488.

*Abstract*: Management of forests to promote habitat needs of bats requires information on all life requisites of each species. Data on roosting habitat of northern bats (*Myotis septentrionalis*) is limited for eastern deciduous forests. We radiotracked 13 adult female and 2 adult male northern bats as they used 57 day roosts in mixed mesophytic forest in northeastern Kentucky from 18 May to 5 August 1998. Northern bats used day roosts in 12 species of trees, with sourwood (*Oxydendrurn arbmeurn*) and shortleaf pine (*Pinus echinata*) each comprising 29.8% (n = 17/57) of the roost trees, respectively. Colonies, >1 northern bat, were predominantly found in cavities of hardwood snags (44.2%, n = 19/43) or under the bark of shortleaf pine snags (32.6%, n = 14/43). Snags possessing sloughing bark with branches absent were more frequently used as roosting sites by northern bats (52.9%, n = 18/34) than any other stage class of snag. Solitary bats were primarily found roosting in cavities of living hardwood trees (92.9%, n = 13/14). Roost trees of northern bats were not distributed equally among topographic locations, with roosts more frequently situated on upper slopes (45.6%, n = 26) and midslopes (38.6%, n = 22) than on lower slopes (15.8%, n = 9). Mean population size of colonies appeared to decline as summer progressed, with pregnant females using the largest colonies (.G = 25.6 + 10.2 bats), lactating females using intermediate-sized colonies ***( 2***= 13.5+ 2.98 bats), and post-lactating females using the smallest colonies ***(2***= 3.8 k 1.66 bats). These data suggest that forest management practices that sustain diversity in tree species, tree-size class (3.1-55.8 cm dbh), and snag-condition class (stages 3 and 4) are necessary to provide habitat for northern bats in mixed mesophytic forests.

Lacki, M.J., D.R. Cox, and M.B. Dickinson. 2009. Meta-analysis of Summer Roosting Characteristics of Two Species of Myotis Bats. American Midland Naturalist. 162:318–326.

*Abstract*: We compared roost site characteristics of the Indiana bat (*Myotis sodalis*) and northern bat (*M. septentrionalis*), which form maternity colonies in cavities and beneath bark of dead (snags) and living trees in eastern North American forests. We used published data (n 5 28 sources; n 5 1145 roost trees) from studies completed where the distributions of the two species overlap and evaluated a suite of habitat features that might affect roost selection and interspecific competition between these two congeners. We found no differences between these species in average height of roost aboveground, density of snags in the vicinity of roosts, selection of live trees versus snags or relative elevation. Populations of northern bats were more likely to choose roosts in crevices or cavities (88.9%) than Indiana bats (30.0%; P ,0.1), and roosted in trees that averaged smaller in diameter (30.0 6 5.4 cm) than trees selected by Indiana bats (41.4 6 2.4 cm; P , 0.1). Northern bats demonstrated greater variability than Indiana bats in height of roosts aboveground and in stem diameter of roost trees. Existing data indicate northern bats exhibit greater plasticity in choice of summer roosts than Indiana bats, explaining, in part, why northern bats are more widely distributed and more common in forests of eastern North America than are Indiana bats.

Lausen, C. 2009. Status of the Northern Myotis (*Myotis septentrionalis*) in Alberta, Alberta Wildlife Status Report No. 3 (Update 2009).

*Abstract*: The northern myotis (*Myotis septentrionalis;* previously known as the northern long-eared bat) is a forest-dependent bat commonly found in eastern Canada and the United States. It is encountered less frequently in western Canada, including Alberta. At present, the northern myotis is considered *May Be At Risk* in Alberta. This general status designation was based on the relative rarity of this species in the province, and its apparent reliance on mature forest habitats, which are affected by current forestry practices. However, recent captures in Alberta's boreal forest bring into question whether this species may be relatively abundant in some areas of northern Alberta; further standardized survey effort across central and northern Alberta is needed to establish relative abundance, and determine if this species is widespread across its range or whether it has patchy distribution.

Owen, S.F., M.A. Menzel, 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. USDA Forest Service, General Technical Report NE-292, Northeastern Research Station, Newtown Square, PA, p. 6.

*Abstract*: We attached radio transmitters to 20 pregnant or lactating northern long-eared myotis (M*yotis septentrionalis*) and located 43 maternity roost colony trees in the intensively managed hardwood forests in the Allegheny Mountains of east-central West Virginia. Maternity colonies ranged in size from 7 to 88 individuals. We compared 23 characteristics of the 43 roosts to 43 randomly selected trees with cavities of exfoliating bark. Roost trees selected by maternity colonies differed from randomly located roost trees in that they were taller, smaller in diameter, surrounded by more live overstory trees and snags, and surrounded by a higher basal area of other snags. Black locust (*Robinia pseudoacacia*) and black cherry (*Prunus serotina*) were used as day roosts more frequently than expected based on their abundance across this landscape. Intensively managed hardwood forests in the central Appalachians apparently provide adequate roosting habitat for northern long-eared myotis.

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

*Abstract*: We examined home range size and habitat use of nine female northern myotis (*Myotis septentrionalis*) within an intensively managed forest in the central Appalachians of West Virginia. Using the 95% adaptive kernel method, we calculated a mean home range of 65 ha. Northern myotis used recent diameter-limit harvests and road corridors more than expected based on availability of these habitats. Intact forest stands and more open deferment harvested stands were used less than expected based on the availability of these habitats, although intact forest stands still constituted the overall majority of habitat used. Partial timber harvests that leave a relatively closed canopy appear to promote or improve northern myotis foraging habitat in heavily forested landscapes. However, the long-term ecological impacts on bats and other biota from this silviculturally unacceptable practice are unclear.

Park, A.C. 2010. Factors affecting the distribution and roost-site selection of bats on the Island of Newfoundland. M.Sc., Saint Mary's University (Canada), 66 pages.

*Abstract*: Ecological studies at the periphery of a species' distribution provide an opportunity to explore the limits of population viability under unique conditions. Research regarding specific factors that limit temperate bat distribution is lacking; therefore, the goal of this project was to characterize these factors for resident bats on the island of Newfoundland (NL) by species and sex (four bat groups in total). The first objective was to document the occurrence of little brown (*Myotis lucifugus*) and northern long-eared (*M. septentrionalis*) bats throughout NL, and relate their occurrence to stand and landscape factors. All bat groups were patchily distributed. *Myotis septentrionalis* were present in areas further east and north than previously documented but were not ubiquitous. Factors influencing distributional limits were unique for each bat group, and included number of buildings and forest area in a landscape (for *M. septentrionalis* females and males, respectively); and number of snags and average tree diameter in a stand (for *M. lucifugus* females and males, respectively). The second objective was to compare female roost-site selection on NL to that of central areas in their North American distribution. Smaller and shorter softwood trees were common on NL, and frequently used as roosts. The final objective was to characterize roost-site selection of female *M. septentrionalis* at different reproductive stages (lactation and non-lactation). Sites used during the lactation period were within cavities of large diameter trees that maintained warm, stable microclimates.

Sasse, D.B. 1995. Summer roosting ecology of cavity-dwelling bats in the White Mountain National Forest. M.Sc., University of New Hampshire, 74 pages.

The objective of this project was to study the summer roosting ecology of female cavity-dwelling bats in the White Mountain National Forest and to examine the relationship of snag and stand characteristics in bat roosting choices. A total of 281 bats were caught, of which most (71%) were little brown *(Myotis lucifugus)* (LBB) and northern long-eared (27%) *(Myotis septentrionalis)* (NLE) bats. Radiotransmitters were used to track 26 NLE and 3 LBB to roosts. Forty-nine roosts were identified, 66% of which were in snags. Roosts of NLE included 14 *Fagus grandijalia,* 13 *Acer saccharum,* 6 *Acer rubrum,* 8 *Betula alleghaniensis,* a single *Tsuga canadensis,* and four other species. Bats changed roost sites often and seemed to use a network of roost trees in close proximity to each other. Little brown bats roosted in two red maples and a yellow birch. Roost snags were larger in diameter (41 m), taller (14.8 m), had more bark remaining (78%), and were less decayed than a random sample of snags in the surrounding area. Characteristics of the surrounding stand were also related to roost sites; live trees had larger diameters (p= 0.002) and there was more snag basal area (x= 3.9$m^2$/ha) in roost plots than the surrounding forest. Potential roost trees (n= 104) were surveyed for bat activity in 1994 using ultrasonic bat detectors; 28 had bat activity and 5 were visually identified as roost sites. Several limitations preclude the use of this technique to study roosting preferences, but it may prove useful as an alternative to radiotelemetry for locating bat roosts. Bat conservation efforts in the White Mountain National Forest should focus on the maintenance of mature and overmature forest stands near foraging areas. Characteristics of these stands allow bats to maximize their opportunity to choose roosts providing a range of physical and environmental conditions.

Sasse, D.B., and P.J. Pekins. 1996. Summer roosting ecology of northern long-eared bats (*Myotis septentrionalis*) in the White Mountain National Forest. Bats and forests symposium. British Columbia Ministry of Forests Working Paper 23:91-101.

*Abstract*: We studied the summer roosting ecology of female northern long-eared bats in the White Mountain National Forest of New Hampshire, and examined the importance of snag and stand characteristics at bat roosting sites. Radio-transmitters were used to track 26 northern long-eared bats to 47 roost trees; 39 (66%) were in snags. Roosts were in 14 *Fagus grandifolia*, 13 *Acer saccharum*, 8 *Betula alleghaniensis*, 6 *Acer rubrum*, and 5 other species. Roost snags were larger in diameter (mean = 41 cm; p = 0.007), taller (mean = 14.8 m; p < 0.001), had more bark remaining (mean = 78%; p = 0.039), and were less decayed than random samples of snags in the surrounding area. Characteristics of the surrounding stand were also related to roost sites; live trees had larger diameters (p = 0.002) and there was more snag basal area (3.9 m2/ha) in roost plots than the surrounding forest. We surveyed potential roost trees (n = 104) for bat activity in 1994 using ultrasonic bat detectors; 28 had bat activity and five were visually confirmed as roost trees.

Thompson, F.R., III, ed. 2006. Conservation assessments for five forest bat species in the Eastern United States. Gen. Tech. Rep. NC-260. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 82 p.

*Abstract*: Assesses the status, distribution, conservation, and management considerations for five Regional Forester Sensitive Species of forest bats on national forests in the Eastern United States: eastern pipistrelle, evening bat, southeastern myotis, eastern small-footed myotis, and northern long-eared bat. Includes information on the taxonomy, description, life history, habitat distribution, status, and population biology of each species.

USFWS. 2013. Federal Register 50 CFR Part 17, 78(191): 61046-61080.

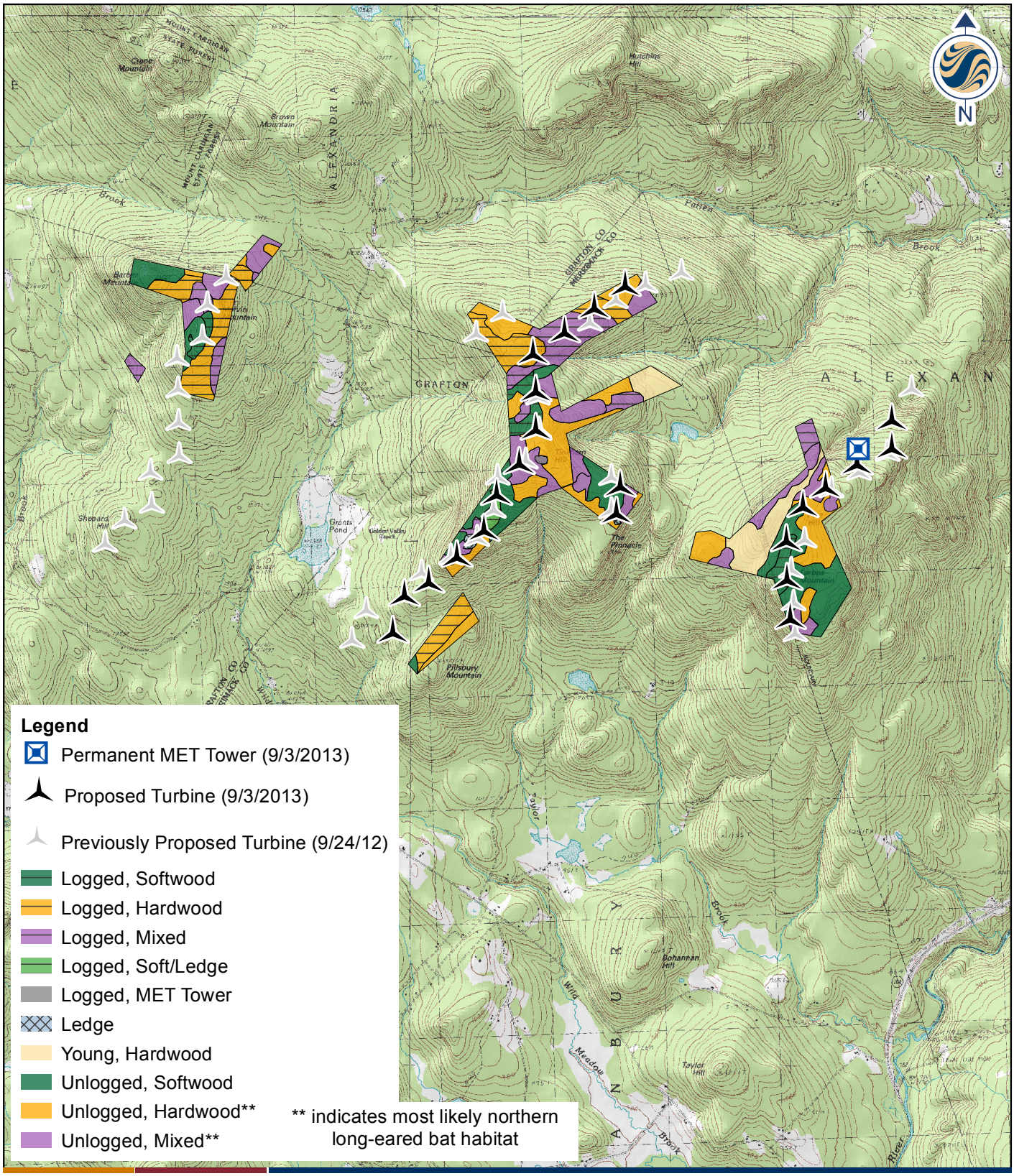
The document proposing listing of northern long-eared bats includes a detailed summary of the species range, behavior, and habitat requirements as well as factors influencing the USFWS' decision to propose listing the species.

Yamasaki, M. 2004. Bats and small mammals in old growth habitats in the White Mountains. In, Bennett, K.P. technical coordinator. 2005. Moving toward sustainable forestry: lessons from old growth forests. University of New Hampshire Cooperative Extension Natural Resource Network Report.

*Abstract*: Broadband ultrasonic detection and mist net survey work (Krusic et al. 1996; Krusic and Neefus 1996) has identified nine bat species (*Eptesicus fuscus*, *Lasiurus cinereus*, *L. borealis*, *Lasionycteris noctivagans*, *Pipistrellus subflavus*, *Myotis lucifugus*, *M. septentrionalis*, *M. leibii*, and *M. sodalis*) present during the snow-free seasons. Radiotelemetry work by Sasse and Pekins (1996) has also identified maternity colony habitats used by female northern long-eared bats.

Yates, M.D., and R.M. Muzika. 2006. Effect of forest structure and fragmentation on site occupancy of bat species in Missouri Ozark forests. Journal of Wildlife Management 70:1238-1248.

*Abstract*: Changes in structure and arrangement of forests may influence the distribution of bat communities by affecting roosting and foraging habitat. Using Anabat bat detectors, we determined presence of bat species at 316 sample plots in southeastern Missouri, USA, through qualitative identification of echolocation calls collected. We used maximum-likelihood estimation techniques incorporating detection probabilities into estimation of site occupancy by species of bats. We compared a priori models at 2 geographic scales using information theoretic methods. At the local-site scale, eastern pipistrelle (*Pipistrellus subflavus*) and red bat (*Lasiurus borealis*) occupancy was most influenced by structural characteristics of forested areas, whereas Indiana bats (*Myotis sodalis*) were influenced most by density of large-diameter snags that could provide roosting habitat. At the landscape scale, occupancy of Indiana bats was directly related to amount of nonforested land cover. Northern long-eared bat (*M. septentrionalis*) occupancy was inversely related to edge. These data describe implications of forest fragmentation and provide information that can be used when integrating forest-management practices into bat conservation.

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**Client/Project**
**Atlantic Wind LLC**
**Wild Meadows Wind Project**
**Merrimack & Grafton Counties, New Hampshire**

Figure No.
**1-1**

Title
## Project Location Map

8/15/2012
REV: 9/6/13