PHASE I BAT RISK ASSESSMENT

Mount Wachusett Community College Wind Energy Project

Worcester County, Massachusetts

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EXECUTIVE SUMMARY

Mount Wachusett Community College ("MWCC") has proposed the construction of a one- or two-turbine wind project on its campus in Gardner (Worcester County), Massachusetts. As part of the environmental assessment of this proposal, North East Ecological Services (NEES) was contracted to conduct a Phase I Bat Risk Assessment. The purpose of the risk assessment was to determine the potential for habitat loss and collision mortality to bats from the construction and operation of the MWCC wind project. The risk assessment involved 1) an on-site evaluation to determine habitat features that may be predictive of bat usage, including roosting habitat, foraging habitat, and hibernacula; 2) a literature search to determine known populations of bats near the project site; and 3) consultation with appropriate MADFW and US Fish and Wildlife Service biologists to determine the presence of protected species or hibernacula near the project site.

The on-site evaluation was conducted on 21 August, 2008 by a NEES biologist (J. Veilleux). The proposed turbine location is an old-field habitat surrounded by second growth forest, wetland, open water, and open grassland habitats. A walking survey of the area revealed a low density of appropriately-sized snags that could contain roosting habitat for cavity- and bark-roosting bat species. The southeast corner of the project area did, however, contain some taller snags that would receive adequate insolation to provide suitable roosting habitat. There appeared to be very little exposed rock habitat that could be used as roost sites by the eastern small-footed myotis (MA Species of Special Concern). Several small ponds and marshes surrounded the project site and could be used as foraging habitat by local bats.

NEES has been contracted to conduct pre-construction acoustic monitoring at the project site for the Summer 2008 and Fall 2008 migratory season. This study has recently been completed and data analysis has commenced. Based on the data collected during the risk assessment and a preliminary overview of the acoustic data collected at the project site, NEES makes the following recommendations:

1) Ground-based acoustical monitoring should be conducted during the early summer near the exposed rock habitat and adjacent to the wetland habitat to document the presence of bats roosting in either of these habitats. If data collected during this monitoring suggests the presence of either the eastern small-footed myotis or the Indiana myotis, additional monitoring or mist-net sampling may be needed to confirm the presence of these protected species.
2) Any habitat alteration involving the southeast corner of the project area should be conducted during the winter months to minimize impact of project construction on bat roosting habitat

3) The wind turbine(s) should not be placed on the field edge or adjacent to the pond and wetland habitat where commuting and foraging bats would be at higher density
4) MWCC should conduct additional pre-construction acoustic monitoring in the Spring 2009 migratory season to document the complete migratory cycle of bats at the project site.
5) MWCC should create a Technical Advisory Committee to ensure that all additional study protocols meet the recommendations of the MADFW, USFWS, and other interested parties.
6) MWCC should conduct an appropriate post-construction mortality survey under the technical guidance of biologists familiar with fatality studies at wind turbine facilities
7) MWCC should conduct post-construction acoustic monitoring to help generate predictive models that would provide effective operational controls to mitigate bat mortality.

A review of published and gray literature, including analysis of New England Bat Colony database (S. Reynolds, unpublished data) revealed that the Worcester County region has a relatively diverse bat community. These data suggest that house-roosting bats are common throughout the region. Consultation with Massachusetts Division of Fisheries and Wildlife (MADFW) and the U.S. Fish and Wildlife Service (USFWS) revealed relatively little information about the presence of protected species or migratory tree-bats in the region. MADFW was helpful in identifying caves and abandoned mines near the project site, but none of these sites were considered potential hibernacula. Therefore, it is unlikely that the MWCC project site contains resident populations of either species of concern.

Based on the results of the risk assessment, NEES concludes that fatality numbers at the project site are likely to be similar in both composition and magnitude (on a per turbine basis) to other wind projects sites in the eastern United States. However, given the small size of the project, total impact of the project is unlikely to significantly impact local bat populations. Based on the on-site survey and consultation with the MADFW and USFWS, there are no data to suggest that protected bat species reside on or near the MWCC project site; therefore, it is unlikely that populations of either the eastern small-footed myotis or the Indiana myotis will be impacted by development of the MWCC project site.

1.0 PROJECT OVERVIEW

1.1 The Mount Wachusett Community College Wind Project

The Mount Wachusett Community College (hereafter termed MWCC) Wind Project proposal is for the construction and operation of one or two 1.5 MW wind turbines (estimated 1.5 to 3.0 MW total capacity) on the MWCC campus located in northern Worcester County, Massachusetts (Fig. 1). The project layout encompasses approximately 4.5 ha. The project consists of a single parcel of publicly owned land, located within the City of Gardner, approximately 1.5 km south/southeast of the intersection of SR-140 and Green Street.

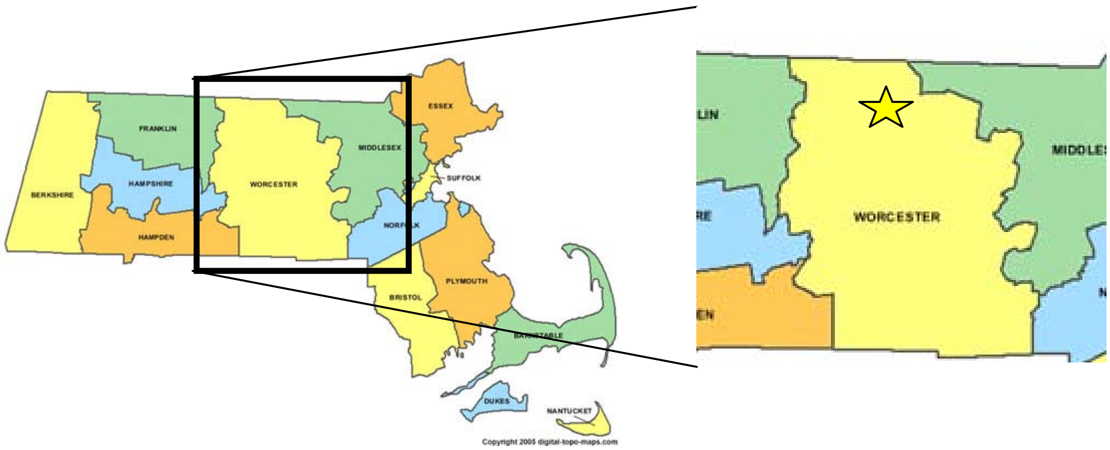

Figure 1: General location of the MWCC Wind Project in Massachusetts

1.2 Phase I Habitat Assessment

The proposed MWCC Wind Project is located in northern Worcester County within the Worcester/Monadnock Plateau of the Northeastern Highlands EcoRegion (Omernik, 1987). A habitat assessment of the Project site was conducted on 21 August, 2008. Habitat was assessed by foot along the proposed turbine site and within an approximate 0.5 km radius area surrounding the turbine site. Additional regional features were assessed by vehicle. The site visit assessed major habitat features associated with roosting and foraging activity by the species of bats likely to occur on or near the project area (e.g. dominant tree species, presence of tree snags, general tree size (height and dbh), presence of exposed rock outcrops, available water, and open field habitat).

The elevation of the project site is approximately 355 m (asl), with topography sloping to the west (elevation change = - 22 m to Crystal Lake) and rising to the northwest (elevation gain of 27 m at Howe Hill). Another hill (Reservoir Hill) rises to the south (elevation gain of 41 m). The project area is generally characterized by gentle rolling hills, containing a heterogeneous habitat landscape. Natural habitat types occurring with the project area include mainly second growth forest, open water habitat, wetland/marsh habitat, and old field habitat. Additional open space, such as the Gardner Municipal Golf Course, occurs adjacent to the project area. The city of Gardner is located approximately 15 km south of the project site, offering a more urbanized environment.

The site assessment began at the proposed location for the wind turbines. The proposed turbine location(s) is located within an approximately 4.5 ha old field, with very few invading trees. Herbaceous ground cover was dominated by various grasses (*Poa* spp.), goldenrod (*Solidago* spp.), wild carrot (*Carota dioca*), and purple clover (*Trifolium purpureum*). The old field was bordered by a second growth forest to the east, which extended to both the east and northeast. Dominant overstory tree species within the forest border and interior included eastern white pine (*Pinus strobus*), northern red oak (*Quercus rubra*), ornamental spruce (*Picea* spp.), black cherry (*Prunus serotina*), white ash (*Fraxinus americana*), red maple (*Acer rubrum*), sugar maple (*A. saccharum*), and eastern hemlock (*Tsuga canadensis*). Dominant understory tree species included red maple, mountain laurel (*Kalmia latifolia*), aspen (*Populus* spp.), staghorn sumac (*Rhus typhina*; located on forest/field edges), and American beech (*Fagus grandifolia*). Several small dbh (e.g. ≤ 20 cm) snags (mainly trembling aspen, white pine, and red oak) with visible hollows and/or exfoliating bark were observed along the forest/field edge. Canopy height within the forested regions of the project area was approximately 20 to 25 m, with mean tree dbh of approximately 35 cm (ranging from approximately 25 to 85 cm dbh). Overstory tree snags were observed at relatively low numbers throughout the project area, with most snags observed within the forested border located on the southeast edge of the project area. Northern red oak and white pine snags, in various stages of decay, were observed in this area. Snags contained exfoliating bark and/or crevices and interior hollows. Most of the observed snags were exposed to sunlight throughout most of the day. Very little exposed rock habitat (i.e. roosting habitat for the eastern small-footed myotis; see Section 2.2.2) was observed. A relatively long (at least 100 m), narrow (~ 2 m width) area of rock jumble was observed along the east edge of the project field, and approximately 3 to 6 m into the forest interior. This area of rocks was composed of medium and large size boulders, which likely constituted a historical stone wall. The boulders occurred mainly at ground level, and since the rocks were shaded by overstory trees, received only intermittent exposure to the sun.

Perennial water commonly occurs both within the project area and regionally. Within a 2 km radius of the project area, a relatively large number of open water and wetland habitats were observed during the site assessment. A small (0.75 ha) open water pond borders the project field to the west. The pond is surrounded by a cat-tail/*Phragmites* marsh. Additional wetlands occur to the east of the project field, including a small red maple swamp located approximately 150 m east/northeast of the project field. Several large pond and lakes were observed, including Crystal Lake and Perley Brook Reservoir to the west, Lake Wampanoag, Mamjohn Pond, and Hobby's Pond to the northeast, and Dunn Pond to the southeast. Several additional small ponds were observed both on the MWCC campus property and within the adjacent golf course to the west.

Consultation with Massachusetts Division of Fisheries and Wildlife (Dr. Tom French, Assistant Director of Natural Heritage and Endangered Species, pers. comm.) was initiated to determine the possible presence of abandoned mines within, and adjacent to, the project boundary that could serve as hibernation sites. Although several open pit mines and quarries are present in northern Worcester County, no known underground mines that could serve as bat hibernacula are known from the MWCC project area (T. French, pers. comm.).

2.0.0 CURRENT STATE OF KNOWLEDGE ON BAT SPECIES

2.1.0 Bats in the State of Massachusetts

There are nine species of bats that have been observed in the state of Massachusetts, with eight species having been documented in the region of Worcester County (Table 1; Appendix One. Two listed bat species have been observed in Massachusetts: the federally endangered Indiana myotis (*Myotis sodalis*) and the state Species of Special Concern, the eastern small-footed myotis (*M. leibii*).

Table 1: Bat species occurring in Massachusetts and their distribution relative to the MWCC Wind Project (species in bold are Federal or State Listed Species)

Species Name	Scientific Name	Regional Record[1,2]	County Record[1,2]	Section Reference[3]
Little brown myotis	*Myotis lucifugus*	yes	yes	2.4.1
Indiana myotis	***Myotis sodalis***	**no**	**no**	**2.2.1**
Northern myotis	*Myotis septentrionalis*	yes	yes	2.4.2
Eastern small-footed myotis	***Myotis leibii***	**yes**	**no**	**2.2.2**
Hoary bat	*Lasiurus cinereus*	yes	yes	2.3.1
Silver-haired bat	*Lasionycteris noctivagans*	yes	yes	2.3.2
Eastern red bat	*Lasiurus borealis*	yes	yes	2.3.3
Eastern pipistrelle	*Perimyotis subflavus*	yes	yes	2.3.4
Big brown bat	*Eptesicus fuscus*	yes	yes	2.4.3

1. Based on data from surrounding counties: Franklin, Hampden, Hampshire, Middlesex and Norfolk Counties (MA) and Cheshire and Hillsborough Counties (NH).
2. Distribution data based primarily museum records (Museum of Comparative Zoology (MCZ), Harvard University; Peabody Museum (YPM), Yale University; U.S. National Museum (USNM), Washington, D.C.) unpublished data (J. Veilleux, pers. comm.), primary literature reports, and data from the MADFW web-site.
3. Refers to the report section that details the distribution, biology, and/or relative risk for a particular species.

2.2.0 Distribution and Brief Biology of Listed Species in Massachusetts

2.2.1. Indiana myotis, *Myotis sodalis*

The U.S. Fish and Wildlife Service listed the Indiana myotis as federally-endangered in 1967 because of dramatic population declines and destruction of key maternity roosts and hibernacula (Trumbulak et al., 2001; Clawson, 2002). Despite over forty years of protection, Indiana myotis populations continue to decline in their core range, although the cause of the decline remains unclear (Clawson, 2002). In their core range, the distribution pattern of the Indiana myotis is associated with cavernous limestone areas (Thomson, 1982: Kurta et al., 1993). Indiana myotis hibernacula are classified as Priority I, II, III or VI, generally depending on current or historical population size at the cave or mine (*see* USFWS, 2007 for specific details; Table 2; Fig. 2). Currently, most of the known population of Indiana myotis exist in 23 Priority I hibernacula mainly located in Indiana, Kentucky, and Missouri (USFWS, 2007).

Indiana myotis typically spend at least 190 days in hibernation (Menzel et al., 2001), and appear to prefer lower ambient temperatures but higher humidity and airflow than other *Myotis* species (Menzel et al., 2001). Indiana myotis begin to leave hibernacula in late March through April (Richter et al., 1993; Hicks, 2003). Females tend to leave hibernation first, so that by early May, only males are still emerging from the hibernacula (Humphrey et al., 1977).

No extant Indiana myotis hibernacula are known from Massachusetts (USFWS, 2007). The only available valid historical record is from 1939, when approximately 60 individuals were observed within the Chester Mine located in Hampden County (T. French, pers. comm.; Fig. 2). Although the Massachusetts Natural Heritage endangered species fact sheet for the Indiana myotis (MassNH, 2008) indicates historical records in both Worcester and Berkshire Counties, these records are currently considered in error (mistaken identification) and should not be considered valid occurrence records (T. French, pers. comm.).

Figure 2. Historical county distribution of the Indiana myotis hibernaculum record in Massachusetts

Table 2: Historical record of the single Indiana myotis hibernaculum in the state of Massachusetts by Priority level (USFWS, 2007). No Indiana myotis have been documented at the single Priority III hibernaculum since 1939.

Hibernaculum Category	Population Size Range	Massachusetts Hibernacula
Priority I	≥ 10,000	0
Priority II	1000 – 10,000	0
Priority III	50 - 1000	1
Priority IV	< 50	0

During the reproductive season, Indiana myotis have a life history similar to other *Myotis* bats. Upon emergence from their hibernacula in the spring, Indiana myotis migrate to their summer range. Indiana myotis are known to migrate up to 532 km to reach their summer territory (Kurta and Rice, 2002), although most migratory events in the northeast tend to be less than 50 km (Griffin, 1970; Hicks, 2003). This appears to be particularly true for males, which often live near the hibernacula all summer (Fenton and Downes, 1981; Hicks, 2003). Upon reaching their summer range, adult females form reproductive colonies to raise their young. These 'maternity' colonies remain relatively intact from June through August and are generally located under exfoliating bark or in tree cavities (Kurta and Rice, 2002). Although Indiana myotis are known to use man-made structures (Butchkoski and Hassinger, 2002), including bathouses (Carter et al., 2001; Carter, 2002), most maternity colonies are formed in tree roosts. Roost trees are generally located in riparian, floodplain and bottomland forest habitat. Indiana myotis roosts appear to have key characteristics that are generally independent of the tree species (Scherer, 1999). Specifically, roost trees are large (greater than 36 cm dbh), tall, near water, and in direct sunlight most of the day (Kurta et al., 1993: Menzel et al., 2001: Kurta and Rice, 2002). Within these roosts, each female within the colony (typically 5 – 45 females) raises a single pup that is born by the end of June and reaches adult size by the end of August. During the summer months, females use multiple roosts and appear to switch between them on a regular basis (Hicks, 2003). During the summer months, adult males are believed to live alone or in small groups under exfoliating bark (Ford et al., 2002).

Foraging by the Indiana myotis is generally concentrated in riparian habitat. Although the standard protocol suggests that Indiana myotis predominantly forage over water (USFWS, 1999), there is a considerable amount of research that suggests they are more diverse in habitat selection (Kurta et al., 1993: Menzel et al., 2001: Carroll et al., 2002). This diversity of habitat use is supported by fecal analysis studies which have shown the Indiana myotis consuming at least twelve different Orders of insects and arthropods (Murray and Kurta, 2002), many of which are not commonly found along rivers. Capture data suggests that most Indiana myotis fly below the canopy at a height between 2 and 4 m (Fenton and Downes, 1981; Gardner et al., 1989), with some individuals foraging around the canopy at 28m (Humphrey et al., 1977: Fenton and Downes, 1981). In Pennsylvania, Butchkoski and Hassinger (2002) determined general foraging patterns of six Indiana myotis (one male and five females). Their data show that individuals foraged mainly in interior forests, and in hollows with intermittent streams. Foraging areas ranged from 39-122 ha, and bats foraged between 275 and 375 m in elevation. The maximum travel distance between a day roost and foraging area was 4.5 km.

Data pertaining to the distribution of Indiana myotis in Massachusetts (and adjacent New Hampshire counties) during the summer period were assessed through published literature, gray literature, museum records, and through personal communications with MADFW (T. French, pers. comm.). The literature search, museum records, and personal communications with state biologists yielded no summer records for the Indiana myotis in Massachusetts (or adjacent New Hampshire counties).

2.2.2 Eastern small-footed myotis, *Myotis leibii*

The eastern small-footed myotis has an extensive distribution (from Ontario to New England, southward to Georgia and Westward to Oklahoma), although it is not considered common anywhere within its range. The status of the eastern small-footed myotis has been the subject of regular revision throughout the 20th century. Prior to its current classification as *M. leibii* in 1984 (van Zyll de Jong, 1984), the eastern small-footed myotis was considered a subspecies (*Myotis leibii leibii*) of neartic small-footed bats (Glass and Baker, 1968). Prior to 1968, this species was referred to as *M. subulatus* (Miller and Allen, 1929 cited in Thomas, 1993). This taxonomic discontinuity has most likely played a significant role in the lack of federal protection afforded to this species, considering the eastern small-footed myotis is one of the rarest bats in North America (Griffin, 1940) and 'without doubt the least known of all northeastern bat species' (Thomas, 1993). Although *M. leibii* is not federally protected, it is considered a species of management concern and has conservation status in most of the New England states (including Species of Special Concern in Massachusetts), and several states in the mid-Atlantic region, including Pennsylvania, Maryland, West Virginia, Tennessee, and Kentucky.

Because of its relative rarity, the eastern small-footed myotis has proven difficult to research in significant numbers, and therefore most of our knowledge of this species comes from individual captures and hibernacula surveys. Summer records of reproductive eastern small-footed myotis are relatively rare, and recent capture data (post-1980) are often limited to a few individuals within any state. Although they appear to exhibit some summer flexibility in roost use, with some roosts reported from hollow trees, exfoliating bark, abandoned tunnels, and even human structures (Thomas, 1993; Best and Jennings, 1997), available data suggest that reproductive groups (pregnant females and their offspring) typically use rock outcrops and talus slopes as maternity roosts during the summer months (J.P. Veilleux, Franklin Pierce University, unpublished data). Summer populations of eastern small-footed myotis appear to have a patchy distribution throughout their range, and activity is often concentrated around hibernacula (Thomas, 1993; Johnson and Gates, 2008). No data are available that describe foraging habitat used by eastern small-footed myotis, although recent data indicate that this species feeds primarily on moths, flies, and beetles (Moosman et al., 2007).

Most records of eastern small-footed myotis are from hibernacula surveys. They appear to be a relatively cold-tolerant species, choosing to hibernate near entrances in narrow crevices (Best and Jennings, 1997), often hanging low along the wall or even among rock debris (Thomas, 1993). They enter hibernation later than most other species and leave earlier (Thomas, 1993; Best and Jennings, 1997), giving them a substantially longer active season that other hibernating species. Recent data from spring emergence studies in Maryland indicate that some eastern small-footed bats leave their winter hibernaculum for summer roosts sites between 13 March and 04 April (Johnson and Gates, 2008), while in southern New Hampshire, individuals have been observed at their summer roost area as early at 06 April (J.P. Veilleux, unpublished data). Additional recent data on spring migration patterns suggest that some eastern small-footed myotis travel extremely short distances between winter hibernacula and summer roost areas. In Maryland, Johnson and Gates (2008) reported migration distances of between 0.1 and 1.1 km from hibernacula to summering locations for four female eastern small-footed myotis.

Few data are available in the published literature pertaining to the distribution of eastern small-footed myotis in Massachusetts during both summer (reproductive) and winter (hibernation) periods. The only published winter record of eastern small-footed myotis in Massachusetts was provided by Veilleux (2007). A total of five eastern small-footed myotis was observed within Bat's Den Cave, in the town of

Egremont, Berkshire County (128 km southwest of MWCC). The only additional winter records of the eastern small-footed myotis in Massachusetts are from the town of Chester, Hampden County (90 km southwest of MWCC; T. French, pers. comm.), where individuals have been observed within both the Chester Emery Mine and the Macia Mine. A single individual was observed in the Macia Mine in 1981, while 20 surveys of the Chester Emery Mine conducted between 1937 and 1999 yielded between one and five individuals on six survey occasions (Veilleux, 2007).

No summer colonies are known from Massachusetts, although regional summer occurrences are available for both Cheshire and Hillsborough Counties, New Hampshire. In Cheshire County, the largest summer population known for this species across its range is present at an Army Corps of Engineers dam installation (Surry Mountain Dam), located in the town of Surry (55 km northwest of MWCC). At least 120 individuals have been captured at the Surry Mountain Dam during summers of 2005 through 2008 (J.P. Veilleux, unpublished data). A second summer population is known from the New Boston Air Force Station (NBAFS), located in New Boston (Hillsborough County), NH (48 km northeast of MWCC). During three summer sampling efforts at the NBAFS (2002, 2006, 2007), 12 eastern small-footed myotis were captured (LaGory et al., 2002; LaGory et al., 2008). Radiotelemetry data indicated that individuals roost along an exposed south/southeast facing rock face of Joe English Hill.

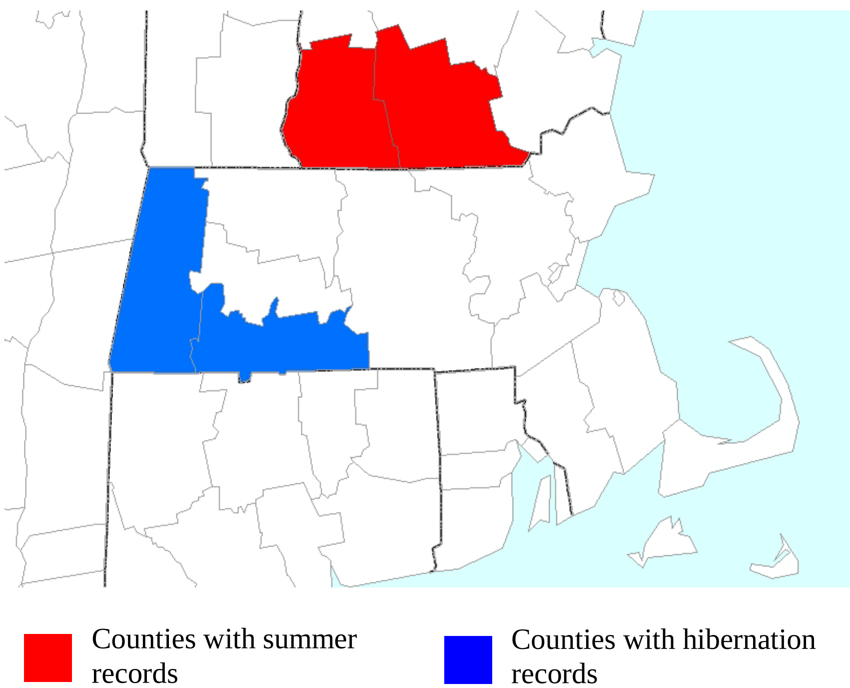

Fig. 3. County distribution of winter (hibernacula) and summer records of the eastern small-footed bats in Massachusetts (and regional counties relative to the MWCC project county)

2.3 Bats At Higher Risk of Turbine Collision Mortality

Post-construction mortality surveys at wind turbine sites have revealed a relatively consistent pattern of bat mortality despite diverse methodologies and sampling periods. Surveys from across North America suggest that migratory tree bats are being killed at higher rates than other species (Table 3). For example, a summary of mortality data from nine wind facilities in the United States showed 86% of the identified mortality came from three species (hoary bats, red bats, and silver-haired bats: Erickson et al., 2002). A more recent review of wind development by Johnson (2005) suggests that 83% of the total mortality involves these same three species. Projects in the eastern United States also see a relatively large number of eastern pipistrelle mortalities. The reason for these species being at higher risk of collision mortality is uncertain. The hoary bat and silver-haired bat are found across North America and are therefore potentially found at any wind development site in this region. The other two species (eastern red bat and eastern pipistrelle bat) are more regional in distribution than these pan-continental species, but still have geographic ranges that extend over thousands of miles. It is likely that these large geographic ranges and the long-distance migratory behavior of these species (except pipistrelles) expose them to a higher risk of turbine-related collision mortality.

Table 3: The percent of bat mortality attributed to the 'high-risk' species (hoary bat, silver-haired bat, red bat, and eastern pipistrelle).

Wind Development Site	Percent of Migratory Bats (total bats killed) [1]	Literature Source
Nine Canyon (WA)	100% (27)	Erickson et al., 2003
Buffalo Mountain (TN)	98% (120)	Fiedler, 2004
Buffalo Ridge (MN)	93% (151)	Johnson et al., 2004
Vancycle (OR)	90% (10)	Erickson et al., 2000
Locust Ridge (PA), 2007	90% (211)	S. Whitten, unpublished
Foot Creek Rim (WY)	88% (79)	Young et al., 2003
Mountaineer (WV), 2003	86% (466)	Kerlinger and Kerns, 2004
Mountaineer (WV), 2004	87% (466)	Arnett, 2005
Meyersdale (PA)	87% (299)	Arnett, 2005
Maple Ridge (NY)	74% (383)	Jain et al., 2007
Top of Iowa (IA)	63% (108)	Koford et al., 2005
Solano (CA)	59% (116)	Kerlinger et al., 2006
Klondike (OR)	50% (6)	Johnson et al., 2003b
Overall	86% (3,247)	

[1] percentage of total mortality attributable to migratory bat species

Although the determination of relative risk is somewhat arbitrary in the absence of site-specific population densities for each species, it is clear that these species are being killed at a higher rate than would be predicted based on the abundance of these species from capture surveys. For example, at the Mountaineer facility in West Virginia, these four species represented 85.7% of the total mortality but only 22.6% of the total bats captured in a 1999-2000 statewide survey, resulting in mortality rates that ranged from 2.5 – 34.0 times the rate at which they were captured (Kerlinger and Kerns, 2004). Similar mortality bias has been observed at other wind projects where local bat surveys have been conducted (Johnson et al., 2004; Johnson, 2005; Jain et al., 2007).

2.3.1 Hoary bat, *Lasiurus cinereus*

The hoary bat occurs throughout much of North and South America (Cryan, 2003). In Massachusetts, hoary bats are likely found statewide (Godin, 1977), particularly during spring and fall migration, with records available for eight Massachusetts counties (Godin, 1977). Regional summer records (relative to the project site) exist from Worcester (Worcester County; 24 km southeast of MWCC; Godin, 1977), Surry (Cheshire County, NH; 55 km northwest of MWCC; J. Veilleux, unpublished data), and New Boston (Hillsborough County, NH; 48 km northeast of MWCC; Veilleux et al. *in press*).

There are no detailed data that describe migration patterns of this species in Massachusetts. Generally, female and male hoary bats winter in more southern latitudes. Both males and females appear to migrate to northern latitudes during spring, with males migrating to more western regions and females to more eastern regions, although there are scattered exceptions to these generalities (Cryan, 2003, Perry and Thill, 2007).

Summer roosting habits of hoary bats are not well documented (Whitaker and Hamilton, 1998; Willis and Brigham, 2005), and no roosting data are available for Massachusetts. Roosts are located primarily in foliage, but are also known from other atypical sites such as woodpecker holes and squirrel nests (Shump and Shump 1982a). Neither adult female nor male hoary bats are colonial. Except for reproductive females roosting with their young, they are believed to roost alone during all times of the year (Shump and Shump 1982a). Females give birth to twins and wean their young within the foliage roosts.

The nearest data on summer roost use by hoary bats relative to the MWCC project area were reported from New Hampshire (Veilleux et al., *in press*). A single mother/pup group was radiotracked to its roost sites. The bats roosted near the tops of eastern hemlock trees and all trees were located within a 0.5 ha area. Willis and Brigham (2005) radio-tracked 21 reproductive females and four juveniles to 32 roost sites (19 roosts were included in the analyses) in Saskatchewan, Canada. All roosts but one were located within the foliage of white spruce (*Picea glauca*), with the one additional roost being located in a trembling aspen (*Populus tremuloides*). In Arkansas, Perry and Thill (2007) reported roosts used by nine hoary bats (4 males and 5 females). Roosts were typically located in foliage along the eastern edge of white oaks, post oaks (*Q. stellata*), and shortleaf pines (*P. echinata*). Mean roost height was 16.5 m, and, on average, roosts were larger (height and DBH) than a random set of trees used for comparison. In terms of habitat surrounding roost trees used by hoary bats, Willis and Brigham (2005) found reduced forest density on the roosting side of roost trees, possibly providing an open 'flyway' for bats returning to and leaving the roost. In terms of landscape level patterns, hoary bats roosted at lower elevations, possibly due to the increased number of white spruce and lower wind levels in such areas. In Pennsylvania, Hart et al. (1993) found hoary bats utilizing forested and aquatic habitats as foraging habitat (based on echolocation recordings) in greater proportions than non-forested and non-aquatic habitats. In New Hampshire, Veilleux et al. (*in press*) reported foraging data for a single juvenile hoary bat. Most foraging activity occurred in forested habitats (nearly 70%), with less foraging occurring in open fields (17%) or wetlands (15%).

Hoary bats have been documented migrating throughout their range and there is evidence to suggest some individuals remain in the same area but move towards higher elevation sites during the winter (Dalquest, 1943; Vaughan and Krutzsch, 1954; Cryan, 2003). Although this species does not hibernate to the extent of the cave bats, the use of torpor at low temperatures has been documented in this species (Brisbin, 1966; Cryan and Wolf, 2003; Genoud, 1993).

2.3.2 Silver-haired bat, *Lasionycteris noctivagans*

The silver-haired bat occurs throughout much of the majority of southern Canada and the United States (Kunz, 1982). In Massachusetts, silver-haired bats are likely found statewide (Godin, 1977), particularly during spring and fall migration, with records available for ten Massachusetts counties (Godin, 1977). Regional summer records (relative to the project site) exist from Harvard (Worcester County; 35 km east/southeast of MWCC; Godin, 1977), Tyngsboro (Middlesex County; 46 km east/northeast of MWCC; MCZ database), and New Boston (Hillsborough County, NH; 48 km northeast of MWCC; LaGory et al., 2002).

There are no detailed data that describe migration patterns of this species in Massachusetts. Female appear to migrate to northern latitudes during spring to give birth, while males appear to remain closer to their winter range (Cryan, 2003). Although this species is likely widely distributed in Massachusetts (Godin, 1977), particularly during spring and fall migration, few data are available that indicate its population status in the state.

The silver-haired bat is a tree-roosting species and during summer months roosts in tree hollows (e.g. Vonhof, 1996; Betts, 1998; Crampton and Barclay, 1998). Most of the data on roost use by this species are from studies in the northwestern United States and southwestern Canada (i.e. Campbell et al., 1996; Vonhof and Barclay, 1996; Betts, 1998; Crampton and Barclay, 1998). Crampton and Barclay (1998) examined aspects of the roosting ecology of silver-haired bats in Alberta, Canada. Individuals preferred to roost in deep cavities within trembling aspen (*Populus tremuloides*) and other aspen species. In Oregon, Betts (1998) found pregnant and lactating female silver-haired bats roosting in ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), douglas fir (*Pseudotsuga menziesii*), and grand fir (*Abies grandis*). In Washington, Campbell et al. (1996) found silver-haired bats mainly roosting in ponderosa pine and white pine (*Pinus monticola*). In British Columbia, Vonhof (1996) found silver-haired bats preferring to roost in trembling aspen and lodgepole pine (*Pinus contorta*). Parsons et al. (1986) described characteristics of a maternity roost of silver-haired bats from Ontario. The roost was located in a dead section of a basswood tree (*Tilia americana*) within an abandoned woodpecker hollow located 5.4 m from the ground.

In terms of landscape level choice, Betts (1998) found most roosts used by silver-haired bats in mature rather than young stands. Campbell et al. (1996) found roost sites located > 100 m from riparian areas, on slopes averaging 38%, and the slope aspect for 11 of 15 roosts within 70° of north. The maternity roost described by Parsons et al. (1986) was located within a mixed-wood stand dominated by sugar maple (*Acer saccharum*), eastern white cedar (*Thuja occidentalis*), and white birch (*Betula papyrifera*). The roost tree was located near (8 m) an actively used building, and approximately 500 m from a large (400 ha) marsh. Major foods of silver-haired bats include moths, true bugs, flies, beetles, and caddisflies (Kunz, 1982). Foraging typically occurs near conifer or mixed coniferous/deciduous woods that are located relatively close to a pond or stream (Schmidly, 2004).

The best available data on migratory behavior of the silver-haired bat comes from a study conducted by Barclay et al. (1988) that examined the roosting habits of females moving through Manitoba during spring. A total of 177 bats was located in 36 roosts in nearly as many trees (n = 32). Most bats roosted alone, although 15 pairs and eight groups of 3 to 6 bats were observed. Bats roosted in folds of bark and crevices in trunks, preferentially choosing large trees of species that were likely to have furrowed bark, splits, and cracks. Some roost sites were used on multiple occasions both within and between years. On several occasions, bats did not emerge from roosts on cold nights, suggesting that they wait for warmer temperatures before they continue migrating. Other documented spring roosts of silver-haired bats include a torpid bat found beneath ground debris in western Oregon (Sanborn, 1953), crevices in sandstone ledges, and a cave in West Virginia (Frum, 1953). The latter bats had enough food in their systems to suggest they had recently fed (Frum, 1953). Silver-haired bats have historically been seen migrating in large groups along the Atlantic coast (Miller, 1897; Mackiewicz and Backus, 1956), although specimen collections from Canada suggest they are also migratory in the western United States (Schowalter et al., 1978). Data from California and New Mexico suggest that silver-haired bats would be more common early in the summer (Jones, 1965), although there is evidence of non-migratory individuals throughout their range (Heady and Frick, 1999). Although this species does not hibernate to the extent of the cave bats, the use of torpor at low temperatures has been documented (Neuhauser and Brisbin, 1969)

2.3.3 Eastern red bat, *Lasiurus borealis*

The eastern red bat is a common resident of much of the United States and extends its range to Central and South America (Shump and Shump, 1982b). In Massachusetts, eastern red bats are likely found statewide (Godin, 1977), particularly during spring and fall migration, with records available for nine Massachusetts counties (Godin, 1977; MCZ museum records). Regional summer records (relative to the project site) exist from Worcester (Worcester County; 24 km southeast of MWCC; Godin, 1977), Surry (Cheshire County, NH; 55 km northwest of MWCC; J. Veilleux, unpublished data), and New Boston (Hillsborough County, NH; 48 km northeast of MWCC; LaGory et al., 2002; LaGory et al., 2008).

Eastern red bats are one of the best known migratory tree bats. In the spring, they migrate into the northern region of their distribution. During migration, they appear to use a variety of roosts; including woodpecker holes (Fassler, 1975) and leaf litter (Saugey et al., 1998; Boyles et al., 2003). Although this species does not hibernate to the extent of the cave bats, the use of torpor at low temperatures has been documented (Davis and Lidicker ,1956; Genoud, 1993).

During summer months, eastern red bats roost in the foliage of trees (Shump and Shump, 1982b; Whitaker and Hamilton, 1998). Neither adult female nor male eastern red bats are colonial, but roost singly during all times of the year (except for reproductive females roosting with their young; Mumford, 1973, Shump and Shump, 1982b, Hutchinson and Lacki, 2000). Females give birth and wean their young within these foliage roosts.

Three studies by Menzel et al. (1998), Mager and Nelson (2001), and Hutchinson and Lacki (2000) examined summer roosting habits of eastern red bats in Georgia/South Carolina, Illinois, and Kentucky, respectively. Menzel et al. (1998) located eastern red bat roosts in 18 tree species, but oaks (*Quercus* spp.) and sweetgum (*Liquidambar styraciflua*) were the preferred roost tree types. Mager and Nelson (2001) located eastern red bats in oaks, sweetgum, black walnut (*Juglans nigra*), maples (*Acer* spp) and hickories (*Carya* spp.). Hutchinson and Lacki (2000) located eastern red bat roosts in hickories, yellow poplar (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*) and white oak (*Quercus alba*).

In terms of overall habitat preference, both Menzel et al. (1998) and Hutchinson and Lacki (2000) found that the majority of roost trees used by eastern red bats were located in hardwood forests and in upland areas. Roost trees are typically located relatively close to permanent water sources. For example, Hutchinson and Lacki (2000) reported roosts located at approximately 500 m or less from available water. Major foods of eastern red bats include moths, beetles, and leafhoppers (Schmidly, 2004). Foraging takes place above tree top level early in the evening, and eventually takes place at or below canopy level (Shump and Shump, 1982b).

2.3.4 Eastern pipistrelle bat, *Perimyotis subflavus*

The eastern pipistrelle bat occurs throughout much of the eastern United States, north to extreme southeastern Canada, and south through Honduras (Fujita and Kunz, 1984). The eastern pipistrelle is widely distributed in Massachusetts (records exist for seven counties), and likely occurs statewide where suitable habitat exists (Godin, 1977). Regional summer records (relative to the project site) exist from East Templeton (Worcester County; 5 km southwest of MWCC; Godin, 1977) and Harvard (Worcester County; 40 km east of MWCC: S. Reynolds, unpublished data). Additional records from adjacent counties include Erving (Franklin County; 40 km west of MWCC: S. Reynolds, unpublished data) and Surry (Cheshire County, NH; 55 km northwest of MWCC; J. Veilleux, unpublished data). Additional current distribution data for eastern pipistrelles relative to the MWCC project were requested from MADFW, but were not provided for this report.

During summer months female eastern pipistrelles typically form small maternity colonies (under 10 individuals) in dead leaf clusters or in live foliage (Veilleux et al., 2003), although larger (approximately 15 individuals) maternity colonies are also formed in buildings (Whitaker, 1998). In Missouri, maternity colonies have been reported from caves (Humphrey et al., 1976), but this is a very rare roosting behavior. In terms of roost tree preference, eastern pipistrelles prefer oak trees (*Quercus* spp.) over other available tree species, but maples (*Acer* spp.), yellow poplar (*Liriodendron tulipifera*), eastern cottonwood (*Populus deltoides*), and hackberry (*Celtis occidentalis*) are used relatively often as well (Veilleux et al., 2004a). Capture data indicate that eastern pipistrelles are captured with equal frequency in upland, riparian, and bottomland forests, but prefer to roost in trees within upland forests and riparian woodlands (Veilleux et al., 2003). Eastern pipistrelles appear to exhibit philopatry, including female natal philopatry. Veilleux and Veilleux (2004) reported individual female eastern pipistrelles returning to the same specific summer habitat area across years.

Female eastern pipistrelles give birth to two young, typically in late June through early July (Veilleux and Veilleux, 2004), and the young become volant at approximately three to four weeks of age (Whitaker, 1998). Summer foraging habitat includes bottomland hardwood forests, pine stands, and upland hardwoods (Carter et al., 1999). Eastern pipistrelles appear to remain relatively close to roost sites while foraging. Veilleux et al. (2003) reported minimum foraging distances ranging from 0.05 to 2.61 km (mean = 0.72 km) from roost sites. Major foods of eastern pipistrelles include leafhoppers, beetles, flies, and moths (Whitaker and Hamilton, 1998).

During winter, caves and mines are typically used as hibernation sites. Eastern pipistrelles tolerate warmer temperatures within their hibernaculum than most other bat species (Raesly and Gates, 1987; Briggler and Prather, 2003). This species does not form large hibernating congregations, but instead roosts singly or in small groups (Fujita and Kunz, 1984), although up to 750 individuals have been reported from a single hibernacula (Hicks, 2003).

Little is known of the migration behavior of eastern pipistrelles. Some researchers believe that individuals travel short distances from summering areas to local hibernacula (caves or mines), while others believe that the relatively high mortality rates of this species at some wind turbine sites may indicate a longer migration route along defined migratory pathways. The largest reported distance traveled by eastern pipistrelles from summer areas to winter hibernacula is approximately 137 km (Griffin, 1940). In Indiana, Veilleux et al. (2004b) reported that eastern pipistrelles first arrived at their summering areas during the first two weeks of May, and most individuals appeared to leave their summering area for their hibernation site by late August. In Missouri, LaVal and LaVal (1980) reported eastern pipistrelles leaving summering areas for hibernacula during late July through August.

2.4 Other Bats Likely to Occur Near the MWCC Wind Project Site

Each of the eight species regularly occurring in Massachusetts (Indiana myotis not considered a regularly occurring species in Massachusetts) have geographical ranges that occur with the Project county, or in the surrounding counties (Table 1). Neither listed species (the Indiana myotis and eastern small-footed myotis) have been identified as occurring within the Project region. Four species (hoary bat, silver-haired bat, eastern red bat, and eastern pipistrelle) that occur regionally have been identified as species at higher potential risk of turbine collision mortality (Section 2.3). None of the remaining three species (little brown myotis, northern myotis, and big brown bat) are provided federal or state legal protection . A brief summary of biology and known distribution of these three species is presented below.

2.4.1 Little brown myotis, *Myotis lucifugus*

The little brown myotis occurs throughout most of North America (Fenton and Barclay, 1980), and is one of the most common species encountered throughout its range. The little brown myotis is likely the most common species in Massachusetts and likely occurs statewide (Godin, 1977), with records available for 11 Massachusetts counties. Regional summer records (relative to the project site) exist from 12 towns in Worcester County (Godin, 1977; S. Reynolds, unpublished data), with additional records from adjacent counties, including two towns in Franklin County, four towns in Middlesex County, 7 towns in Hillsborough County, NH, and five towns in Cheshire County, NH (S. Reynolds, unpublished data).

In late spring and early summer, females form maternity roosts which are nearly always located in human made structures (e.g. barns, attics, etc.). Colonies can be small (under 100 individuals), but also may reach sizes of several thousand bats, with the largest known colony in the eastern United States (located in Pennsylvania) estimated at approximately 20,000 bats (Butchkoski and Hassinger, 2002). Females give birth to a single young between mid-June and mid-July (depending on latitude and regional climate patterns) within these maternity roosts, and young are volant and weaned by approximately 4 weeks old (Whitaker and Hamilton, 1998). In contrast to females, males do not roost with the nursery colonies, but rather roost alone or in small groups in other locations. These roosts are more variable, including buildings and other structures such as lumber piles, under tar paper, or even in caves (Fenton and Barclay, 1980). Forest edges along streams and lakes appear to be preferred summer foraging habitat (Fenton and Bell, 1979), and data indicate a foraging home range of up to 30 ha (Henry et al., 2002). In southeastern Canada, little brown myotis will travel up to 1 km from roosts to foraging areas (Henry et al., 2002). Major foods of the little brown myotis include midges, flies, beetles, leaf hoppers, caddisflies, and moths (Whitaker and Hamilton, 1998).

During winter, little brown myotis typically hibernate within caves and mines (Fenton and Barclay, 1980). There is variability in the timing that individuals arrive at and enter hibernacula in fall and exit hibernacula in spring. This variability follows a latitudinal gradient, with individuals entering hibernacula earlier and leaving later in the north, while the converse is typical at lower latitudes. For example, in Ontario, little brown myotis enter hibernation in early September and leave hibernacula by early to middle May (Fenton and Barclay, 1980). At lower latitudes, hibernation may not begin under November and end by mid-March (Fenton and Barclay, 1980). Regardless of when hibernation begins, individuals arrive at caves and mines (which may or may not serve as hibernacula) during early fall and initiate swarming behavior. During fall swarming, individuals gather in large numbers near the entrance to a cave or mine. Fall swarming behavior may function in mate choice and reproduction (i.e. the time of copulation), as well as familiarize juvenile bats with potential hibernacula (Fenton and Barclay, 1980). Soon after fall swarming, individuals enter their hibernaculum and commence hibernation. Raesly and Gates (1987) reported that the little brown myotis preferred hibernacula with temperatures near 7.5° C. Little brown myotis often prefer to roost on the side walls of hibernacula, rather than the ceiling (Raesly and Gates, 1987).

2.4.2 Northern myotis, *Myotis septentrionalis*

The northern myotis ranges throughout much of the eastern United States, and much of the lower Canadian provinces (Caceres and Barclay, 2000). This species is forest-dependent, and is likely widespread in Massachusetts (records are available for eight Massachusetts counties) where suitable habitat exists. Regional summer records (relative to the project site) exist from East Templeton and Harvard (Worcester County, 5 km southwest and 35 km east/southeast of MWCC, respectively), with additional records from adjacent counties, including two towns in Cheshire County, NH (J. Veilleux, unpublished data; S. Reynolds, unpublished data) and two towns from Hillsborough County, NH (LaGory et al., 2008; S. Reynolds, unpublished data).

During summer, the northern myotis roosts primarily within trees, either within tree hollows, crevices, or under exfoliating bark (Foster and Kurta, 1999). Tree species used as roosts are variable. In Michigan, major tree species used as roosts include silver maples (*Acer saccharinum*), red maples (*A. rubrum*), and green ash (*Fraxinus pennsylvanicus*). In Nova Scotia, major trees species used by northern myotis include sugar maple (*A. saccharum*), yellow birch (*Betula alleghaniensis*), and red spruce (*Picea rubens*; Broders and Forbes, 2004). In West Virginia, roost trees include red maple, northern red oak (*Quercus rubra*), sassafras (*Sassafras albidum*), American basswood (*Tilia americana*), Fraser magnolia (*Magnolia fraseri*), black cherry (*Prunus serotina*), and black locust (*Robinia pseudoacacia*; Menzel et al., 2002). In West Virginia, Owen et al. (2003) found that the majority of roost trees used by *M. septentrionalis* were located in intact forests (70-90 year old forests with no timber harvest activity within 10-15 years). Data indicate that the northern myotis forages within upland forested sites, rather than in lowland riparian woodlands or in bottomland forests (Harvey et al., 1999; Owen et al., 2003). Data from Owen et al. (2003) indicate a mean foraging area of 65 ha for reproductive female northern myotis. Females form small maternity colonies during summer, with less than 30 bats typically found in a particular roost (*see* Foster and Kurta, 1999; Menzel et al., 2002; Owen et al., 2003). Females give birth to a single young, with parturition commencing in early June and juveniles becoming volant by late-June (Feldhamer et al., 2001). No data are available that describe the migratory behavior of the northern myotis.

During winter, the northern myotis requires cave or mine habitat that provides adequate characteristics for successful hibernation. Such characteristics mainly include the proper microclimate (i.e. temperature stability) and a low level of human disturbance. During hibernation, the northern myotis often retreats into small holes, cracks, and crevices along the walls and ceiling (John Whitaker, Indiana State University, pers. comm.; Durham, 2000), although they will also cling to the wall and ceiling surface. It is unknown whether the northern myotis hibernates preferentially in caves and mines with large numbers of small crevices discussed above. Northern myotis are often found deeper within a mine shaft (Durham, 2000), although it is not clear what influences this preference. Northern myotis bats are known to use caves and mines year-round and often maintain some activity throughout the winter months (Whitaker and Rissler, 1992).

2.4.3 Big brown bat, *Eptesicus fuscus*

The big brown bat occurs throughout the entire United States, where suitable roosting habitat exists (Kurta and Baker, 1990). Following the little brown myotis, the big brown bat is the next most common bat species in Massachusetts and likely occurs statewide (Godin, 1977), with records available for 11 Massachusetts counties. Regional summer records (relative to the project site) exist from six towns in Worcester County (Godin, 1977; S. Reynolds, unpublished data), with additional records from adjacent counties including 17 towns in Middlesex County, MA (S. Reynolds, unpublished data), 12 towns in Hillsborough County, NH (LaGory et al., 2008; S. Reynolds, unpublished data) and two towns in Cheshire County, NH (J. Veilleux, unpublished data; S. Reynolds, unpublished data).

During summer, populations of big brown bats in eastern North America typically roost within human related structures (attics, barns, etc.), while in western North America roost in buildings, as well as trees, rock outcrops, and other natural roosts (Kurta and Baker, 1990). In the east, females form maternity roosts to give birth to young; these roosts range in size from several dozen up to 600 bats (Whitaker and Hamilton, 1998). Males are mainly solitary during this period, and may roost in the same building as the maternity colony, but not within the colony itself (Whitaker and Hamilton, 1998). In the east, females give birth to two young, typically during late May through the middle of June (parturition may occur earlier at warmer, southern latitudes). Young are volant and weaned by approximately four weeks old (Whitaker and Hamilton, 1998). Big brown bats forage in a variety of habitats, including over water, along woodland edges, within woodlands, and in urban areas (Kurta and Baker, 1990). In Alberta (Canada), big brown bats were found to prefer riparian habitat for foraging, over prairie or urban habitats (Wilkinson and Barclay, 1997). Foraging distances for big brown bats range from 1 to 2 km, and individuals often forage at a height of approximately 50 m early in the evening, and descending to under 15 m later in the evening (Kurta and Baker, 1990). The major food item of big brown bats is beetles, although leafhoppers, ants, caddisflies, mayflies, and flies are consumed as well (Whitaker and Hamilton, 1998).

During winter, eastern populations of big brown bats hibernated in cave and mines, as well as in buildings with suitable attic temperatures. Hitchcock et al. (1984) reported that big brown bats prefer to hibernate in the cooler sections of hibernacula located in southeastern Ontario. Raesly and Gates (1987) reported a mean hibernacula temperature of 7.1° C where big brown bats were found roosting. Many big brown bats hibernate singly, but small groups are often formed as well (Kurta and Baker, 1990)

3.0 MIGRATORY BEHAVIOR OF BATS

Insectivorous bats that inhabit temperate forests of North America during the summer months face important challenges as the seasons change. During winter, insect prey (energy) is generally unavailable, and these species are unable to fulfill the energetic requirements of remaining active. Therefore, these species generally avoid the energetic stresses of winter in one of three ways: 1) by hibernating at regional caves, mines, or other suitable hibernacula, or 2) by migrating into different latitudes where prey sources remain available (Cryan and Veilleux, 2007), and 3) by migrating into different elevations where prey sources remain available. Although considerable variation exists in migratory behavior, North American migratory bats can be categorized into two general groups: long-distance and short-distance migrants. Long-distance migratory species include the 'tree bats', such as the eastern red bat (*L. borealis*), hoary bat (*L. cinereus*), and the silver-haired bat (*Lasionycteris noctivagans*). Some individuals of these species undergo seasonal trans-continental migrations, traveling hundreds of miles between winter and summer habitat areas. Upon reaching their wintering grounds, some individuals remain active if insect prey is available, while others may enter torpor for prolonged periods. Short-distance migrants include those species that travel from summer habitat areas to regional caves, mines, and other suitable structures that serve as hibernation sites during late fall through early spring. Regardless of migration strategy, individuals undergo such movements twice per year: once when leaving wintering ground for summering areas, and another for the return trip from summer to wintering grounds.

3.1 Long-Distance Migratory Bats

Seasonal migrations of long distance migratory bats can surpass 500 km in each northward and southward direction. Unfortunately, the lack of suitable technology (e.g. miniature satellite transmitters) limits our current understanding of migration behavior and movement patterns in these species. Despite the lack of extensive data (although see Cryan, 2003), it is believed that most of the tree-roosting bat species have extensive migratory ranges. Forty-six bat species occur north of Mexico, and over half (n = 24) are known to use trees as roosts during some portion of the year (Kunz and Reynolds, 2004). The majority of these species roost in trees only during late spring through early autumn before moving to caves, mines, buildings, or other structures for the winter. Such species enter long-term torpor bouts during winter within these thermally stable sites and are often referred to as either "hibernating" or "cave" bats. This section focuses on the classic tree- and foliage-roosting bats within the Family Vespertilionidae that are found in the eastern United States. These species include the eastern red bat (*L. borealis*), the hoary bat (*L. cinereus*), and the silver-haired bat (*Lasionycteris noctivagans*). Data on the distribution of tree bats indicate that few leave the continent during winter and it is likely that individuals use torpor to some degree while within their winter range.

During the winter, North American tree bats generally occur at latitudes below 40ºN and in coastal regions where freezing temperatures are infrequent. Species-specific data are presented in Section 2.3 for all the eastern migratory tree-roosting bats. However, our knowledge of migratory behavior and winter roosting habits is incomplete because tree bats use torpor, roost in situations where they are not readily observed, and are rarely sought out by biologists during winter. Thus far, it has been ineffective to use banding efforts to determine detailed movement patterns in tree bats. However, mapping regional distribution records (Cryan, 2003; Findley and Jones, 1964) and analysis of stable isotopes (Cryan et al., 2004) have helped reveal patterns of bat migration. Cryan (2003) used museum data to summarize the potential seasonal movements of several tree-roosting bats in North America. Four important patterns emerged in the seasonal distributions of these wide-ranging species, including, 1) the migration route of each species is apparently contained within the continent of North America (i.e. there is no mass movement of individuals to extreme south latitudes, 2) individuals of each species may occur in the majority of available forested habitat in North America (within their geographic range) during some part of the year, 3) the timing and nature of local habitat usage, as well as the population structure of bats in a particular area, will vary regionally, and 4) there are apparent differences in the migratory movements of males and females. Specifically, females appear to migrate in advance of the males, travel greater distances, and often exhibit disparate distributions from the males. For example, data from the hoary bat and silver-haired bat suggest sex-biased summer distributional differences in the range of hundreds of kilometers (Cryan, 2003; Findley and Jones, 1964). Data pertaining to the seasonal whereabouts and migratory movements of these species are lacking.

3.2 Short-Distance Migratory Bats

Although the longest migratory patterns are typically seen in the tree-roosting bats, the majority of data that describe migration come from mark-recapture (banding) studies using colonial species (e.g., Brazilian free-tailed bat, cave myotis, and little brown myotis) that winter in caves. Although we have categorized these as ‘short-distance migratory bats’, several studies have documented long-distance movements of individuals. For example, banding studies of little brown myotis (Humphrey and Cope, 1976) and the Indiana myotis (Kurta and Murray, 2002) revealed travel distances between winter and summer habitats of 455 and 532 km, respectively. Detailed reviews of seasonal movement patterns of colonial hibernating bats can be found in Griffin (1970), Baker (1978), and Fleming and Eby (2003). However, bat species that winter in subterranean structures generally make shorter migrational movements, and those movements are less influenced by latitude, than tree bats (Baker, 1978). Such subterranean roosts are thermally stable and roost microclimate is relatively independent of latitude compared to aboveground structures. Hence, the autumn migratory movements of bat species that hibernate during winter in underground sites are typically influenced by geography, and oriented toward nearby regions with suitable conditions for hibernation rather than areas with warm surface temperatures.

3.2.1 Hibernating Bats

The best data on short-distance migratory bats comes from the Family Vespertilionidae. In particular, the best historic data on migration come from the seasonal movement of hibernating *Myotis* bats. Most of these data were collected as the result of large-scale mark-recapture studies conducted on the east coast. These include research conducted by Davis and Hitchcock (1965) in Vermont, which showed the little brown myotis radiated up to 300 km from a single hibernaculum to at least seven states and the province of Quebec. Their data also suggested that most of the bats were using a narrow migration corridor. Data from Indiana (Humphrey, 1971) suggest that individuals are capable of migrating over 450 km to reach their summer foraging areas. More recent data from Pennsylvania (Chenger, 2004) suggests these bats “carefully avoided high elevation hilltops” during the spring migration.

3.2.2 Regional and Elevational Migrants

Other species remain semi-active by migrating regionally into more moderate climates (towards the coast, into lower elevation, or migrating into more southern latitudes). In their wintering range, they may become torpid (inactive) during cold periods and feed on warmer nights. Other species may migrate into colder climates (moving inland or to higher elevation sites) and remain inactive throughout the winter months. Furthermore, migration along gradients of elevation may occur in hibernating or migratory species (Cryan et al., 2000). For example, big brown bats (*Eptesicus fuscus*) that spend the warmer months in buildings around Fort Collins, Colorado (elevation 1,500 m) move into the nearby Rocky Mountains during autumn, where they spend the winter in rock crevices at higher-elevation (> 1,600 m) sites (D. Neubaum, U.S. Geological Survey, pers. comm.).

3.3 Evidence of Bats Migrating in Groups

Although mainly solitary (*Lasiurus* spp.) or forming small colonies (*L. noctivagans*) during summer, data indicate that some tree bats migrate in groups (Fleming and Eby, 2003) and may even form mixed species groups or 'flocks' similar to migratory birds. For example, Mearns (1898) reported "great flights of [red bats, *L. borealis*] during the whole day" in the Hudson Highlands of New York. During late September in Washington D.C., Howell (1908) reported a diurnal migration of what he presumed to be red bats and/or silver-haired bats. Several reports of flocking behavior in tree bats indicate migratory movement. Carter (1950) reported two red bats collected in late September from a flock of an estimated 200 bats that circled a ship 65 miles off the New England coast. During early September, Thomas (1921) reported silver-haired bats and red bats being collected from a group of approximately 100 bats that landed on a ship 20 miles off the North Carolina coast. Byre (1990) observed groups of two to four individuals of silver-haired bats and red bats during autumn mornings as they reached shoreline following an apparent migration over Lake Michigan. Reports of daytime flights of hoary bats are available from Minnesota (Jackson, 1961) and Nevada (Hall, 1946).

Observations of roosting bats also provide evidence of larger aggregations and mixed-species groups during migration. Roosting groups of migrating hoary bats on Southeast Farallon Island, approximately 32 km off the coast of California, sometimes number up to 60 individuals in a single tree (A. Brown, *pers. comm.*). During late August in the North Bay Area of California, Constantine (1959) found a group of approximately 15 western red bats (*L. blossevillii*) roosting in an apricot tree, whereas none were found in the area later in winter. Grinnell (1918) noted "many" western red bats roosting together with a hoary bat during April in California.

Survey efforts have documented both spring and autumn migratory "waves" of tree bats moving across a landscape; these data show multiple individuals being captured (Barclay et al., 1988; Findley and Jones, 1964; Mumford, 1963; 1973; Vaughan, 1953) or acoustically detected (Reynolds, 2006) within a relatively short time period. The details of how North American tree bats form and maintain aggregations during migratory periods are unknown, but evidence of communication does exist. Downes (1964) observed red bats using specific roost sites during autumn and noted that different individuals somehow found and used the exact same roost on subsequent days. Constantine (1966) observed a similar phenomenon where both red bats and hoary bats used the same foliage roost on different days. In Georgia, Seminole bats (*L. seminolus*) and red bats also used the same roost, although others were available (Constantine, 1958). Barclay et al. (1988) noted that migrating silver-haired bats somehow (e.g., olfactory clues) found roosts previously used by others but, as with all of these cases, were unable to determine the method of communication.

Although tree bats sometimes possess fat reserves during autumn and winter (Gosling, 1977; Layne, 1958; Tenaza, 1966; van Gelder, 1956), some species apparently feed during autumn migration. Miller (1897) observed both silver-haired bats and red bats foraging during a migration stopover on the Atlantic Coast and a female hoary bat collected while migrating through Florida was feeding during late October (Zinn and Baker, 1979).

3.4 Potential Threats to Migratory Bats

There are certain factors that make migratory bats particularly susceptible to population decline (Fleming and Eby, 2003). First, migratory bats often require contiguous, yet seasonally distinct, habitats that sometimes span hundreds of kilometers along their annual migration pathway. Degradation of a single region along such annual circuits has the potential to negatively impact populations that move through the area. For example, if some disturbance along a migration corridor disrupts the ability of bats to locate summering grounds, hibernacula, or mating grounds, individual fitness may be reduced and mortality increased. Secondly, bat populations may concentrate in small areas during migration, rendering them vulnerable to mass mortality events. There is currently no means by which to monitor the population status of migratory tree bats (O'Shea and Bogan, 2004), nor do we possess a clear understanding of their habitat needs or mortality risks during migration and winter.

Evidence indicates that tree bats may sometimes migrate with, or under similar conditions as, birds and therefore be susceptible to similar mortality factors. For example, dead red bats were found among migratory birds that washed ashore after both spring and autumn storms on Lake Michigan (Mumford, 1973; Mumford and Whitaker, 1982). There are numerous reports of tree bats found among dead birds that collided with human-made structures. Most of these incidents transpired during autumn and involved multiple species: silver-haired bats, red bats, and hoary bats at a lighthouse on Lake Erie (Saunders, 1930); red bats at a television tower in Kansas (van Gelder, 1956); red bats, hoary bats, Seminole bats, and eastern yellow bats at a television tower in Florida (Crawford and Baker, 1981); red bats and silver-haired bats at a building in Chicago (Timm, 1989); and red bats at the Empire State Building in New York City (Terres, 1956). For many of these collision events, tens to hundreds of birds were reported as killed, whereas only a few bats were encountered. For example, Crawford and Baker (1981) reported 54 bats killed on 49 nights over 25-year monitoring period and Timm (1989) reported 79 bats killed over an 8-year period. In addition to the perils of collisions during flight, migrating bats may be susceptible to predation both during migration and on the wintering grounds. Stomach contents of predators captured during winter revealed the remains of both *L. noctivagans* and *L. borealis* (Sperry, 1933). If trees with adequate roost sites are not available during migration or on the wintering grounds, torpid bats may be vulnerable to higher rates of predation. Unlike the mortality data from buildings, wind turbines appear to impact migratory tree bats at high rates. Although the causes of this mortality are unknown, wind turbines clearly represent an additional mortality risk for these species.

4.0 SOURCES OF MORTALITY FOR BATS

Potential sources of mortality for bats are numerous, but observations concerning mass mortality, predation, or accidents are sporadic at best (Booth, 1965, Gillette and Kimbrough, 1970). Potential impacts on bats include many species of opportunistic predators, including mammals, birds, reptiles, amphibians, fish, and insects (summarized in Gillette and Kimbrough, 1970). All the available data suggest that predation is not a significant source of mortality for bat populations due to the fact that predators are opportunistic and have only a localized impact on bats. Bats are also known to succumb to several abiotic factors such as cold stress, hypothermia, and collisions with vegetation (Gillette and Kimbrough, 1970; Reynolds, pers. obs.), but again these events are generally considered to be relatively infrequent and minor at the population level and the cumulative impact of these stresses are likely to be localized (for a given hibernaculum or maternity colony) and age-dependent (due to the lower fat loads and agility of young bats). In fact, the only natural source of mortality that appears to play a large role for bats is over-winter mortality (Davis and Hitchcock, 1965).

Bats are also susceptible to the impact of humans on their environment, including pesticide poisoning (Geluso et al., 1976; Clark et al., 1988), traffic casualties (Kiefer et al., 1995), collisions with fixed structures (see Section 3.4), habitat fragmentation or loss (Grindal and Brigham, 1988), and disturbance during hibernation (Johnson and Brack, 1998). For commensal (house-roosting) species such as the big brown bat (*Eptesicus fuscus*) and the little brown myotis, the impact of physical exclusions and other pest control operations probably represents the largest population-level source of mortality (Kunz and Reynolds, 2004). Although there is some evidence for a decline in the abundance of house-roosting bat species (Kunz and Reynolds, 2004), historical data for non-commensal species is sporadic at best. Data from winter hibernation surveys (containing both commensal and non-commensal species) throughout New England and New York over the last ten years suggests a slightly increasing wintering population. Although part of this increase is due to conservation efforts at several major hibernacula (Trombulak et al., 2001), most of the sites have seen stable or increasing populations despite not receiving any form of physical protection. Unfortunately, little historic data exist for the non-hibernating migrating species.

5.0 THE IMPACT OF WIND POWER ON BATS

Data from wind projects throughout the United States have shown that bats and birds collide with wind turbines. A summary of bat mortalities at nineteen wind projects in 15 states and several international sites show estimated annual mortality rates between 0.1 – 63.9 bats per turbine (Table 4). Concern has been raised over the level of bat mortality experienced at several sites in the eastern United States, and existing data suggest eastern wind development sites experience higher rates of bat mortality than western sites (Johnson, 2005). These post-construction mortality surveys have shown that the migratory bats are more susceptible to wind turbines than other bats (Gruver, 2002; Johnson et al., 2003a). The migratory bats, specifically the hoary bats, red bats, and silver-haired bats account for 52%, 24%, and 9%, respectively, of all reported bat mortalities. Temporal analysis of these same data show that most of this mortality occurs in the month of August (53.8% of total mortality) when these bats would be beginning their fall migration. Therefore, the distribution and timing of mortality seems to be biased toward non-hibernating migratory bats.

Table 4: Overall of Turbine-Related Bat Mortality at Wind Resource Areas

Project Name	No. turbines	Completion Date	Estimated mortality [1]	References
Buffalo Ridge, Phase 1 (MN)	73	1998	0.3	Johnson et al., 2003a
Vancycle (OR)	38	1999	0.7	Erickson et al., 2000
Castle River (Alberta, CA)	41	2001	0.9	Barclay et al., 2007
Buffalo Mountain (TN)	3	2001	20.8	Fiedler, 2004
Butler Ridge (WI)	33	2001	4.3	Howe et al., 2002
Pickering (Ontario, CA)	1	2001	10.7	Barclay et al., 2007
Klondike Phase I (OR)	16	2002	1.2	Johnson et al., 2003b
Foote Creek Rim (WY)	105	2002	1.3	Young et al., 2003
Buffalo Ridge, Phase 2 (MN)	281	2002	3.0	Johnson et al., 2004
Nine Canyon (WA)	37	2003	3.2	Erickson et al., 2003
High Winds (CA)	90	2003	3.4	Kerlinger et al., 2006
McBride Lake (Alberta, CA)	115	2003	0.5	Barclay et al., 2007
Top of Iowa (IA)	89	2003	5.9	Koford et al., 2005
Mountaineer (WV)	44	2003	47.5	Kerlinger and Kerns, 2004
Meyersdale (PA)	20	2004	23.0	Arnett, 2005
Mountaineer (WV)	44	2004	38.0	Arnett, 2005
Freiburg (Germany)	32	2004	37.1	Brinkmann et al., 2006
Summerview (Alberta, CA)	39	2004	18.5	Barclay et al., 2007
Buffalo Mountain (TN)	15	2004	63.9	Fiedler et al., 2007
NPPD Ainsworth (NE)	15	2005	1.91	Derby et al., 2007
Maple Ridge (NY)	195	2006	24.5	Jain et al., 2007
Judith Gap (MT)	20	2006	13.4	TRC, 2008
Locust Ridge (PA)	13	2007	43.0	Whitten, unpublished

1. *bat mortality per turbine per migratory season*

It is difficult to identify the key physiogeographic features that increase bat mortality at any proposed wind turbine project. However, the three sites with the highest rates of bat mortality are in the east coast. Across the east coast, there also appears to be more mortality at the southern sites. Given the negative correlation between bat biodiversity and latitude (Heithaus et al., 1975), it is possible that these sites are causing more mortality because bats are more abundant in this region. These studies also identify a knowledge gap that results from the absence of baseline population surveys or migratory surveys. Without knowing how many bats are resident or migrating near a wind turbine project, the significance of any mortality that occurs at a site cannot be accurately assessed.

The reasons for such disproportionate kills during autumn are unknown. Curiously, unusual encounters with migrating tree bats typically happen during autumn rather than spring (Cryan, 2003). It is possible that spring migration by tree bats is relatively low-altitude, whereas autumn movement occurs at greater heights. For example, hoary bats fly low (1-5 m off the ground) within riparian areas while migrating through New Mexico during spring, but apparently not during autumn (P. Cryan, *in prep.*). Similarly, Reynolds (2006) documented hoary bats flying low (<10 m off the ground) during spring in New York. In contrast, a hoary bat collided with an airplane 2,438 m above Oklahoma during October (Peurach, 2003).

6.0 EXISTING DATA RELEVANT TO THE PROPOSED PROJECT

The data on the potential impact of wind development on bats is constantly improving, and there are data available from several wind power projects that have received or are seeking regulatory approval. Although the data collected from the MWCC project site has not been analyzed to date, there are data from other wind projects that should be informative for identifying potential risks at the Project site.

6.1 HOOSAC Wind Project (Massachusetts), 2006

The Hoosac Wind Project is a proposed 20-turbine wind farm in Berkshire and Franklin Counties of western Massachusetts. The project has two turbine fronts (Bakke Mountain and Crum Hill) which run north-northeast along the Hoosac Range in the Taconic Mountains Ecoregion at an elevation of up to 867 m asl. The Hoosac Wind Project is located approximately 25 miles north of the Chester Mine complex (containing *M. leibii*) and approximately 35 miles east of Hale's Cave (Albany, New York) where approximately 500 *M. sodalis* hibernate.

NEES and Bat Conservation International (BCI) began a long-term pre-construction acoustic monitoring project at the Hoosac site in 2006 using five meteorological towers situated across the project site. Bat activity was divided into high frequency bats (HIGH; *Myotis* bats, red bats, and eastern pipistrelle) and low-frequency bats (LOW; big brown bat, hoary bat, and silver-haired bat). Data from these four towers revealed that bat activity was generally highest in the early evening with seasonal peaks in late July, early August, and mid-September (Arnett et al., 2007). The low microphones (10 m altitude) had more total bat activity and this activity was predominantly from the HIGH bats. The high microphones (39 m altitude) had less total activity but a higher proportion of LOW bats. The data show that bat activity is correlated with wind speed and ambient temperature, with HIGH bat activity more sensitive to temperature than LOW bat activity.

6.2 Locust Ridge Wind Project (Pennsylvania), 2006-2008

The Locust Ridge I wind project is a 13-turbine project that runs 12.7 km along the ridge of Locust Mountain in Schuylkill County. Pre-construction acoustic monitoring was initiated on 06 April, 2006 and operated continuously until 06 December, 2006, for a total of 245 days of sampling. Acoustic monitoring was performed using two vertical acoustic arrays set up on existing meteorological ('met') towers at the site. Three microphones were installed on each met tower and designated as Low (10m), Mid (30m), and High (49m); see Reynolds (2006) for system details. There was no bat activity detected for the first five days of monitoring, and very little activity detected after mid-October, suggesting the entire active period was monitored at the project site (Reynolds, 2007). Data revealed a general increase in bat activity in late July and early August, more bat activity near the ground than in the rotor-swept zone (5.7 calls/night vs 1.2 calls/night), and almost twice as much bat activity on the eastern side of the project relative to the western side. *Myotis* bats represented almost 35% of all calls and were 10-fold more likely to be heard at the Low microphones relative to the High microphones. The migratory tree bats were the dominant bats heard within the rotor sweep zone, with activity peaking in late July for the East Tower and early September for the West Tower.

Post-construction carcass surveys were supervised by Dr. Howard Whitten of East Stroudsburg University, Pennsylvania. These surveys were conducted from 01 May through 17 November at the project site following protocols from the Pennsylvania Game Commission's Wind Energy Voluntary Cooperative Agreement. A total of 202 daily mortality surveys were conducted, resulting in the documentation of 211 bats and 10 bird carcasses. The total estimated mortality at the project site was 391 bats per year. Six bat species were documented, including the red bat (32%), hoary bat (28%), eastern pipistrelle (16%), silver-haired bat (14%), big brown bat (5%), and little brown myotis (5%). Temporal analysis of the carcasses show a large increase in bat mortality beginning the first week in August and remained high into the second week of September. Too few bats were found on the nets to reach any conclusions about their effectiveness as a sampling protocol.

6.3 Mountaineer Wind Project (West Virginia), 2003-2004

The Fall 2003 post-construction mortality survey was a watershed event that raised concern among the wind industry and state and federal agencies. Prior to this survey, turbine-related bat mortality was generally considered low and unlikely to impact local populations. However, the Mountaineer survey found 475 dead bats (estimated to represent a total actual mortality of 2,092 bats) at an estimated mortality rate of 47.5 bats per turbine (Kerlinger and Kerns, 2004). Similar levels of mortality were documented during the Fall 2004 migratory period (38 bats/turbine: Arnett, 2005). Most of the bats that were killed were migratory bats such as the hoary bat (33%) and the red bat (24%). There were also a significant number of migratory hibernators such as the eastern pipistrelle (24%) and little brown myotis (13%). Although the sampling interval was limited, temporal analysis from both years suggests that most of the mortality occurred in August. It is also known from the transect surveys that most bat carcasses were found within 30m of the base, with 42% found within 15m of the base. The mortality was also distributed across the site, with 43 of the 44 turbines causing at least one collision event (Kerlinger and Kerns, 2004).

6.4 Meyersdale Wind Energy (Pennsylvania), 2004

The Meyersdale Wind Energy Center is a 20-turbine wind facility located in Somerset County, Pennsylvania. Meyersdale is located on a ridgetop at approximately 850m asl and began operation in December 2003. In the fall of 2004, Meyersdale was part of an extensive study on the impact of wind projects on bat mortality (Arnett, 2005).

During a six-week period starting in August, 262 bat carcasses were located with a 500 search hour sampling effort. Similar to Mountaineer, the mortality was predominantly hoary bats (46%), red bats (27%), and eastern pipistrelles (7.7%). Total *Myotis spp*. mortality was lower at Meyersdale than at the Mountaineer location. The overall mortality rate was estimated at 13.1bats/turbine/season in 2004 (Arnett, 2005).

6.5 Casselman Wind Energy (Pennsylvania), 2006

The Negro Mountain project site (Casselman Project) is a 23-turbine wind project in Somerset County, Pennsylvania. The project consists of two turbine strings, with 15 turbines on the western string and 8 turbines on the eastern string (Arnett et al., 2006). The project site is within the Appalachian mixed mesophytic forest, with most of the western turbines in dense second-growth hardwood forest habitat and all of the eastern string turbines on open grassland on a reclaimed coal strip mine. A multi-year research project is currently underway at the project site under the coordination of Ed Arnett from Bat Conservation International. Currently, there are 12 monitoring platforms at the Casselman study site (5 met towers and 7 portable towers) that are monitoring bat activity at the project area.

The first set of data was completed in 2006. During the period of August 01 through November 01, a total of 9,162 bat calls were recorded across the project site. This results in an acoustic activity average of 3 calls/night/tower across the project site for high-frequency bats and 2.5 calls/night/tower for the low-frequency bats. Most of the bat activity was recorded from mid-August through mid-September but the pattern was highly variable across each night. Most of the bat activity was heard soon after sunset and declined throughout the evening until sunrise. The preliminary findings of these data are that 1) most of the acoustic activity occurs at the ground level (1.5m) microphones, 2) most of the variation between towers occurs at the ground-level microphone, 3) there was more bat activity in the forest habitat (versus the grassland) at the ground microphone and the canopy (22m) microphone, but not at the rotor height microphone, 4) there was relatively little spatial variation in bat activity at the rotor height microphones (44m) in terms of habitat or tower location. Comparison of bat activity data with weather data suggests that bat activity increased with increasing ambient temperature, but that most of this increase was documented at the ground microphone. Bat activity appeared to decline with increasing wind speed across all habitats and microphone heights, with an 11% - 39% decrease in bat activity for each 1 m/s increase in wind speed.

6.6 Maple Ridge Wind Project (New York), 2004-2008

The Maple Ridge Wind Project is a 198 turbine project that began operation in 2006. The area encompassed approximately 67 km^2 within the Northeastern Highland Ecoregion of western New York (Omernik, 1987). Vegetation within the study area was Northern Hardwood Forest, although much of the current regional land use was devoted to agricultural crops. The Maple Ridge study site has a mean elevation of 545 m above sea level (asl), rising from 300 m asl at the eastern margin up to 600 m asl along the western edge of the plateau. The wind energy project was 32 km southeast of a Priority II hibernaculum for the endangered Indiana myotis and wholly within the geographic distribution of the eastern small-footed myotis, a New York State Species of Special Concern. This combination of cropland, lowland forest, mixed hardwood forest, and slow-moving water made the Tug Hill Plateau, and the adjacent Black River watershed, potential roosting and foraging habitat for most of the bat species found in the Northeast.

Pre-construction research was conducted at this site by North East Ecological Services in 2004, and all data outlined below are from Reynolds (2006). Mist nets and ground-level acoustic monitoring were used across the Project site from 22 June through 05 July, 2004. A total of 35 bats of 3 species were captured during 130 net-nights across 24 sampling sites, yielding a 0.3 bats/net-night capture success. A total of 4,259 bat passes were recorded during 208 detector-hours across 28 sampling sites, yielding a mean activity level of 20.6 calls/hr. The median activity level was only 6.2 calls/hr across the project site, with 96% of the calls from *Myotis* spp. bats. Migratory behavior was acoustically monitored during the spring 2005 migratory season (10 Apr through 22 Jun) at two locations using vertical acoustic arrays set up on a 50m meteorological tower. A total of 459 bat passes were recorded during 5,328 hours of acoustic monitoring, yielding an acoustic capture rate of 0.09 bat passes/hr. Major findings of this study were that 1) most of the variation in migratory activity was temporal, 2) bat activity generally declined with altitude across the three sampling heights, 3) there are high-activity events that could represent migratory flocks of bats moving across the project site, 4) bat migratory activity decreased with increasing wind speed, with most of the activity occurring on days with minimum wind speeds below 1.2 m/s, 5) bat migratory activity increased with higher ambient temperatures, 6) wind direction did not appear to influence migratory activity levels.

Post-construction monitoring has been conducted at the Maple Ridge project site from 2006 through November, 2008. Mortality data from 2005 and 2006 have revealed a mortality rate of 24.5 bats/turbine/year, with most of the mortality during the late summer and fall migratory period (Jain et al., 2007). NEES, in cooperation with the New Jersey Audubon Society, has been conducting long-term bird and bat monitoring at the Maple Ridge project site to help identify the causes of these mortality events, but these data have not yet been analyzed.

6.7 Overview of Data Relevant to the MWCC Wind Project

An overview of six comparison sites outlined above represent a summary of some of the potentially relevant wind development projects that may be informative for the MWCC wind project. The data represent the complete spectrum of activity, from pre-construction field surveys (Hoosac, Locust Ridge, Casselman, and Maple Ridge) through post-construction mortality surveys (Mountaineer, Meyersdale, and Maple Ridge). Although the sites differ in location, elevation, habitat, and size and type of turbines, there are consistencies between them:

1) migratory tree bats (hoary bat, red bat, silver-haired bat) appear to be at the greatest risk of turbine collision;
2) when measured, bat migratory activity appears to decrease at high wind speeds and increase with high ambient temperatures
3) when measured, most of the variation in bat migratory activity appears to be temporal (across the migratory season) and vertical (more bats at lower microphones) rather than spatial (at different locations across the project site).

6.8 Other Data Relevant to the Construction and Operation of the MWCC Wind Project

In addition to the findings summarized in Section 6.7, there are other data available that may be relevant to the construction or operation of the MWCC Wind Project.

6.8.1 Current Hypotheses on the Cause of Wind-Related Bat Mortality

There are currently twelve hypotheses relating to why bats collide with wind turbines (Kunz et al., 2007):

a. Linear Corridor Hypothesis – the linear corridors produced during the construction of wind projects creates linear landscape elements that attract bats during summer foraging and seasonal migration;
b. Roost Attraction Hypothesis – turbines are tall and conspicuous and perceived as potential roosts by bats;
c. Landscape Attraction Hypothesis – modifications to the landscape that occur during construction of the wind project, such as access roads and clearings, create favorable habitat that attracts bats;
d. Insect Attraction Hypothesis – insects are attracted to the white turbines, or heat generated from the turbines, and bats are struck by the rotating blades while foraging on these insects;
e. Motion Attraction Hypothesis – bats are attracted to the movement of the turbine blades visually or through the production of false echolocation targets;
f. Visual Attraction Hypothesis – bats, or the insects they prey upon, are attracted to the physical characteristics of the turbines (color, FAA lighting, etc.) and are struck by the rotating blades when in their proximity;
g. Acoustic Attraction Hypothesis – bats are attracted to sounds produced by the turbines (audible or ultrasonic);
h. Echolocation Failure Hypothesis – migratory bats fail to detect wind turbines while flying in proximity to them;
i. Visual Distortion Hypothesis – lights reflecting off the white turbine blades alter celestial or other visual cues used by bats during migration;
j. Electromagnetic Field Distortion Hypothesis – wind turbines produce complex EM fields near the nacelle that disorient migratory bats;
k. Decompression Hypothesis – bats flying near turbines would pass through the helical vortex wake, causing injury or disorientation;
l. Thermal Inversion Hypothesis – the migratory altitude of bats is influenced by thermal inversions on a large scale, and may also be influenced by small scale inversions created by the turbines;

The first seven hypotheses all presume that bats are attracted to some features of a wind project such that there local abundance would increase after construction of a project. Bach (2001) found that some bat species appear to be more abundant following construction of wind turbines, and attributed this attraction to the increase in linear elements (Hypotheses 1 and 3). However, he also noted that the bats modified their foraging behavior (flying closer to the ground) to reduce their risk of impact (Bach, 2001). Ahlén (2003) has also shown that wind turbines typically generate infrasound rather than ultrasound, and that bats show no attraction to such noise (Hypothesis 7).

Data collected in the northeast and throughout the mid-Atlantic Highlands shows that migratory bats do echolocate. Data collected by Ahlén (2003) in Sweden also show migratory bats echolocating. These data, in conjunction with the relatively low mortality associated with communication towers, buildings, and other fixed structures, suggests that it is unlikely bats are colliding with wind turbines due to their inability to detect the towers.

Collectively, there is little data available to evaluate any of the hypotheses put forward by the BWEC committee, and many of the hypotheses are not mutually-exclusive. However, they do represent some of the most reasonable proximate factors that may be causing the high levels of bat mortality seen at some wind projects. In addition to these hypotheses, Barclay et al. (2007) has suggested that tower height may play a significant role in the increased bat mortality seen at wind projects over the last five years.

6.8.2 The National Research Council Assessment

The National Research Council (NRC) was charged by Congress to address the impact of wind development on bats. The NRC report provides recommendations for both pre-construction analysis and post-construction surveys (NRC, 2007). The siting assessments outlined by the NRC include evaluation of the cumulative impact of wind development across the mid-Atlantic Highlands. However, in the absence of federal coordination of research efforts, the lack of certainty about federal energy policies, and a general lack of baseline research that is beyond the resources of individual developers, the NRC concedes that pre-construction assessments that accurately predict population-level impacts are difficult to achieve (Kunz et al., 2007).

In reference to post-construction monitoring, the NRC recommends multi-year, full-season evaluations of mortality that includes an assessment of the number, composition, and timing of mortality across the project site (NRC, 2007). These data should then be used to look at small-scale and large-scale impacts on bats and inform adaptive management options and experimentation on mitigation techniques (NRC, 2007). The NRC also recommends research that is both methodological (to improve tools and monitoring protocols) and hypothesis-driven in nature, recognizing that the resources (both human and economic) necessary to conduct such research will require collaboration at multiple levels.

6.8.3 The European Union EUROBAT Advisory Committee

The European Union, under the guidance of the EUROBAT Advisory Committee, has recently produced a guidance document for assessing the impact of wind development on bats (Rodrigues et al., 2006). Although collision rates are typically lower in Europe than in the eastern United States, bats are protected throughout the European Union. In Germany, for example, a survey of 13 project sites revealed 245 dead bats from ten species (Rodrigues et al., 2006). In response to similar numbers throughout the European Union, the EUROBAT Advisory Committee has carcass searches be performed at greater than 50% of the turbines on a 2-5 day rotation. These surveys should be done for five years, with the first two years focusing on pre-construction correlation in a BACI analysis and the last three years focusing on long-term trends in bat populations (Rodrigues et al., 2006).

6.8.4 Bats and Wind Energy Cooperative

The Bats and Wind Energy Cooperative (BWEC) was formed in 2004 to address concerns created after the post-construction mortality surveys conducted at the Mountaineer Wind Energy facility in West Virginia (Kerlinger and Kerns, 2004). The BWEC group is composed of academic bat biologists, federal agencies (USFWS), non-profit organizations (Audubon Society, Bat Conservation International), and industry representatives (AWEA, FPL). Members of the BWEC group recently published a paper outlining their recommendations for wind development (Kunz et al., 2007). The recommendations include full-season (April through October) pre- and post-construction surveys that determine species composition and temporal and geographic variation in species distribution for both local and migratory bats. They also recommend establishing standardized protocols for such surveys and methodological research to determine the effectiveness of different research tools (such as ceilometry, radar, thermal imaging, and acoustic monitoring). Lastly, the BWEC researchers recommend research on potential deterrent technologies and the development of predictive models at the local and regional scale.

Although many of these recommendations are well beyond the scope of effort that is likely to be required for the MWCC project, any research conducted for this project should be consistent in nature and scope. This includes correlating bat activity and mortality events with meteorological data collected on site, comparing the impact of feathering wind turbines during peak migratory periods, and creating an adaptive management strategy that remains flexible enough to incorporate new research as it becomes available.

6.8.5 California Bat Working Group

The California Bat Working Group (CBWG) has recently completed a draft survey protocol designed to 1) reduce the impact of wind development on bats in California, 2) provide state and federal biologists with information collected from bat biologists throughout the region, and 3) help wind developers by producing standardized research requirements that can be used to determine the economics of a project early in the siting process. The CBWG protocol calls for daily carcass searches for 33% - 50% of the turbines for large projects, and at least some turbines daily for small projects, from March through October (Hogan, 2006). They also call for acoustic monitoring in a post-construction environment, but do not think ground-based monitoring can adequately assess migratory activity (Hogan, 2006); this is consistent with data collected by NEES at sites throughout the east coast, and Fiedler (2004) in Tennessee. In case of high mortality, the CBWG recommends thermal imaging surveys to document the collision behavior and estimate total mortality (Hogan, 2006).

7.0 FUTURE RESEARCH RECOMMENDATIONS

The projects outlined in Sections 6.1 through 6.6 above each have different objectives and methodologies, making it difficult to draw conclusions that would be directly informative for the MWCC project. However, consistencies between these projects and recent improvements in both our understanding of bat migration and the technology available to monitor migration, suggest that site-specific research is warranted at these project sites. The research below, listed in decreasing priority, would be a key step in would greatly improve our ability to assess the potential impact of the Project site on bats in Massachusetts.

7.1 Post-Construction Impact Analysis

The need to document and understand the impact of wind resource development on bats has become an increasingly important priority, and most of these data have come from post-construction surveys at operating wind resource areas. Unlike the biological assessment and the pre-construction surveys, post-construction analysis quantifies the actual risk and impact of wind development on bats. For this reason, it is imperative that well-designed post-construction monitoring be performed at the MWCC project site. This should include a carcass search protocol that will identify the distribution, species composition, and timing of all bat and bird mortality across the project site. In addition, the protocol should include acoustic monitoring during the migratory season so that a Before-After Control Impact (BACI) study can be performed to determine the impact of the project site on migratory behavior. These protocols should be appropriate for the size and terrain of the project. In addition to these conditions, a truly informative post-construction impact analysis should also include resources for impact mitigation through the development of adaptive management protocols (to account for meteorological influences on migratory behavior) and possibly physical deterrents to reduce bat mortality.

Data collected from several wind development sites have shown that most bat activity (Reynolds, 2006) or bat mortality (Arnett, 2005; Bach and Rahmel, 2006) occurs on warm, low wind nights before after bad weather. Data collected in Germany by Bach and Rahmel (2006) has shown that restricting turbine operations when wind speeds are less than 5 m/s significantly reduces mortality. Although the actual ‘threshold’ wind speeds may differ in the mid-Atlantic Highlands region, this type of information may be extremely helpful in minimizing bat mortality while also minimizing the economic impact of such operational constraints.

7.2 Pre-Construction Migratory Monitoring

Most bat mortality appears to occur during migration. Consequently, an understanding of the baseline migratory activity across the MWCC project site during both the fall and spring migratory period is critical in understanding the potential impact of these projects on bats. Data collected from these efforts will help inform biologists and managers about the scale of geographic, altitudinal, and temporal variation in bat activity across the project areas. This, in turn, should help identify the potential impact of wind turbine development and provide quantitative data for BACI comparison following construction of the project. These studies have been completed for the summer breeding season and the fall migratory season using a protocol that is consistent with the recommendations of the National Research Council (NRC, 2007) guidelines (Appendix Two). Additional monitoring during the spring migratory season (15 March – 14 June) may also be helpful so that a complete year of site-specific bat activity data will be available. . The United States Fish and Wildlife Service recommends multi-year, multi-season pre-construction monitoring (USFWS, 2003), however these recommendations were initially drafted as interim guidelines in the absence of pre-existing monitoring data. NEES is unaware of any discussion of multi-year pre-construction acoustic monitoring at the MWCC project site. NEES has been retained to conduct additional migratory monitoring during the Spring 2009 migratory season.

7.3 Summer Mist-netting Survey

Mist-netting is primarily used to assess habitat usage and species composition of bat communities during the summer months. Mist net surveys general follow the US Fish and Wildlife Service Indiana Bat Mist-Netting Guidelines (USFWS, 2007) in terms of sampling effort, sampled habitats, and equipment. If any species of concern were captured, detailed habitat usage data could be collected by attaching radiotransmitters to each bat and documenting foraging areas and roost locations. Although mist-netting is a valuable research tool that provides critical information about the biology and community ecology of bats, it is relatively uninformative in regards to the potential impact of wind development at a project site for five reasons.

First, the summer months are periods of relatively low bat mortality, with many wind farms documenting less than 10% of all mortality across the summer months (Erickson et al., 2000; Johnson & Strickland, 2003; Johnson et al., 2003b; Kerlinger & Kerns, 2004; Johnson, 2005; Kerlinger, 2006; Fiedler et al., 2007). Second, mist-netting has a known taxonomic bias that favors low-flying bats such as *Myotis spp.*, big brown bats (*Eptesicus fuscus*), and the eastern pipistrelle (*Perimyotis subflavus*); these are not the primary species being impacted by wind development in the United States (Table 3). Third, mist-netting is limited in the types of habitats that can be sampled and by the relatively small sampling area of the net (Kunz & Brock, 1975; O'Farrell & Gannon, 1999); for wind project risk assessment, this limitation is most evident in our inability to sample bats near the rotor sweep zone. Fourth, mist-netting is not an effective long-term monitoring technique at a fixed location (a necessity for monitoring the extensive active season of bats), with capture rates declining rapidly as bats become habituated to the presence of the nets (Kunz & Brock, 1975, Heady & Frick, 1999). Last, there is no evidence that mist-netting samples are predictive of bat mortality at wind project sites. Specifically, bat mortality data has not been consistent with the composition of the local bat population based on mist-netting results (EPRI, 2003; Gruver, 2002; Schmidt et al., 2003; Jain et al., 2007).

8.0 CONCLUSION

The need to document and understand the impact of wind resource development on bats has become an increasingly important priority in the United States. These data show that bat mortality is likely to occur at the project site, particularly among the migratory tree bats; these are the bats that are killed at the highest rates at other wind projects throughout North America. Data collected in the generation of this report suggest that the MWCC project site is unlikely to contain resident populations of the eastern small-footed myotis (State Species of Special Concern) and the Indiana bat (federally Endangered Species). Consequently, the MWCC project site represents a negligible mortality risk for these two species of concern. The pre-construction monitoring done by NEES for the summer and fall migratory season should provide valuable data on the scale and temporal distribution of bat activity across the project site, and the methodologies employed were consistent with the general recommendations of the U.S. Fish and Wildlife Service (USFWS, 2003), the National Research Council (NRC, 2007), and the Bats and Wind Energy Cooperative. Because of the lack of correlation between mist-net sampling data and subsequent bat mortality, NEES does not recommend site-specific mist-netting at the MWCC project site for the purposes of mortality risk assessment.

Following approval of the MWCC project, NEES would recommend the establishment of a Technical Advisory Committee that will interface with interested parties to design post-construction research protocols, collect and analyze mortality data, and make the results available to the public. The post-construction monitoring protocol established by the TAC should utilize adaptive management techniques that are flexible enough to incorporate new research as it becomes available. For example, if the MWCC project encounters unacceptable levels of bat mortality, shutting down the turbines at low wind speed is one potentially useful technique that might reduce bat mortality significantly. As we learn more about predictive factors for bat and avian collisions, we should be able to provide management options that substantially reduce mortality risk while minimally impact project viability.

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APPENDIX ONE, Page 1 of 1: Bats of Massachusetts with Basic Ecological Properties

Common Name	Scientific Name	Summer Roost	Habitat Association	Winter Pattern	Regional Abundance and status [1]
little brown myotis	*Myotis lucifugus*	commensal	generalist	migratory hibernator	common
northern myotis	*Myotis septentrionalis*	commensal, tree roosting	interior forest	migratory hibernator	common
eastern small-footed myotis	*Myotis leibii*	rock roosting	water unknown	migratory hibernator	rare *State-threatened*
Indiana bat	*Myotis sodalis*	tree roosting	riparian habitat	migratory hibernator	historic and incidental *Federally-endangered*
big brown bat	*Eptesicus fuscus*	commensal	fields open areas	hibernator	common
eastern pipistrelle bat	*Perimyotis subflavus*	commensal, tree roosting	water, fields, forest edges	migratory hibernator	common
eastern red bat	*Lasiurus borealis*	foliage roosting	deciduous forest, artificial lights	migratory	common
hoary bat	*Lasiurus cinereus*	foliage roosting	coniferous forest artificial lights	migratory	uncommon
silver-haired bat	*Lasionycteris noctivagans*	tree roosting	forests	migratory	uncommon

1. the terms ‘accidental’, ‘common’, ‘uncommon’, ‘rare’, and ‘unlikely’ are relative capture estimates and do not imply total population size.