Biological Assessment for the Federally Endangered Indiana Bat (*Myotis sodalis*) and Virginia Big-eared Bat (*Corynorhinus townsendii virginianus*)

NedPower Mount Storm Wind Project, Grant County, West Virginia

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INTRODUCTION

Wind has been used to commercially produce energy in the U.S. since the early 1970's (American Wind Energy Association [AWEA] 1995). Recent advances in wind turbine technologies have reduced costs associated with wind power production, improving the economics of wind energy development (Hansen *et al*. 1992). Wind power produced in the United States in 2001 was comparable in price to conventional power produced using natural gas (AWEA 2001). As a result, commercial wind energy plants have been constructed in 26 states (Anderson *et al*. 1999, AWEA 2002a), and total wind power capacity in the United States increased from 10 megawatts (MW) in 1981 to 4261 MW in 2001, which is enough to supply the electricity needs of approximately 3.2 million homes (AWEA 2002b). Over 2000 MW of new wind projects have been proposed for 2003 (AWEA 2002c).

Although development of renewable energy sources is generally considered environmentally friendly, wind power development has occasionally been associated with the deaths of birds that collide with turbines and other wind plant structures, especially at the Altamont Pass wind plant in California (Erickson *et al*. 2001, 2002). Wind plants have also resulted in loss of habitat and displacement of birds (Leddy *et al*. 1999, Johnson *et al*. 2000a). As a result of these concerns, some state and federal agencies have required monitoring of a number of new wind development areas to assess the extent of and potential for avian impacts. An unexpected outcome of the avian monitoring studies has been the discovery of bat collision fatalities at several wind plants. Although the number of bat collision fatalities has generally been small, in some cases the number of bat fatalities at wind plants has exceeded the number of avian fatalities (Johnson 2003). As with birds, wind plant development may also impact bats indirectly through loss of habitat.

NedPower Mount Storm is proposing an approximately 300 megawatt (MW) wind farm in Grant County, West Virginia (Figure 1, inside back cover) [1]. The project area is within an area potentially used by two federally endangered bat species, the Indiana bat (*Myotis sodalis*) and the Virginia big-eared bat (*Corynorhinus townsendii virginianus*). The U.S. Fish and Wildlife Service has expressed concern that the wind plant could impact these bats in two ways, direct mortality through collision with wind turbines and indirectly through loss or degradation of habitat. The purpose of this report is to assess the potential for the project to impact the endangered bats, including the likelihood of an incidental take of the Indiana bat and the Virginia big-eared bat from construction and operation of the project.

STUDY AREA

The proposed Mount Storm wind power project is located in Grant County, West Virginia. Grant County lies within the Allegheny Mountains physiographic region and is along the western edge of the Ridge and Valley physiographic province (Buckelew and Hall 1994). The Allegheny Mountains are characterized by steep to rolling mountains, ridges, and hills. The proposed development is located on a ridgeline of the Allegheny Mountains known as the Allegheny

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[1] Figure 1 depicts the Northern, Central and Southern Sections of the project. Since the West Virginia Public Service Commission withheld permission to build on the Southern Section, for purposes of this Biological Assessment, all references to the "study area" or "site" refer only to the Central Phase and Northern Phase.

Front. The historical vegetation type through the Allegheny Mountains was hardwood and spruce forest (Buckelew and Hall 1994). The hardwood forest type consisted primarily of oaks, maples, and hickory species, black cherry, black and yellow birch, and beech trees (Canterbury 2002). The conifer types consisted of red spruce, hemlock, and a variety of pines, including red, pitch and Virginia, which are often used for reclamation of abandoned surface mines (Canterbury 2002). Current habitats in the proposed development area are primarily deciduous woodlands and reclaimed mined lands in various stages of succession from recently seeded grassland to developing woodlands. The general vicinity within a few miles of the proposed development area also has scattered wetlands, small rural housing developments, lakes and small ponds.

The turbines will be spread out over an area approximately 16 km (10 miles) long with an average width of 0.8 km (0.5 miles), and located 1.6 – 3.2 km (1-2 miles) east of Mount Storm Lake and Stony River Reservoir and approximately 1.6 km (1 mile) east of Bismarck and 4.8 km (3 miles) west of Sherr. West Virginia Highway 42/93 between Bismarck and Sherr generally bisects the site. Elevation of the site ranges from approximately 800 to 1192 m (2,625-3,910 feet). The site is private land, much of which has been used for commercial logging and coal mining.

PROJECT DESCRIPTION

The project will involve construction of up to 200 turbines, generally arranged in rows along approximately 16 km (10 miles) of ridgeline comprising the Central Phase and Northern Phase (Figure 1). The turbine strings will have access roads and buried transmission lines along the roads. Where turbine strings are located in forests, the total area cleared to accommodate the access roads and transmission line will be approximately 11 m (35 feet) in width for the length of the turbine string. All forest clearing activities will be conducted over the winter period (November 15 to March 31).

A substation will be built adjacent to an existing transmission line in the project area. Therefore, no new overhead transmission line will be required for this project. There are several reclaimed strip mines in the project area, and preference will be given to locating turbines and associated facilities within those areas, if possible. The total area of ground disturbance for the entire project is expected to be less than 80 ha (200 acres).

The proposed turbines will likely range from 1.5 to 2.0 megawatts in size. These turbines typically have towers ranging from 65 to 70 m (213-230 feet) and associated rotor diameters ranging from 70.5 to 80 m (231-262 feet). Therefore, the space occupied by turbine blades typically ranges from 30 – 110 m (98-361 feet) above ground.

METHODS

A literature review was conducted to summarize the relevant ecology of the federally endangered Virginia big-eared bat and Indiana bat. The literature review included habitat use, behavior that may be related to risk of turbine collision, and dispersal and migration patterns. Additional information on the ecology of these species was obtained by contacting experts on the biology of these species and local experts including University researchers and consultants. Available data on bat abundance and species composition in the area were summarized. The review also included a summary and analysis of available information on bat interactions with wind turbines.

To limit impacts to the Indiana bat, the USFWS has developed several guidelines. If more than 7 ha (17 acres) of forested lands are to be cleared, the USFWS will require one of two things. The first option is to conduct a mist net survey for the species between May 15 and August 15. The other option is to conduct the tree clearing between November 15 and March 31, when summer colonies are not present. If the development will result in clearing more than 17 acres, which this project will, the USFWS may request that a habitat survey be conducted within a 3.2-km (2-mile) radius prior to timber clearing to determine if the impacted area contains a significant amount of habitat relative to the surrounding landscape. The USFWS requested that NedPower conduct this analysis in a letter to Potesta & Associates dated August 30, 2002. In addition, the USFWS requested that bat habitat (i.e., presence of roosts and foraging habitat) along the turbine strings be determined in an email to WEST dated March 26, 2003. Therefore, a site visit was made to assess habitat suitability for bats at the proposed development areas and within a 3.2-km (2-mile) buffer of the areas. The general location of all proposed turbine strings was walked to examine habitat that will be directly impacted if the wind plant is built. The review included searching for potential Indiana bat roost trees, and describing habitat types along the general area of the proposed turbine strings (e.g., forest types, reclaimed mine lands, wetlands), as well as a description of other physical and biological habitat characteristics of the area. This review was used to assist with assessing the potential for foraging and/or roosting in the development area by Virginia big-eared and Indiana bats. The assessment also included an evaluation of the area as habitat for other bat species based on presence of roost sites (e.g., buildings, caves, bridges), forest types, topography, elevation and other habitat features. Areas within 3.2 km (2 miles) of the proposed turbine strings were surveyed by foot and vehicle to assess available habitat relative to the impact area.

The results of the habitat survey, information obtained on the ecology and habitat of the two endangered species, data on bat use of the area, and current information on bat interactions with wind turbines were synthesized to assess the potential risk of wind power development impacts to the endangered species. Based on this analysis, a determination of effect was made for both Virginia big-eared and Indiana bat.

LITERATURE REVIEW

Indiana and Virginia Big-eared Bat Ecology and Behavior

Indiana Bat

The Indiana bat (*Myotis sodalis*) occurs throughout much of the eastern U.S. (Gardner and Cook 2002), having been documented in 27 states (Harvey 2002). There are no known caves or other hibernacula used by Indiana bats in or near the project area, and potential impacts to this species would be limited to summer maternal colonies. Summer maternal colonies of Indiana bats are believed to be rare in forested habitats of the central Appalachians of Virginia and West Virginia (Brack *et al*. 2002, Owen *et al*. 2001).

In winter, Indiana bats hibernate in caves and abandoned mines throughout areas dominated by karst (an area characterized by limestone and associated sinkholes and caves). In summer, many males remain near hibernacula, but females migrate to other areas where they form maternity colonies in trees (Clawson 2002). Due to significant population declines, the Indiana bat was listed as an endangered species in 1967. The major source of the decline is thought to be human disturbance of hibernating bats in caves and mines (U.S. Fish and Wildlife Service 1999), although changes in summer habitat may also be a factor. Land use practices that change the extent and quality of forests may have both negative or positive effects (Clawson 2002).

General Habitat

The predominant land cover type in areas where Indiana bats reproduce throughout their range is oak-hickory forest, followed by maple-beech-birch, oak-pine and elm-ash-cottonwood (Gardner and Cook 2002). Surprisingly, 75.7% of the land within counties known to have Indiana bat maternal colonies is nonforested. This is likely due to the Indiana bat's preference for establishing maternity colonies in areas dominated by nonforest landscapes, including cropland, grassland, and pastures (Callahan *et al*. 1997, Carter *et al*. 2002, Kurta *et al*. 1993, 2002). Nonforested habitats likely produce many of the insect prey for bats. A GIS analysis of Indiana bat summer habitat showed a high correlation between presence of maternity colonies and large expanses of nonforested landscapes, and the Indiana bat is most abundant on portions of its range where large, open unforested areas are interspersed with wooded areas (Gardner and Cook 2002). Participants involved in preparing a Habitat Suitability Index (HSI) model for Indiana bat in its core range in the midwestern U.S. agreed that the best conditions for foraging are where at least four types of cover occur within a 2-km (1.3-mile) landscape (Farmer *et al*. 2002).

Indiana bats use a variety of habitats in summer. Maternity colonies have been found along the edge of woodlots and agricultural fields, in heavily logged and heavily grazed open woodlots, in pastures, and even in a piglot (see Brack *et al*. 2002). In Kentucky, radiotracking Indiana bats revealed the presence of four core use areas that contained 76% of all the roost trees (primarily dead tree snags). These core areas were typified by the presence of stands of older forest dominated by both oaks and hickories or pine, and areas of disturbance. Disturbances were either natural (e.g., storm damage) or man-made (e.g., logging activities) (Gumbert *et al*. 2002). In Indiana, roost trees were found in thick woods (7), open woods (2), strips of riparian forest (5), a small patch of woods (1) and open land (1) (Whitaker and Brack 2002).

In Illinois, all 78 roost trees used by 36 radiomarked Indiana bats were in either closed-canopy deciduous forest or bottomland forest (Carter *et al*. 2002). Roosting habitat contained more bottomland hardwood forest than random sites. Bottomland forests occur in low-lying areas subject to flooding, which occasionally leads to the death of trees and therefore creation of roost trees. Roost trees were also significantly closer to water than random sites. Another find was that roost trees were in highly fragmented forests. Roosting habitat existed among more patches of agricultural/grassland habitat than random locations.

According to the HSI model developed for Indiana bat in its core range in the Midwest (Farmer *et al*. 2002), areas in which Indiana bats occur most frequently are comprised of only a moderate amount of forest. The model assumes that any landscape with at least 5% forest is suitable habitat, and areas with 20% to 60% forest cover are ideal. The Indiana bat is not typically common in heavily forested regions. West Virginia, for example, has 5 million ha (12.4 million acres) of woodlands that provide potential habitat, yet has a wintering population of only 10,700 Indiana bats. In contrast, Indiana has only 1.7 million ha (4.2 million acres) of forested lands but an estimated population of 112,500 Indiana bats (Brack *et al*. 2002).

Effects of Elevation

In the western and midwestern U.S., the abundance of breeding bats decreases with increasing elevation (Cryan *et al*. 2000, Fenton *et al*. 1980, Thomas 1988). According to Brack *et al*. (2002), areas of higher elevations are cooler and wetter and experience greater seasonal variability, which can reduce the food supply, increase thermoregulatory demands, and reduce reproductive success of bats. Indiana bat maternal colonies are much less common in Pennsylvania, Virginia, and West Virginia than they are in their core range in the Midwest. Summer temperatures in the three eastern states are notably cooler than in the core range (Brack *et al*. 2002).

Brack *et al*. (2002) examined the effect of elevation on breeding female Indiana bat abundance in several states, including West Virginia, which has the highest average elevation (457 m [1500 feet]) of any state east of the Mississippi River. The authors used surrogate species in the analysis due to a lack of data on Indiana bats in that state. The proportion of reproductively active eastern pipistrelles (*Pipistrellus subflavus*), eastern red bats (*Lasiurus borealis*), and little brown bats (*Myotis lucifugus*) decreased with increasing elevation in West Virginia. Data on little brown bats show that the predicted proportion of female bats drops to around 10% of the population near 1,067 m (3500 feet) in West Virginia. Based on results of their analysis, Brack *et al*. (2002) concluded that Indiana bats attempting to reproduce in mid- and northeastern states face rigors associated with a cooler summer climate, which is intensified by increased elevation in many areas. As a result, the probability that Indiana bats reproduce at higher elevations in those three eastern states (Pennsylvania, Virginia, and West Virginia) is low, and efforts to manage for Indiana bat in these areas is of questionable value (Brack *et al*. 2002). Similar results were found during a recent study of bats in Vermont, at the northern end of the Indiana bat's range. Indiana bats were captured in valleys, but never on ridges in the same vicinity (Virgil Brack, Environmental Solutions & Innovations, Cincinnati, Ohio, pers. commun.).

In North Carolina, an Indiana bat maternal colony with 28 bats was found at an elevation of 1158 m (3800 feet). This was the most southern Indiana bat maternal roost discovered at that time (Harvey 2002). Although this elevation is similar to that in the Mount Storm area, the Mount Storm site is located approximately 560 km (350 miles) further north along the Appalachian Mountains, and cooler temperatures are also associated with higher latitudes as well as elevation (Brack *et al*. 2002). Therefore, environmental conditions at 1158 m (3800 feet) in West Virginia are likely much less conducive for breeding by Indiana bats than areas of similar elevation in North Carolina. A small wind plant in Tennessee located on Buffalo Mountain at an elevation of 1006 m (3300 feet) is within the expected range of Indiana bat and is located approximately 48 km (30 miles) from an Indiana bat hibernacula. Extensive mist netting and bat echolocation detector surveys have not documented a single Indiana bat at that site (Charles Nicholson, Tennessee Valley Authority, pers. commun.).

Female Indiana bats in late pregnancy and small young are poor thermoregulators (Studier and O'Farrell 1972). In Indiana, during an unusually cold early summer, recruitment of flying young Indiana bats was delayed by two weeks and the last migrants departed three weeks later than during a normal summer; the delay exposed several bats to freezing weather at the nursery site (Humphrey *et al*. 1977). In Iowa, heating degree days in June and June maximum and minimum temperatures best predicted the presence of Indiana bats. Minor north-south climactic conditions occur in Iowa, and the authors believed that even this minor clinal variation could affect nursery microclimate or embryonic and neonate growth rates. As a result, Indiana bats are limited to the southern portions of Iowa even though suitable habitat is present further north (Clark *et al*. 1987).

Roost Trees

Indiana bats use a variety of trees for roosting. Typical trees containing maternal colonies in most of their range are those greater than 38 cm (15 inches) diameter at breast height (DBH) that contain exfoliating bark (see Brack *et al*. 2002). Roost trees tend to be larger than other trees in the surrounding stand (Kurta *et al*. 1996). In Indiana, trees used by male Indiana bats included elms, pines, oaks, and shagbark hickory with a mean DBH of 38 cm (15 inches). Of 12 trees used as roosts by males, nine were dead and exfoliating bark covered 10-70% of each dead trunk (Whitaker and Brack 2002). Seventeen maternity roosts examined in Indiana were found in six species of trees, including cottonwoods, American elms, red elms, and shagbark and butternut hickory. Most of the trees were large with an average diameter of 62 cm (24 inches), had sloughing bark, and were located in open areas so that the tree received considerable solar radiation (Whitaker and Brack 2002). The authors concluded that species of tree and whether the tree is located in an extensive forest, small woodlot, or even an open site is of little importance, as long as the tree receives solar radiation during much of the day.

In southern Michigan, 38 roost trees were comprised of maples, elms, ashes, cottonwoods, and shagbark hickory. All but one of the 38 roosts were in wetlands. All roost trees were either dead or mostly dead, except for a shagbark hickory and one green ash. Diameter of roost trees averaged 42 cm (16.5 inches) and tree height averaged 10 m (33 feet) (Kurta *et al*. 2002). Potential roost trees were ranked based on the amount of exfoliating bark present as follows: high probability of use (>25%), medium (10-25%), and low (<10%). Sixty-eight percent of the used roosts were rated medium to high, and 89% were medium or high in the amount of sunlight received. Canopy cover averaged 31%. Bats roosted underneath bark at 32 trees, but used crevices at the other six. A use versus availability analysis indicated that bats were using the roost trees in relation to their abundance, but were actively selecting wetlands for roosting. In Kentucky, Gumbert *et al*. (2002) documented Indiana bats roosting in 280 trees of 17 species. Pines, oaks, and hickories were most commonly used. Eighty-four percent of the roost trees were dead. Average DBH of roost trees was 30.3 cm (11.9 inches) with a range of 6.4 – 76.3 cm (2.5 – 30 inches). The USFWS considers suitable Indiana bat roost trees as any tree greater than 13 cm (5 inches) DBH with exfoliating bark or with holes, cracks or crevices (see Angus *et al*. 2001a). In addition to trees, Indiana bats have also been found roosting under metal brackets on utility poles (Harvey 2002) and in a building (Butchkoski and Hassinger 2002).

Miller *et al*. (2002) classified roost trees as either primary (used by more than 30 bats) or alternate (used by fewer than 30 bats) in Missouri. All primary roosts were in snags located in the open, whereas alternate roosts were in living and dead trees in the interior of forests as well as in snags within open areas. Snags are preferred roost sites across the species range because dead trees have exfoliating bark for bats to roost under and also warm more rapidly than live trees (Humphrey *et al*. 1977, Miller *et al*. 2002). Although most roost trees consist of snags, substantial use of live shagbark hickory occurs, as this species has extensive amounts of exfoliating bark on living trees (Humphrey *et al*. 1977, Gardner *et al*. 1991, Callahan *et al*. 1997).

Roost trees located in the open also are exposed to higher amounts of solar radiation, and warmer temperatures result in increased growth rates of embryonic and juvenile bats, which decrease the time of fetal development (Callahan *et al*. 1997, Miller *et al*. 2002). Indiana bats in a colony in Michigan were found to never use roosts in the interiors of forests (Kurta *et al*. 1996). According to the HSI model developed for Indiana bat in its core range, most roosts occur in open spots with an open canopy above and immediately around the tree or in lone trees found in unforested areas. Suitable maternity roost trees must be have a DBH of at least 22 cm (8.7 inches) and be at least 3 m (10 feet) tall if the trunk is broken. Preferred roosts have no overarching canopy or understory canopy within 2 m (6 feet) of the trunk. Exfoliating bark should cover at least 25% of the tree surface, and the tree trunk should be free of obstructing vines. An arbitrary density of at least 12 roost trees/ha (5/acre) is considered required for optimum conditions in the model (Farmer *et al*. 2002), however, Gardner *et al*. (1991) listed the optimal number of roost trees as 64/ha (26/acre) in upland habitats and 41/ha (17/acre) in floodplain forests. Results of the HSI model indicated that density of roost trees was the only variable examined that influenced presence or absence of Indiana bat. Based on this, the authors recommended that roost tree density be used to assess potential habitat. On national forests, management recommendations to maintain roost trees include retention of all dead, dying, hollow and cull trees during timber harvest (Krusac and Mighton 2002).

Indiana bats do not use the same roost continually, but typically switch roosts every 2-4 days (Kurta *et al*. 2002). In Kentucky, Gumbert *et al*. (2002) recorded 463 roost switches over 921 tracking days of radio-tagged Indiana bats, for an average of one switch every 2.21 days. Consecutive use of roost trees by individual bats ranged from 2 to 12 days. Roost switching likely evolved in Indiana bats because suitable roost trees are ephemeral and can become unusable quickly if they are toppled by wind or otherwise destroyed (Kurta *et al*. 2002). Indiana bat maternity colonies require several roosts to meet their needs; in Missouri each maternal colony used from 10 to 20 separate roost trees (Miller *et al*. 2002).

Behavior

The Indiana bat is considered a migratory bat (LaVal and LaVal 1980) and banded individuals have been found as far as 520 km (325 miles) from hibernacula (Gardner and Cook 2002). Typical migration is from the south to the north in the Midwest. Less is known about movements in the eastern and southeastern U.S.; however, the available data indicate that Indiana bats in those states do not migrate large distances between summer and winter habitats (Gardner and Cook 2002). During the maternity period, radiotelemetry studies indicate that home ranges of Indiana bats are less than 2 km (1.3 miles) in width (see Farmer *et al*. 2002).

Indiana bats forage primarily in upland, bottomland, and riparian forests (Humphrey *et al*. 1977, LaVal *et al*. 1977). Streams and their associated floodplain forests and impounded bodies of water are preferred foraging areas for pregnant and lactating Indiana bats (USFWS 1999). Indiana bats do not routinely forage in open areas, but prefer to forage among trees and over streams (LaVal *et al*. 1977, Brack 1983, Carter *et al*. 2002). However, Brack (1983) reported that Indiana bats preferred to forage along habitat edges, including the edge of pastures and old fields, as well as in small clearings in forests. In Missouri, Indiana bats foraged under the forest canopy in dense wooded areas along ridges and hilltops (LaVal *et al*. 1977). Foraging areas average approximately 4.5 ha (11 acres) per adult (Humphrey *et al*. 1977). Their primary food items are moths, true flies, beetles, and caddisflies (Brack and LaVal 1985, Kurta and Whitaker 1998).

Virginia Big-eared Bat

The Virginia big-eared bat is a subspecies of the Townsend's big-eared bat (*Corynorhinus townsendii*). It was listed as endangered by the U.S. Fish and Wildlife Service in 1979. As is the case for Indiana bat, the cause of its decline is attributed primarily to disturbance in their cave roosts. This bat occurs in Kentucky, North Carolina, Virginia and West Virginia (Barbour and Davis 1969). The estimated population is approximately 20,000, most of which occur in West Virginia (see www.dnr.state.wv.us/wvwildlife/va%20bat.htm).

In comparison to the Indiana bat, there is little documented information on Virginia big-eared bat ecology and use of summer habitat (Adam *et al*. 1994). Unlike the Indiana bat, this species inhabits caves year round. They prefer caves in Karst regions dominated by oak-hickory forest. Female Virginia big-eared bats form maternity colonies in caves in the summer. The location of males in the summer is largely unknown, but several "bachelor" colonies have been found in caves. Most males are solitary during the maternity period, but a few males may occupy caves used as maternity colonies (Barbour and Davis 1969, Humphrey and Kunz 1976).

They are considered non-migratory and seldom move far from their home cave; however they will move between roosts (Kunz and Martin 1982). Radio telemetry studies in West Virginia have shown that these bats will travel up to 10.5 km (6.5 miles) from cave roosts to forage (Stihler 1995). The longest movement known for Virginia big-eared bats in Kentucky and West Virginia averaged 64 km (40 miles) (Barbour and Davis 1969). Virginia big-eared bats do not always return to the cave for day-time roosting, but may occupy night roosts which are often manmade structures near the foraging areas. The have been found night-roosting in old buildings, in trees, and under bridges (Stihler 1995). They will also use rock shelters at the base of cliffs as night roosts (Lacki *et al*. 1993).

In Virginia, Virginia big-eared bats foraged over open pastures, corn and alfalfa fields, and around crowns of trees (Dalton *et al*. 1986). They often return to the same foraging area night after night. In Kentucky, they foraged along cliffs and in forested habitats within hollows enclosed by cliffs (Adams *et al*. 1994). In another Kentucky study, activity of Virginia big-eared bats was greatest in old fields, although cliffs were also used extensively (Buford and Lacki 1995). The authors thought old fields were used because the bats could capture prey more easily in the uncluttered foraging space. Activity by this species was low in timber, including both young and old stands. Open narrow flight paths, such as logging roads, are seldom used by this species (Adams *et al.* 1994).

Radio telemetry studies conducted in Pendleton County, West Virginia also showed that Virginia big-eared bats often use the same areas for foraging on consecutive nights (Stihler 1994, 1995). Foraging habitats were varied and included open areas such as unmowed hayfields, old fields, and croplands, wooded areas, and scattered trees, especially those along small streams. Recent clearcuts and grazed pastures were not used for foraging in the 1994 study, but grazed pastures with a considerable amount of thistles and other plants not eaten by cattle were used in the 1995 study. Night roosts included woodlands, old barns, old sheds, the porch and upper story of abandoned houses and a highway bridge. The primary food of Virginia big-eared bats is small moths (Sample and Whitmore 1993), but they will also consume other insects, including beetles, true flies, lacewings, and wasps/bees (Whitaker *et al*. 1977, Dalton *et al*. 1986).

Bat Use of the Project Area

Indiana Bat

Although significant numbers of Indiana bats hibernate in West Virginia, it was not documented as a summer resident of West Virginia until 1995, when a few males were captured in Tucker County. Known caves used as hibernacula are located in Greenbrier, Hardy, Monroe, Pendleton, Pocahontas, Preston, Randolph, and Tucker Counties. Surveys conducted in 1999 estimated the hibernating Indiana bat population in West Virginia at 11,000 individuals, or approximately 3% of the entire known population of this species (see Angus *et al*. 2001). The West Virginia DNR has identified 34 hibernacula in West Virginia. The only critical habitat for Indiana bat in West Virginia is Hellhole Cave in Pendleton County, which contains 8500 hibernating Indiana bats, or 80% of the state's population. Summer records exist for Randolph, Clay, Nicholas, Tucker and Pendleton Counties (Angus *et al*. 2001a). There are no records of Indiana bat in Grant County (Angus *et al*. 2001a).

Indiana bats apparently occur in extremely low densities in West Virginia and adjacent states during summer. Extensive netting surveys totaling approximately 3,000 net-nights since 1995 in West Virginia, Virginia, and Pennsylvania have produced no reproductively active female Indiana bats, one male of unknown age, seven adult males, and one juvenile (Brack *et al*. 2002). In West Virginia, mist net surveys for Indiana bats have been conducted for numerous projects across the state since 1998. Although 2,438 bats were captured during those surveys, only three were Indiana bats, all of which were males (Angus *et al*. 2001a).

Data on bat abundance and species composition in the vicinity of the project area were collected during mist net surveys for Indiana bats as part of the Appalachian Corridor H study. Two sections of the Corridor H project are in the vicinity of the wind power project, including the Davis to Bismarck Project, which runs from 1.1 km (0.7 miles) east of WV Route 32 along WV Route 93 to 0.6 km (0.4 miles) south of the intersection of WV Route 42 and WV Route 42/93, and the Bismarck to Forman Project, which runs from the end of the previous project to County Road 5 near Thorn Run (Angus *et al*. 2001a, 2001b).

Nine sites were surveyed with mist nets along the Bismarck to Forman Project, and eight sites were sampled with mist nets along the Davis to Bismarck section (Figure 2). Eleven of the sites were within 8 km (5 miles) of the Mount Storm project. Thirty-three bats of 7 species were captured along the Bismarck to Forman section, and two bats of two species were captured along the Davis to Bismarck section (Table 1). No Indiana bats were captured at any of the 17 sites. According to Angus *et al*. (2001b), far fewer bats were captured along the Davis to Bismarck section compared to nearby areas due to a combination of low temperatures at the higher

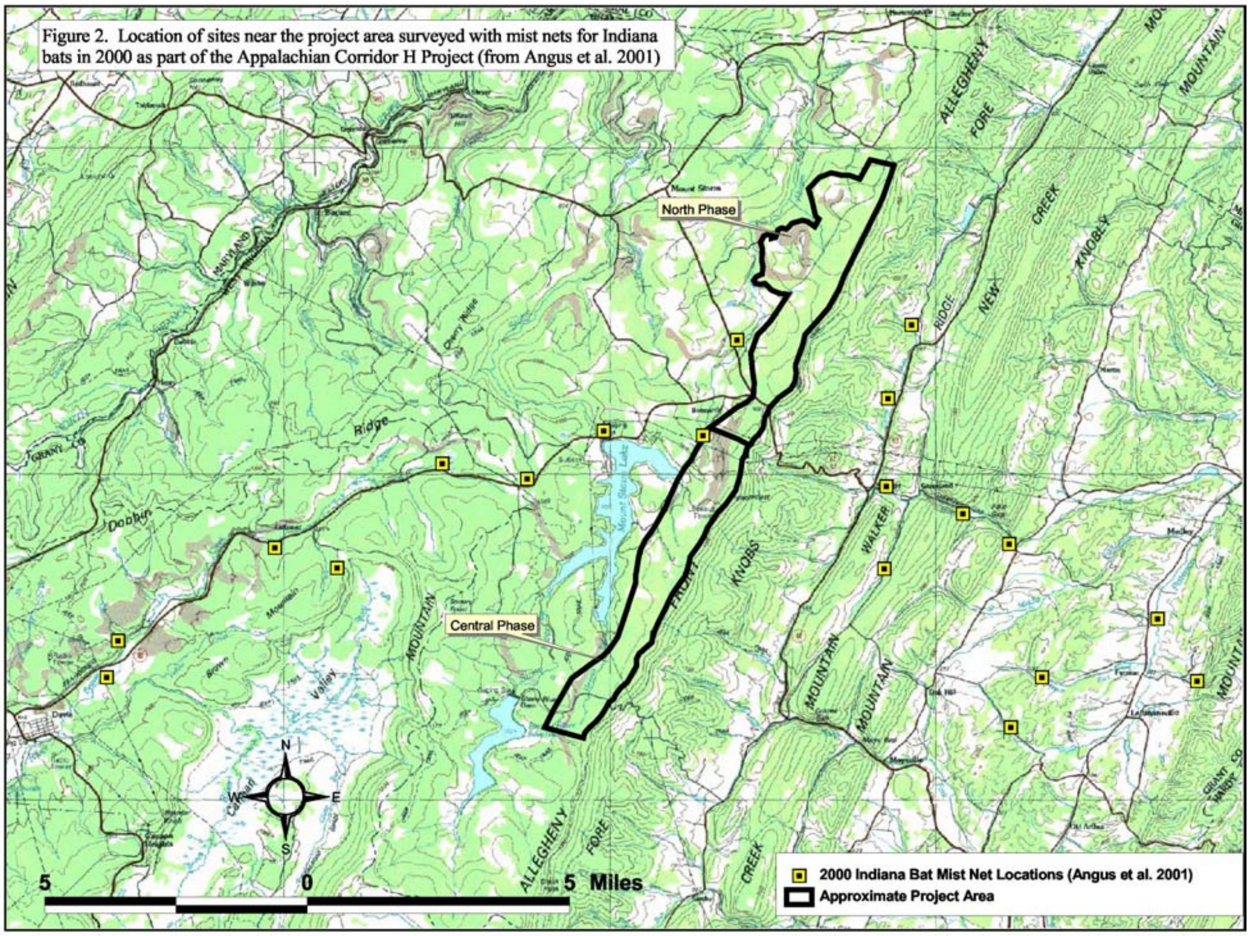


Figure 2. Location of sites near the project area surveyed with mist nets for Indiana bats in 2000 as part of the Appalachian Corridor H Project (from Angus et al. 2001)

Table 1. Species and numbers of bats documented during mist net surveys for those portions of the Appalachian Corridor H project near the Mount Storm wind project (from Angus *et al*. 2001a, 2001b).

Species	Number Captured		
	Bismarck to Forman	Davis to Bismarck	Total
Little Brown Bat (*Myotis lucifugus*)	19	0	19
Northern Myotis (*Myotis septentrionalis*)	8	1	9
Eastern Pipistrelle (*Pipistrellus subflavus*)	1	0	1
Hoary Bat (*Lasiurus cinereus*)	1	0	1
Eastern Red Bat (*Lasiurus borealis*)	2	1	3
Big Brown Bat (*Eptisecus fuscus*)	1	0	1
Virginia Big-eared Bat (*Corynorhinus townsendii*)	1 observed, not captured	0	1 observed, not captured
TOTAL	33	2	35

elevations ($\geq$ 914 m [3000 feet]), lack of insect activity, and windy or foggy conditions along the Davis to Bismarck section.

Virginia Big-eared Bat

The largest population of Virginia big-eared bat in West Virginia is in Pendleton County (Sample and Whitmore 1993), which harbors over 6350 bats. Hellhole Cave in Pendleton County is also considered critical habitat for this bat (Stihler and Brack 1992). Other known cave sites used by this bat include Cave Mountain Cave, Hoffman School Cave and Sinnit Cave, all of which are in Pendleton County, and Cave Hollow Cave in Tucker County (Bagley 1984). Populations in West Virginia are increasing; in some caves the populations have increased as much as 350% from 1983 to 1995 (WV DNR website).

There is a known cave used by Virginia big-eared bats approximately 5.6 km (3.5 miles) southeast of the southern end of the project site at an elevation of approximately 500 m (1640 feet) (Figure 3). A 1999 fall survey documented the presence of two male and five female Virginia big-eared bats in the cave (Jeffrey Towner, USFWS, letter to Potesta & Associates dated 8-3-02). Virginia big-eared bats are known to forage and summer roost up to 8 to 10 km (5-6 miles) from the cave where the colony resides, and the USFWS considers areas within 8 to 10 km (5-6 miles) of each colony site to contain habitat essential to the colony. The approximately southern third of the Mount Storm project area, covering an area approximately 7.7 km^2 (3 mi^2) in size, is within a 10-km (6-mile) buffer of the colony.

In addition to that colony, while conducting mist net surveys for Indiana bat as part of the Bismarck to Forman Corridor H study, one Virginia big-eared bat was observed on July 20, 2000 in the Greenland Gap Falls Cave. This cave is located approximately 6.1 km (3.8 miles) east of the Mount Storm Project at an elevation of approximately 427 m (1400 feet) (Angus *et al.*

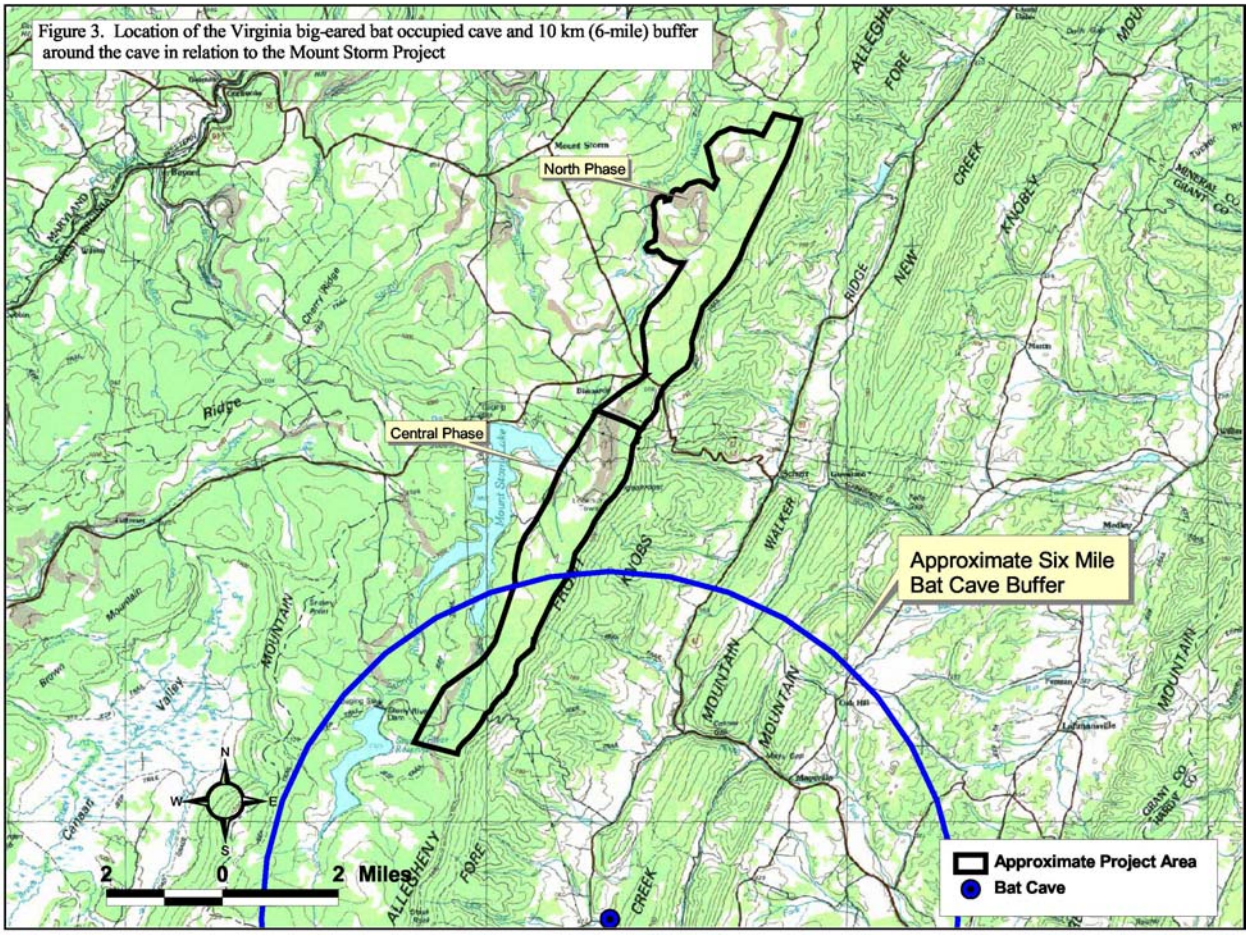


Figure 3. Location of the Virginia big-eared bat occupied cave and 10 km (6-mile) buffer around the cave in relation to the Mount Storm Project

2001b). This bat was likely a lone male, and it was not observed in subsequent nights at the cave. Therefore it was concluded that no colonies occupied the cave (P. Clem, pers. commun.).

Bat Collision Mortality at Wind Plants

Bat collision mortality is not unique to wind plants. Previous studies have documented bats colliding with other man-made structures. The first was that by Saunders (1930), who reported five bats comprised of three species, including eastern red bat, hoary bat (*Lasiurus cinereus*), and silver-haired bat (*Lasionycteris noctivagans*), were killed at a lighthouse in Ontario, Canada. Five eastern red bats were killed by colliding with a television tower in Kansas (Van Gelder 1956). During 25 years of monitoring a television tower in Florida, 54 bat collision victims representing seven species were documented (Crawford and Baker 1981). Twelve dead hoary bats were collected underneath another TV tower in Florida over an 18-year period (Zinn and Baker 1979). Similarly, small numbers (≤ 5) of eastern red bat collision victims have also been reported at communication towers in Missouri (Anonymous 1961), North Dakota (Avery and Clement 1972), Tennessee (Ganier 1962), and Saskatchewan, Canada (Gollop 1965). One yellow bat (*Lasiurus intermedius*) collision victim was found at a Florida TV tower (Taylor and Anderson 1973). Over an 8-year period, 50 eastern red, 27 silver-haired, 1 hoary, and 1 little brown bat collision victims were found underneath large windows at a convention center in Chicago, Illinois (Timm 1989). Four eastern red bats were killed by colliding with the Empire State Building in New York City (Terres 1956) and other studies have documented eastern red bat fatalities at tall buildings (Mumford and Whitaker 1982). No Indiana bat or Townsend's big-eared bat collision victims have been documented at buildings or communication towers, even though several of those studied are within the range of these species. Bats have also collided with powerlines (Dedon *et al*. 1989), barbed wire fences (Johnson 1933, Iwen 1958, Hubbard 1963, Hitchcock 1965, DeBlase and Cope 1967, Denys 1972, Wisely 1978, Fenton 2001) and vehicles (Kiefer *et al*. 1995).

Wind plant-related bat mortality was first documented in Australia, where 22 white-striped mastiff-bats (*Tadarida australis*) were found at the base of turbines over a 4-year period (Hall and Richards 1972). Bat collision mortality at wind plants has also been documented in Scandinavia and Europe. In Sweden, 17 dead bats of six species were collected at 160 turbines (Ahlen 2002), and 11 species of bats have been documented as turbine fatalities in Germany (Bach 2001).

In the United States, significant numbers of bat fatalities have been found at some wind plants, including 420 at Buffalo Ridge, Minnesota (Johnson *et al*. 2003a, 2003b), 242 at Backbone Mountain, West Virginia (Paul Kerlinger, unpublished data), 135 in Wyoming (Johnson *et al.* 2000b, Young *et al.* 2002, Gruver 2002, Young *et al*. 2003), 72 in Wisconsin (Howe *et al*. 2002), 54 at a wind plant on the Washington/Oregon border (Erickson *et al*. 2003a), and 39 at a wind plant in Colorado (Kerlinger *et al*. 2000, Ron Ryder, Colorado State University, pers. commun.) (Table 2).

Table 2. Bat mortality estimates at U.S. wind plants.

Location	Turbine size	Year	Number of bat fatalities found	Bat mortalities per turbine per year	Reference
Buffalo Ridge, MN Phase 1 73 turbines	330 kw 53 m high	1994-1998	20	0.1[a]	Osborn *et al*. 1996 Johnson *et al*. 2000a, Johnson *et al*. 2003a
Buffalo Ridge, MN Phase 2&3 281 turbines	750 kw 74 m high	1998-2002	400	2.0[a]	Johnson *et al*. 2003a & b, Krenz and McMillan 2000
Northeastern Wisconsin 31 turbines	660 kw 89 m high	1999-2001	72	4.3[a]	Howe *et al*. 2002
Foote Creek Rim, WY 105 turbines	660 kw 61 m high	1999-2002	135	1.3[a]	Johnson *et al*. 2000b, Young *et al*. 2002, 2003, Gruver 2002
Buffalo Mountain, TN 3 turbines	660 kw 89 m high	2001	72	28.5[a]	Nicholson 2001, 2003
OR/WA border 399 turbines	660 kw 74 m high	1999-2002	54	0.9[a]	Erickson *et al*. 2003a
Klondike, OR 16 turbines	1.5 MW 100 m high	2002	6	1.2[a]	Johnson *et al*. 2003c
Vansycle, OR 38 turbines	660 kw 74 m high	1999	28	0.7[a]	Erickson *et al*. 2000
Nine Canyon, WA 37 turbines	1.3 MW 91 m high	2003	27	3.2[a]	Erickson *et al*. 2003b
Backbone Mountain, WV 44 turbines	1.5 MW 102 m	2003	476	10.8[b]	P. Kerlinger, unpublished data

[a] estimate adjusted for searcher efficiency and scavenger removal bias, [b] estimate not adjusted for searcher efficiency and scavenger removal bias

Smaller numbers of dead bats have been found at wind plants in Oregon (Erickson *et al*. 2000, Johnson *et al*. 2003c), Washington (Erickson *et al*. 2003b), Iowa (Alan Hancock, Iowa Department of Natural Resources, pers. commun.), California (Howell and Didonato 1991, Orloff and Flannery 1992, Howell 1997, Anderson *et al*. 2000, Thelander and Rugge 2000, Anderson *et al*. 2003a, 2003b), and Pennsylvania (Curry and Kerlinger, unpublished data). The highest mortality reported yet on a per turbine basis was at a 3-turbine wind plant on Buffalo Mountain in Tennessee, where 72 bats were found over a 2-year period at 660 kw turbines (Tennessee Valley Authority 2002, Nicholson 2001, 2003). No bat fatalities classified as threatened or endangered species have been documented at wind plants.

Of 45 species of bats in North America (Wilson and Ruff 1999), only nine species comprise all known wind plant fatalities, despite the fact that wind plants have been constructed in several regions in a variety of habitats. Most (87.5%) of the identified bat fatalities documented at wind plants have been migratory tree bats (Table 3). Of 1044 bat wind plant collision victims identified to species, hoary bats comprised 53.9%, eastern red bats comprised 24.5%, and silver-haired bats comprised 9.1%. The remaining identified fatalities were comprised primarily of eastern pipistrelle (5.4%), little brown bat (4.7%), and big brown bat (*Eptisecus fuscus*) (2.1%). In addition, single specimens of Mexican free-tailed bat (*Tadarida brasiliensis*), long-eared

Table 3. Composition of bat collision fatalities at U.S. wind plants (updated from Johnson 2003).

Location	N	Hoary	Eastern Red	Silver-haired	Big Brown	Little Brown	Eastern Pipistrelle	Mexican Free-tailed Bat	Long-eared Bat	Northern myotis	Unid.
Buffalo Ridge, MN	420	273	73	20	15	8	7	0	0	0	24
Buffalo Mountain, TN	72	10	48	1	2	0	11	0	0	0	0
Northeast Wisconsin	72	25	27	13	1	0	0	0	0	0	6
Nine Canyon, WA	27	12	0	15	0	0	0	0	0	0	0
Vansycle, OR	10	5	0	3	0	1	0	0	0	0	1
Klondike, OR	6	3	0	1	0	0	0	0	0	0	2
Ponnequin, CO	39	36	0	2	0	0	0	0	0	0	1
Foote Creek Rim, WY	135	119	0	5	2	6	0	0	0	0	3
OR/WA border	54	25	0	25	2	1	0	0	0	0	1
Backbone Mountain, WV	242	52	107	10	0	32	38	0	0	1	2
Green Mountain, PA	1	0	0	0	0	1	0	0	0	0	0
California	9	3	1	0	0	0	0	1	1	0	3
Total (Percent)	1087	563 51.8%	256 23.6%	95 8.7%	22 2.0%	49 4.5%	56 5.2%	1 0.1%	1 0.1%	1 0.1%	43 4.0%

myotis (*Myotis evotis*) and northern myotis (*Myotis septentrionalis*) have been found at U.S. wind plants. No Indiana bat collision mortalities have been found at wind plants, even though post-construction mortality surveys have been conducted at several wind plants within the range of the species, including two wind plants in New York and one each in West Virginia, Massachusetts, Pennsylvania, Vermont and Tennessee. The West Virginia, Massachusetts, Tennessee and Vermont wind plants are in forested areas while the New York and Pennsylvania wind plants are in farmland (see http://www.currykerlinger.com/studies.htm, Nicholson 2003). Similarly, no Townsend's big-eared bats are known to have been killed at wind plants, but there are no wind plants sited in close proximity to known roost sites of this species. The wind plant being monitored in West Virginia is north of the Mount Storm site (the Backbone Mountain site). Although 242 bat fatalities have been found at this site to date, no Indiana bat or Virginia big-eared bat fatalities have been documented (Shane Jones, U.S. Fish & Wildlife Service, pers. commun.). As with other wind projects, most (70%) of the mortality at Backbone Mountain has involved migratory tree bats.

Most bat mortality documented at U.S. wind plants occurred in late summer and early fall. Data were available for 1021 bat collision fatalities in the U.S. where the approximate date of the collision was reported (Table 4). Nearly 90% of the fatalities occurred from mid-July through mid-September, with over 50% occurring in August.

The hoary bat is a migratory species with the widest distribution of any bat in North America, ranging from just below the Canadian tree line to South America (Shump and Shump 1982a). They are solitary bats that roost primarily in deciduous trees (Constantine 1966, Barbour and Davis 1969, Nordquist 1997) and occasionally in coniferous trees (Gruver 2002). Eastern red bats are similar to the hoary bat in that they also migrate and are solitary tree roosting bats (Carter 1950, Shump and Shump 1982b, Hutchinson and Lacki 2000). Silver-haired bats are also migratory (Izor 1979, Kunz 1982, Barclay *et al.* 1988). Historically, silver-haired bats were also believed to be strictly solitary tree bats, but recent studies have documented maternal colonies (Betts 1996). The other species most commonly found at wind plants (little brown bat, big brown bat, eastern pipistrelle) are colonial species that roost in buildings, hollow trees, wood piles, and other structures (Fenton and Barclay 1980, Kurta and Baker 1990).

It is unlikely that resident breeding bats comprise the bulk of the collision mortality. If residents were involved, then the collisions should have occurred while bats were commuting from roosting to foraging areas or were foraging within the wind plant. In most cases, there is no pattern in the distribution of fatalities among turbines (Johnson *et al.* 2003a & b, Young *et al.* 2003). If most of the collision victims were local bats commuting from roosting to foraging areas, defined flight corridors between these areas would be expected, and a widespread random distribution of fatalities would seem unlikely. It also seems unlikely that bats would spend significant time foraging at turbine rotor-swept heights within habitats where most wind plants occur. Most turbines in the U.S. are situated within crop fields, pastures, grasslands, short-grass prairie, and shrublands. Although hoary bats have been known to occasionally forage in agricultural areas when insect abundance at preferred feeding areas was low (Hickey and Fenton 1996), most bats prefer to forage near trees or water (*e.g.*, Carter *et al*. 1999, Everette *et al*. 2001). Both hoary and eastern red bats prefer to forage over sites with woody plant cover and are positively associated with edge situations (Furlonger *et al*. 1987), neither of which are present in most areas where wind plants are located; therefore, they would not be expected to

Table 4. Timing of bat collision mortality at U.S. wind plants (updated from Johnson 2003).

Date	Buffalo Ridge, MN	Vansycle OR	Klondike OR	Nine Canyon, WA	Buffalo Mtn, TN	OR/WA border	Foote Creek Rim, WY	Northeast WI	Backbone Mountain, WV	Total (%)
April	0	0	0	0	0	0	0	0	16	16 (1.6%)
May 1-15	0	0	0	1	2	0	0	3	0	6 (0.6%)
May 16-31	1	0	1	2	0	0	1	0	0	5 (0.5%)
June 1-15	0	0	0	2	3	0	1	0	0	6 (0.6%)
June 16-30	4	0	2	1	0	0	2	0	0	8 (0.8%)
July 1-15	16	0	0	1	8	0	3	0	0	28 (2.7%)
July 16-31	101	0	0	0	6	1	26	4	0	138 (13.5%)
Aug 1-15	144	0	0	1	15	1	23	1	0	185 (18.1%)
Aug 16-31	92	4	0	2	17	15	35	54	146	365 (35.7%)
Sep 1-15	55	4	1	5	14	7	25	5	80	196 (19.2%)
Sep 16-30	4	2	2	8	3	15	0	5	?[a]	39 (3.8%)
Oct 1-15	1	0	0	2	2	11	3	0	?	19 (1.9%)
Oct 16-31	2	0	0	2	0	3	0	0	?	7 (0.7%)
Nov 1-15	0	0	0	0	2	1	0	0	?	3 (0.3%)

[a] mortality monitoring is currently ongoing and data are not yet available for these periods

frequently forage in habitats where the turbines are placed. At Buffalo Ridge, Minnesota, bat activity recorded at turbines (*i.e.*, 2.0 passes per night), was very low compared to more suitable habitats such as woodlands and wetlands within 3.6 km (2.25 miles) of the wind project, where bat activity was 24 times higher (*i.e.*, 48.0 passes per night) (Johnson *et al.* 2003b).

Resident bats sometimes do fly at heights making them susceptible to turbine collision. Clark and Stromberg (1987) reported that hoary bats observed feeding over hayfields in Wyoming occasionally circled to high altitudes while feeding, and the eastern red bat is known for erratic flight behavior upon first flight in the evening, when it will often fly at altitudes of 100 to 200 m (328-656 feet) (LaVal and LaVal 1979). In Missouri, both hoary and eastern red bats were observed "foraging high above trees and pastures" (LaVal *et al.* 1977), and in Florida, hoary bats were observed foraging from 5 to 30 m (16-98 feet) above rivers and swamps (Zinn and Baker 1979). In general, however, bats forage at heights well below the space occupied by turbine blades. Hoary and eastern red bats typically forage from treetop level to within a meter of the ground, silver-haired bats spend most of their time foraging at heights less than 6 m (20 feet), and big brown bats forage from 7 - 10 m (23-33 feet) above ground (Barclay 1984, Fitzgerald *et al*. 1994). Little brown bats forage almost exclusively less than 5 m (16 feet) above the ground; much of their foraging is done from 1 - 2 m (3.3 – 6.6 feet) above ground (Fenton and Bell 1979). It seems unlikely that foraging bats would routinely forage above 25 m (82 feet), the lowest height of the blade on most new generation turbines.

Adults of some species of bats have been shown to change foraging patterns and locations once juveniles are capable of flying, presumably due to the increased competition for food (Adams 1996; Adams 1997). However, this was documented only for colonial bats that occur in high densities and has not been shown to occur in solitary species such as the hoary, red or silver-haired bat. Therefore, the late summer increase in mortality is not likely explained by a concurrent shift in diet or habitat use of resident adult bats. Recently fledged juvenile bats have been reported to have reduced abilities to echolocate and fly compared to adults (Gould 1955; Buchler 1980; Timm 1989; Rolseth *et al*. 1994); thus they may be more susceptible to colliding with turbines or other objects (Manville 1963). Juvenile bats also change diets and increase home range size over the first several weeks post fledging (Rolseth *et al*. 1994), thereby possibly making them more susceptible to turbine collision during this period. However, the increase in mortality during late summer cannot be explained by a shift in habitat use by juveniles or an increase in the number of young, inexperienced bats that had recently begun flying. In Minnesota, 68% of all bat collision victims were adults (Johnson *et al.* 2003a&b) and at Foote Creek Rim, Wyoming, all 21 bat collision victims aged in 2000 were adults (Young *et al.* 2002).

Based on all available evidence, it does not appear that bat mortality involves resident bats foraging within wind plants or commuting between foraging and roosting areas. As additional evidence of this, most resident bats are producing young across the U.S. during the period June 1 through July 15, yet only 42 of 1021 bat collision mortalities at windplants (4%) have occurred during this time period. In virtually all cases of bat collision mortality documented at other structures, the timing suggested that migrating bats were involved (*e.g.*, Van Gelder 1956, Zinn and Baker 1979, Crawford and Baker 1981, Timm 1989). Migrant bat species have also comprised the majority of bat collision victims at European wind plants (Bach 2001, Ahlen 2002). Data collected at wind plants in the U.S. also suggest that fall migrants comprise most of the bat collision mortality (Johnson 2003). Findley and Jones (1964) reported that fall migration of hoary bats begins in August, and that migratory concentrations of hoary bats in August have been observed throughout North America, including Nevada, Massachusetts, and New York. At

Delta Marsh along the southern end of Lake Manitoba, Canada, hoary bats started migrating south in mid July (Koehler and Barclay 2000, C. Koehler, pers. comm.), and the latest date for hoary bat captures was 3 September (Barclay 1984). Hoary bats are thought to migrate through Badlands National Park in southern South Dakota in mid-August (Bogan *et al.* 1996). Migrant hoary bats reach Florida as early as late September (Hallman 1968). Similar timing of migration has been documented on the west coast, where migrant hoary bats were found on the Farallon Islands, California from 30 August to 6 September (Tenaza 1966), and museum records indicated a fall migration period of August and September (Dalquest 1943).

LaVal and LaVal (1979) reported that eastern red bats migrate south from September through November. Silver-haired bats are thought to migrate through Wyoming (Clark and Stromberg 1987) and Illinois (Izor 1979) in August and September. At Delta Marsh, Manitoba, both red and silver-haired bats began migrating through the area in mid July (C. Koehler, pers. comm.), and the last capture date at Delta Marsh was 10 September for silver-haired bat and 19 September for both eastern red and little brown bats (Barclay 1984). The big brown bat, little brown bat and eastern pipistrelle spend the winter in hibernacula, but the little brown and eastern pipistrelle may migrate several hundred kilometers to hibernate (Davis and Hitchcock 1965, Griffin 1970, Humphrey and Cope 1976), and the big brown bat may migrate up to 80 km (50 miles) to hibernate (Mills *et al*. 1975). Autumn migration of little brown bats in Indiana and north-central Kentucky occurred from the last week of July to mid-October (Humphrey and Cope 1976), and little brown bats departed from central Iowa to areas near hibernacula after late August (Kunz 1971). Dispersal of summer colonies of eastern pipistrelles and big brown bats also occurs as early as August (Barbour and Davis 1969). The timing of migratory or dispersal movements by species other than hoary bat also corresponds to the timing of collision mortality that has occurred at most wind plants.

The factors that account for the differential susceptibility among species to turbine collisions are unknown. Because most of the mortality apparently involves migrating bats, we do not know if the species involved are more susceptible than others or if composition of the fatalities is proportional to composition of bats during the migration period. Because they have high wing loading (mass per unit area of wing) and aspect ratio (relatively pointed wing tips) (Norberg and Rayner 1987) hoary bats fly rapidly but are not very maneuverable (Farney and Fleharty 1969, Barclay 1985) compared to most other bat species in the U.S. These characteristics may make hoary bats more susceptible to turbine collision than other species. This is not likely the only factor, however, because big brown bats have similar physical characteristics and low maneuverability (Aldridge and Rautenbach 1987), yet they are rarely killed at wind plants.

Most birds appear to migrate at elevations above the rotor-swept area of commercial wind turbines (Kerlinger 1995, Johnson *et al*. 2002). There is little information on flight heights of migrating bats. Some groups of bats are known to migrate much higher than 100 m (328 feet) above the ground (Altringham 1996). Bats migrating during the day over Washington, D.C. were reported flying from 46 to 140 m (151-459 feet) above the ground (Allen 1939), which is within the rotor-swept height of newer-generation turbines. Radar studies have found that Mexican free-tailed bats are capable of flying from 180 to 3050 m (591-10,000 feet) high in pursuit of migrating moths (McCracken 1996). Many species of bats make extensive use of linear features in the landscape while commuting (Limpens and Kapteyn 1991) and migrating (Humphrey and Cope 1976; Timm 1989), and perhaps linear features such as rivers are followed by migrating bats. However, linear features do not occur at many wind plants where bat mortality frequently occurs (e.g., Erickson *et al.* 2000, Johnson *et al.* 2000b, Johnson *et al.* 2003c).

Based on the timing of spring migration (e.g., Koehler and Barclay 2000), migratory tree bats are assumed to be migrating north through North America in mid to late May. However, very few collision fatalities have been found in the spring at U.S. wind plants. Of 1021 bat collision mortalities reported at wind plants across the U.S., only 27 (2.6%) were killed in April and May (Table 4). The only wind plant studied in the U.S. with several bat fatalities in the spring is the Backbone Mountain site in West Virginia, where fatality monitoring is ongoing; 16 dead bats were found there in the spring of 2003 (Shane Jones, U.S. Fish & Wildlife Service, pers. commun.). Spring migrants have also rarely been found at other structures; of 50 dead eastern red bats collected at a building in Chicago, 48 were found in the fall and 2 were found in the spring (Timm 1989). Why spring migrants are not as susceptible to colliding with turbines as fall migrants is not clear. Several species of birds are known to follow different migration routes in the spring and fall (*e.g.*, Cooke 1915, Lincoln 1950, Richardson 1974, 1976), and perhaps some bat populations may follow similar patterns. Behavioral differences between migrating hoary bats in the spring and fall may be related to mortality patterns. Such differences have been reported; in Florida, autumn migration of hoary bats occurred in waves whereas the spatial distribution of bats during spring migration appeared to be far more scattered (Zinn and Baker 1979).

Evidence indicates that only a small fraction of bats that traverse wind plants actually collide with turbines. At Buffalo Ridge, Minnesota, based on sampling bat activity at turbines with echolocation detectors, the authors estimated that a minimum of 96,102 bat passes occurred at turbines over the 2-year study (Johnson *et al*. 2003b). There was no relationship between bat activity at turbines and the number of bat fatalities (*p*=0.889). Similarly, at the Foote Creek Rim, Wyoming wind plant, data from Anabat® bat detectors indicated 2.6 bat passes per turbine per night during the summer and fall (Gruver 2002), yet mortality was much lower on a per turbine basis than at Buffalo Ridge. At the Buffalo Mountain, Tennessee wind plant, bat activity as measured with Anabats® was also not correlated with collision mortality (Nicholson 2001).

At Buffalo Ridge, Minnesota, Anabat® and mist net data indicated that there were relatively large breeding populations of bats in close proximity (i.e., within 3.6 km [2.25 miles]) to the wind plant in June and early July when collision mortality was virtually non-existent. Although most of these bats were big brown and little brown bats, small numbers of eastern red bats and silver-haired bats were captured during this time period (Johnson *et al*. 2003b). Similar results have been found at other wind plants. At Foote Creek Rim, Wyoming, of 260 bats captured in mistnets in the vicinity of the wind plant, 81% were bats in the genus *Myotis*, with long-legged myotis (*Myotis volans*) and little brown bat being the most prevalent, yet members of this genus comprised only 6 (5%) of the 123 turbine collision mortalities during the study (Gruver 2002). Low mortality of *Myotis* and other bats in the area (i.e., big brown and silver-haired bat) occurred even though these species were documented within the wind plant. Although hoary bats comprised 88.1% of the fatalities, species other than hoary bats were responsible for 95% of all identifiable calls recorded at turbines with a bat detector. At a small wind plant on Buffalo Mountain in Tennessee, two species of bats (little brown and northern long-eared bat [*Nyctophilus bifax*]) were detected near the wind plant with Anabats® and mist nets, yet neither species was among the bat fatalities documented at the wind plant (Nicholson 2003). At a Wisconsin wind plant, even though large populations of big brown and other bats were present in the area, only six of 72 bat carcasses found underneath turbines were non-migratory species; the remainder were comprised of hoary, eastern red and silver-haired bats (Howe *et al*. 2002). At the Condon, Oregon wind plant, considerable bat activity was recorded at nearby (0.4 – 0.8 km [0.25 - 0.5 miles]) stream and pond sites, where bat activity was nearly continual for portions of the night when bat activity was monitored. All bats recorded at stream and pond sites were *Myotis* bats (Hayes and Waldien 2000a). No bat mortality was documented at that site during one full year of post-construction monitoring (Steve Steinhour, SeaWest Energy, pers. commun.).

The National Wind Technology Center (NWTC) near Boulder, Colorado has numerous wind turbines and meteorological (met) towers used for research purposes. During a recent study of the NWTC, 216 bats representing as many as six species were detected during 26 surveys. The mean number of bats per survey was significantly higher on the NWTC than on adjacent undeveloped "open space" areas, likely due to the presence of tree and rock outcrop roost habitat on a portion of the NWTC (Schmidt *et al*. 2003). Despite high levels of bat activity on portions of the NWTC, no bat fatalities were found during extensive standardized searches of the turbines. Results of these studies indicate that populations of breeding bats near wind plants are not highly susceptible to turbine collision.

The cause of bat collisions with wind turbines or other man-made structures is not completely understood (Johnson 2003). Foraging bats locate their prey primarily through echolocation (Simmons *et al*. 1979). Bats have the ability to navigate through constructed clutter zones made of staggered vertical strands of twine 3 mm (0.12 inches) in diameter spaced 1 m (3.3 feet) apart (Mackey and Barclay 1989, Brigham *et al*. 1997). Bats are also able to detect large landscape and background features by echolocation out to 100 m (328 feet) (Griffin 1970, Suthers 1970). Surprisingly, studies with captive bats have shown that they can avoid colliding with moving objects more successfully than stationary objects, presumably because their foraging habits program them to detect moving objects (Jen and McCarty 1978). Given these abilities, it seems unlikely that bats using echolocation would be unable to detect wind turbines, especially given the hoary bat's ability to detect prey at long distances (Simmons and Stein 1980, Belwood and Fullard 1984, Barclay 1985, Barclay 1986). As evidence that foraging bats can detect turbines, bats were observed foraging within 1 m (3.3 feet) of an operating wind turbine in Europe, yet no mortality was documented (Bach *et al.* 1999). Similarly, during a study of bat use at the National Wind Technology Center in Golden, Colorado, several bats were observed foraging around research wind turbines, many of which were at heights similar to those occupied by turbine blades, but no mortality was documented during routine carcass searches (U.S. Department of Energy 2002).

According to Van Gelder (1956), most bat collisions at other man-made structures also occur during migration and are normally associated with avian collision mortalities. Based on this, he hypothesized that inclement weather forced migrating birds to fly lower, and the birds somehow confused migrating bats. Other researchers have documented bats migrating with flocks of birds (Banfield 1974). However, at a communication tower in Florida, bat fatalities were found largely in the absence of associated avian mortalities (Crawford and Baker 1981), and there appeared to be no relationship in the number of bat and bird fatalities found at U.S. wind plants (Osborn *et al*. 1996, Erickson *et al*. 2000, Johnson *et al*. 2000b, Johnson *et al*. 2003a,b,c, Young *et al*. 2002, 2003).

Inclement weather does not appear to be strongly correlated with bat collision mortality. At Buffalo Ridge, Minnesota, it was estimated that approximately half of the bat collisions occurred in clear weather, while the other half may have possibly occurred during inclement weather such as high winds and rain (Johnson *et al*. 2000b). Over one-third of the bat collisions at Foote Creek Rim, Wyoming occurred when inclement weather was ruled out as a factor (Young *et al*. 2003). At Buffalo Mountain in Tennessee, bat collision fatalities also occurred during clear as well as inclement weather (Nicholson 2001, 2003).

Even though echolocation in flying bats does not require additional energy expenditures (Speakman and Racey 1991), anecdotal evidence suggests that migrating bats may sometimes navigate without use of echolocation (Van Gelder 1956, Griffin 1970, Crawford and Baker 1981, Timm 1989). This is supported by bat echolocation data collected at the Foote Creek Rim, Wyoming wind plant. Of 20 bat echolocation calls recorded at wind turbines that could be identified to species, only one was a hoary bat, even though mortality data indicated numerous hoary bats were apparently migrating over the wind plant during the study (Gruver 2002).

Data collected at Buffalo Ridge, Minnesota indicate that migrating bats likely do echolocate, at least to some extent (Johnson *et al*. 2003b). During that study, bat activity at turbines based on echolocation calls peaked in late July and August, which corresponds to the time that much of the mortality occurred. Preliminary analyses indicate that several of these echolocation calls were made by hoary bats. This would indicate that at least a portion of the hoary bats migrating through the Buffalo Ridge WRA were echolocating.

Despite the common phrase “blind as a bat”, bats have good visual acuity (Suthers 1966, Suthers 1970, Bell 1985) and evidence indicates that bats depend on vision, rather than echolocation, for long-distance orientation (Mueller 1968, Williams and Williams 1970, Fenton 2001). Bats possibly rely on vision more than echolocation while migrating due to the relatively short distance (15-100 m [49-328 feet]) over which echolocation is effective (Griffin 1970, Fenton 1982). If migrating bats are flying through wind farms primarily by sight, then causes of bat mortality could be similar to causes of avian nocturnal migrant collision mortality at wind plants.

Is there something about turbines that attracts bats? Hayes and Waldien (2000a) speculated that noise generated by wind turbines could attract or repel bats, jam their echolocation signals, or have other effects not currently predictable. However, Anabats® placed at turbines do not pick up any ultrasonic sounds (Johnson *et al*. 2003b), indicating that the turbines do not emit any ultrasonic noises that might confuse or attract bats. Because wind turbines capture some of the kinetic energy in wind, wind speed is reduced on the leeward side of the turbine. Aerial insects are known to concentrate on the lee side of wind breaks such as tall trees (Lewis 1970), and some studies have found that bats take advantage of these wind shadows during windy periods (Barclay 1985, Racey and Swift 1985). Based on echolocation characteristics of foraging hoary and eastern red bats (Schnitzler 1987, Obrist 1995), Schnitzler and Kalko (1998) stated that “an echo from any moving target is a typical food-specific situation and indicates a flying insect” to a bat. Based on this information, Gruver (2002) speculated that higher insect densities near turbines may attract bats or that bats may mistake rotating turbine blades for an insect or swarm of insects and are therefore enticed into the blades. Bat foraging activity can be differentiated from regular flight activity by the presence of feeding buzzes, which are very characteristic high pulse repetition rate calls (Griffin *et al*. 1960). Insects apparently did not swarm at turbines on

Buffalo Ridge based on the absence of feeding buzzes among the 452 bat echolocation passes recorded at turbines, which indicates bats were not foraging near turbines (Johnson *et al*. 2003b).

Although not documented, Osborn *et al*. (1996) suggested that bats may possibly roost temporarily on the catwalk or other external turbine structures present on some small, obsolete turbines at Buffalo Ridge. Most modern turbines, including those planned for the NedPower project, do not have any external structures suitable for bat roosting, and bats have never been observed on turbines by wind plant maintenance personnel at Buffalo Ridge (Jim Mikel, Enron Wind, pers. commun.). Dalquest (1943) reported that migrating hoary bats often seem to select the nearest available tree as a daytime roosting place; therefore, the possibility exists that bats are able to detect the turbines but mistake them for trees and attempt to roost on them, even if there is no roosting structure.

At one study area in Ontario, Canada, both hoary and eastern red bats spent most of their foraging time near street lights (Hickey and Fenton 1990, Hickey 1992), where moth abundance is much higher than areas away from the lights (Hickey and Fenton 1990). Other studies have also shown high foraging activity around artificial lights by bats (e.g., Wilson 1965, Hamilton and Whitaker 1979, Fenton *et al*. 1983, Belwood and Fullard 1984, Geggie and Fenton 1985, Barclay 1985, Furlonger *et al*. 1987, Fullard 1989, Hutchinson and Lacki 1999); therefore, it has been suggested that Federal Aviation Administration (FAA) airplane warning lights on turbines may increase the probability of bat collisions. A good test of the relationship between FAA lighting on turbines and bat collision mortality was made with data collected at Buffalo Ridge, Minnesota (Johnson *et al*. 2003b). Of two modern wind plants studied there, the Lake Benton II wind plant with 138 turbines had FAA lighting on every other turbine due to its proximity to an airport. The other windplant (Lake Benton I), with 143 turbines, only had 6 lighted turbines (3 on either end of the windplant). The lighting was comprised of non-pulsating red lights. Poisson regression was used to examine the relationship between bat activity and mortality and presence of FAA lighting on turbines. Separate analyses were conducted for Lake Benton II and for Lake Benton I and II combined. At the Lake Benton II wind plant, where every other turbine is lighted, 37 (52%) of the 71 bat collision victims were found at lighted turbines and 34 (48%) were found at unlit turbines. There was no significant relationship between bat mortality and presence of lighting for Lake Benton II alone ($p = 0.214$) or for Lake Benton I and II combined ($p = 0.589$). At the Lake Benton II wind plant, there was also no significant difference in bat activity between lighted and unlighted turbines (p=0.138). During an earlier, 4-year study of avian and bat mortality at Buffalo Ridge, 34 of the 184 dead bats (18%) were found at lighted turbines, which is similar to but somewhat lower than the proportion of turbines in the WRA that are lighted (22%) (Johnson *et al*. 2000a). The mean number of bat mortalities at lighted turbines was not significantly higher than the mean number of fatalities at unlit turbines (z=-1.3, P=0.9) (Johnson *et al*. 2003a). These data indicate that non-pulsating red FAA lights on turbines do not attract bats. In addition, mortality at the Lake Benton I wind plant, with only 6 of 143 turbines lighted, was similar to the Lake Benton II wind plant that had every other turbine lighted. Therefore, it does not appear that wind plants with numerous lighted turbines attract bats to the area, where they may collide with both lighted and unlit turbines.

As additional evidence that lights on turbines do not attract bats, bat mortality at the Foote Creek Rim Wind Plant in Wyoming is one of the highest recorded (estimated at 137/year), yet none of the 105 turbines are lighted (Johnson *et al*. 2000b, Young *et al*. 2003). Presence of FAA lighting did not appear to be related to bat fatality rates at the Klondike wind plant in Oregon, where nine of the 16 turbines have pulsating red lights; three bats were found at lighted turbines and three were found at unlit turbines (Johnson *et al*. 2003c). At the Stateline Wind Plant on the Oregon/Washington border, where approximately one-third of the turbines have pulsating red lights, there was no significant difference ($p > 0.10$) in bat mortality rates between lit and unlit turbines based on a sample size of 54 dead bats (Erickson *et al*. 2003a).

Only one study has attempted to address behavior of bats around turbines. In Wisconsin, Puzen (2002) collected 26 hours of video at turbines using an infrared camera. Only one bat was captured on film moving past the turbine, and this individual was echolocating at a normal rate and did not appear disturbed by or attracted to the turbine. In no instances during the 26 hours of tape were bats observed circling the turbines, acting confused, or foraging at the red lights on top of the turbines.

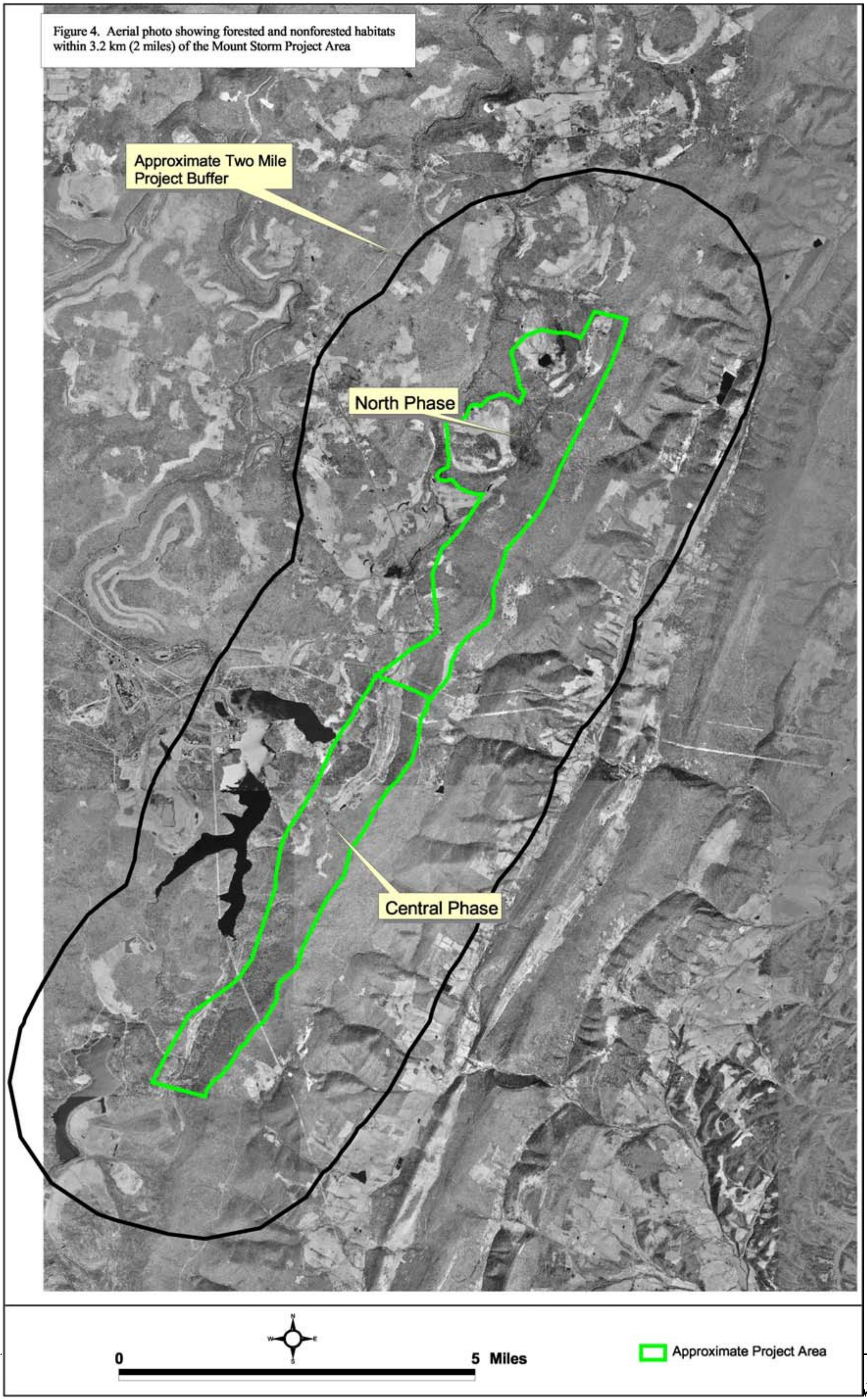
If bats are not attracted to the turbines and bats are simply colliding with an obstacle, then higher mortality should be expected at meteorological towers typically placed within wind plants. These towers are often supported by thin guy wires, theoretically making them more hazardous to bats than turbines, as is the case for birds (Manville 2001). At the Foote Creek Rim wind plant in Wyoming, the number of avian collision fatalities associated with met towers supported by guy wires was approximately six times that of wind turbines of similar height (Johnson *et al.* 2000b). Despite the fact that the six met towers at Foote Creek Rim were searched with the same intensity as turbines, none of the 135 dead bats found during the study were found at met towers. At Buffalo Mountain, Tennessee, 72 bat fatalities were found at three wind turbines and one was found in a control plot, yet none were found at a single met tower also routinely searched for casualties (Nicholson 2003). Similarly, although six dead bats were found at 16 turbines within a wind plant in Oregon, no bats were found at a met tower searched with the same intensity (Johnson *et al*. 2003c). At Buffalo Ridge, Minnesota 13 met towers were searched and no dead bats were found, but dense vegetation underneath the towers would have made it difficult to detect any bat carcasses present (Johnson *et al*. 2003b). Of 1087 dead bats recorded at wind plants, only one was found at a meteorological tower, a Mexican free-tailed bat at the San Gorgonio wind plant in southern California (Anderson *et al*. 2003a).

HABITAT SURVEY

Project Area

At the extreme northern end of the project area there is a large, recently reclaimed coal strip mine dominated by grasses (Figure 4). A few small ponds are present within the reclaimed area, as are small emergent wetlands dominated by cattail and sedges. The project area also encompasses another smaller strip mine further south that has been very recently developed and reclaimed, as it does not appear on an aerial photo taken in 1999. Wooded areas are dominated by red maple, white and red oak, black cherry, and American beech, with an understory dominated by mountain laurel and azalea. Most trees in this area are less than 30 cm (12 inches) dbh, but several trees are 46-61 cm (18-24 inches) dbh, and a few oak trees with trunks over 76 cm (30 inches) dbh were observed. Snags do occur in this area at relatively low densities, and most occur within the interior of forests due to the lack of openings in this area. One relatively large snag (61 cm [24 inches]) in dbh was found in a small opening on top of the ridge created to

Figure 4. Aerial photo showing forested and nonforested habitats within 3.2 km (2 miles) of the Mount Storm Project Area



construct a compressor unit for a gas pipeline that traverses much of the ridgeline. A few cabins as well as elaborate wooden deer blinds occur in the area. The ridge slopes gradually to the west, but the east side of the ridge is very steep, and several large cliffs are present near the top of the ridgeline.

Immediately south of Highway 42, and continuing southward for approximately 4.8 km (3 miles), a large portion of the project area is located within a relatively disturbed area comprised of reclaimed mined land, roads, cabins, and electric transmission line crossings. The reclaimed mine lands in this area are older than those at the north end of the project. Although these areas are still mostly open, much of the reclaimed mines have stands of young locust trees as well as shrubs and other small trees. Occasional small ponds and wetlands dominated by cattail and sedges are present in this area, as is a small stream within the reclaimed mine land.

A portion of the project area is immediately east of the east arm of Mount Storm Lake. The area adjacent to the lake is occupied by cabins and trailers. Permanently occupied dwellings also occur in this area. Habitats in this area are varied and include large pastures, abandoned orchards, and stands of forest dominated by oak, maple, beech, elm, fir and pine trees. Most trees are less than 30 cm (12 inches) dbh, but occasional deciduous as well as pine trees are over 76 cm (30 inches) dbh. There are a few scattered snags in the area.

The approximately southern four miles of the project area occur along a ridgeline comprised entirely of deciduous or mixed deciduous/coniferous forest typical of higher elevations in West Virginia. Trees in this area include red maple, red and white oak, birch, red spruce, balsam fir, pine, black cheery, American beech, and bigtooth aspen, with an understory dominated by rhododendron, mountain laurel, striped maple and azalea. Most trees are less than 30 cm (12 inches) dbh, but several are 46-61 cm (18-24 inches) dbh, and occasional trees are over 61 cm (24 inches) dbh. Snags also occur in this area, again at relatively low densities. The entire ridgeline is heavily forested and lacks any openings. The southern end of the project traverses an area with several cabins. As was the case with the north end, the ridgeline tapers slowly to the west, but is very steep on the east side.

Surrounding Vicinity

A large portion of the area within 3.2 km (2 miles) of the project site is comprised of deciduous forest (Figure 4). Several active as well as reclaimed coal strip mines occur within 3.2 km (2 miles) of the project area, as does all of Mount Storm Lake and Stony River Reservoir. Several streams and associated riparian areas are in the vicinity; the major streams include Abram Creek to the west and New Creek to the east. Large wetlands occur in lower areas, such as along Helmick Run south of Mount Storm Lake.

Valleys to the east and west of the project site are at much lower elevations. For example, elevations along Highway 93 where it parallels the north end of the project on the east side are as low as 488 m (1600 feet), or 500 m (1640 feet) lower than the adjacent ridgeline within the project area. These lower valleys are comprised of deciduous forest interspersed with numerous pastures and occasional ponds and wetlands. Several large snags were observed in or adjacent to many of the pastures. Shagbark hickory, a species commonly used by Indiana bat, was not observed within the project area itself. However, this species was fairly common at lower elevations surrounding the project area. Our review indicates that there is substantial habitat for

Indiana bat within 3.2 km (2 miles) of the project. Indeed, the surrounding habitats appear to be much more suitable for this species as well as other bats than the project area itself.

EFFECTS OF THE ACTION

Indirect Impacts Through Habitat Loss

Based on his research for the Appalachian Corridor H project in the area, it was Dr. Clem's opinion that the area is not suitable habitat for most bats, including both of the endangered species. The foremost reason that the area is poor bat habitat is the high elevation of the project area, which results in much lower temperatures and more precipitation than areas of lower elevation in West Virginia. Dr. Clem also felt the area was not optimal foraging habitat for bats, primarily due to the high average wind speeds which are not conducive to bat foraging activities. Preliminary data collected by NedPower show that mean wind speeds in the project area are approximately 29 km/hour (18 miles/hour).

Although several dead bats were found at the Backbone Mountain wind site in West Virginia, the timing of the fatalities suggest that these bats were migrants rather than resident bats foraging at that site. All of the fatalities were found in the spring and fall during the time frame that bats are migrating or dispersing between summer breeding areas and winter hibernacula. No fatalities were found during the June-July breeding season for bats.

The first task when assessing the potential for impacts to Indiana bats through habitat loss is to determine whether or not the affected habitat is suitable for the species. At the Mount Storm study area, there are snags with diameters greater than 30 cm (12 inches) and presence of exfoliating bark that could provide suitable roost trees for Indiana bats. Because Indiana bats are known to forage in upland forests, there is also abundant foraging habitat for this species in the project area. Although apparently suitable roost sites for the Indiana bat and foraging sites are present in the area, available information indicates that the project area is likely not suitable for this species due primarily to its high elevation. The literature review indicated that Indiana bats are not normally associated with similar elevations throughout most of their range, with the exception of a single colony in North Carolina, much further south of the project area.

Even if one were to assume the presence of Indiana bats, the clearing associated with development of the Project is not likely to impact Indiana bats. There will be no potential to directly impact Indiana bats during construction, as all tree removal will occur over the winter (November 15 to March 31). Furthermore, the relatively small amount of forest removal required for this project will not significantly reduce available Indiana bat habitat in the region. As is the case throughout Grant County, the majority of the area within 3.2 km (2 miles) of the Project is forested; therefore a relatively small loss of forest to turbines and access roads would likely be inconsequential, as this resource is not limiting in the vicinity of the project. Surrounding forested areas interspersed with pastures in valleys surrounding the project area likely provide much more suitable habitat than the project site itself.

Timber harvest activities did not discourage Indiana bats from continuing to forage in a harvested area in Illinois (Gardner *et al*. 1991). In one case where a tree used by a maternal colony of Indiana bats was cut down, the bats moved to another tree (Cope *et al.* 1974). Based on this evidence, the U.S. Fish and Wildlife Service (1999) concluded that the Indiana bat may be a more adaptable species than previously thought. According to Miller *et al*. (2002), Indiana bats are adaptable to a wide variety of habitat conditions and are able to sustain maternity colonies despite considerable man-made or naturally caused changes in their environment.

The entire portion of the project within potential Virginia big-eared bat use areas is heavily forested, and clearing of timber for the project will not impact important foraging habitat of Virginia big-eared bat. Virginia big-eared bats do forage along cliffs, and several cliffs occur along the east side of the ridgeline turbines will be constructed on. However, as is the case for Indiana bat, available information indicates that the project area is likely not suitable for Virginia big-eared bat due to its high elevation and high mean wind speeds.

Direct Impacts Through Collision Mortality

As stated earlier, most bat collision mortality involves non-hibernating migrant species that generally roost singly in tree foliage, especially the hoary bat, eastern red bat, and silver-haired bat, all of which are fairly common species in North America. These bats make truly long-distance migrations from Canada and the northern U.S. as far south as Mexico and South America. The Virginia big-eared bat is considered nonmigratory, although it has been documented to travel up to 64 km (40 miles) between caves. The non-migratory behavior of this species likely reduces its risk of collision with wind turbines.

Although the Indiana bat is considered a "migratory" species, its migratory behavior is much different from that of the other long-distance migratory species that do not hibernate. The Indiana bat migrates from winter hibernacula in the U.S. to other portions of the U.S., which involve much shorter distances than the other species. Although banded individuals have been found as far as 520 km (325 miles) away from hibernacula (Gardner and Cook 2002) in the Midwest, available data indicate that Indiana bats in the eastern and southeastern U.S. do not migrate large distances between summer and winter habitats (Gardner and Cook 2002). In this regard, their movements closely resemble dispersal from summer habitat to hibernacula described above for such species as big brown bat, little brown bat, and eastern pipistrelle, which are also known to travel up to several hundred kilometers between breeding areas and hibernacula. Although the relationship between collision mortality and behavior associated with non-hibernating long-distance migratory bats versus dispersing bats that do hibernate is not well-understood, bat mortality data at all U.S. wind plants show that the non-hibernating long-distance migrants suffer much higher mortality than species that travel much shorter distances between hibernacula and summer breeding areas. Available data indicate that the risk of collision mortality is likely much lower for Indiana bats than the foliage roosting long-distance migratory species. Even if, in the unlikely case a "migrating" Indiana bat were to collide with a turbine at an existing U.S. wind plant, our review indicates that this would be an exceptional event not likely to occur with any frequency or indicate a likely adversely affect of the project on the species.

Our review indicates that it is unlikely maternal colonies of Indiana bats are present on the project site, and it is unlikely that Virginia big-eared bats would forage in the project area. Even if these bats occasionally were present in the area, foraging bats do not seem susceptible to turbine collisions throughout the U.S., and neither species would be expected to collide with turbines. Most of the project area within potential use areas of Virginia big-eared bat is forested. Use of the narrow openings cut through timber for placement of turbine strings and access roads by Virginia big-eared bat would likely be limited, as open flight paths, such as logging roads, are seldom used by this species (Adams *et al*. 1994). Similarly, risk to Indiana bats of turbine collision is also low, as they do not routinely forage in open areas, preferring instead to forage among trees and over streams (LaVal et al. 1977, Carter *et al*. 2002). In addition, Indiana bats usually forage and fly from 2 to 30 m (6.6-98 feet) above ground (Humphrey *et al.* 1977), and Virginia big-eared bats typically do not forage above tree-top levels (Craig Stihler, West Virginia Department of Natural Resources, pers. commun.), which is below the space occupied by turbine blades of the proposed turbines for the Mount Storm project.

Data collected at other wind plants indicate that presence of FAA lighting on turbines does not lead to increased bat mortality. Although other sources of lighting may also be present within wind plants (e.g., lighted substations), bats foraging at these lights would not be directly exposed to turbines, and radiotelemetry studies of Virginia big-eared bats in West Virginia showed that this species never foraged at numerous artificial lights within their home range (Craig Stihler, West Virginia Department of Natural Resources, pers. commun.). Available evidence indicates that the potential for Virginia big-eared bats and resident Indiana bats to collide with turbines appears to be very low to nonexistent.

CONCLUSIONS AND RECOMMENDATIONS

Under the Endangered Species Act (ESA), effects of actions are classified as “not likely to adversely affect” or “likely to adversely affect” a listed species. Not likely to adversely affect is the appropriate conclusion when effects are expected to be discountable, insignificant, or beneficial. Discountable effects are those which are extremely unlikely to occur and are essentially not expected to occur. Insignificant effects refer to the size and/or magnitude of the effect and are those effects which should never reach a scale where take occurs. Insignificant effects are effects which cannot be detected, measured, or evaluated to any meaningful degree. Beneficial effects are positive effects to a species which occur without any associated adverse effects.

The responsibility under the Endangered Species Act for parties that propose actions on private lands are to avoid take. Although Section 7 consultation is not required for this project, for the purposes of this document, NedPower decided to address potential effects on the endangered bats as if Section 7 consultation was required. For species listed as endangered or threatened the threshold for initiating formal consultation with the USFWS (to acquire a biological opinion and incidental take statement) is the “likely to adversely affect” determination. The ESA (Section 3) defines “take” as “to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt to engage in any such conduct”. The USFWS further defines harass as “actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering”.

Based on results of our review, we believe that construction and operation of the wind plant would not likely result in the “take” of either Indiana bats or Virginia big-eared bats. For this reason, we believe the appropriate determination is that construction and operation of the Mount Storm wind project is not likely to adversely affect Indiana bat and Virginia big-eared bat.

This determination was based on the following conclusions:

1. Due to its high elevation, it is unlikely that breeding populations of Indiana bats and Virginia big-eared bats use the project area.
2. The high average wind speeds in the project area are not conducive for foraging by bats.
3. All tree removal for this project will be conducted when Indiana bats and Virginia big-eared bats are not present (i.e., from November 15 to March 31).
4. The amount of tree removal required for this project is minimal and will occur in unsuitable habitat due to the high elevations and wind speeds in the project area. The project will not impact wooded habitats at lower elevations in the vicinity of the project, which provide much better bat habitat than the project site itself. In addition, The portion of the development within expected use areas of Virginia big-eared bat represents less than 3% of the 289 km^2 (113 mi^2) (10 km [6-mile] radius around cave) considered essential to the colony, and is comprised of unsuitable habitat for this species.
5. Previous mist-netting near the project area conducted by Dr. Phillip Clem did not result in any Indiana bat captures, and captures of other bat species were rare.
6. The lack of bat mortality at the Backbone Mountain wind project during the June through July breeding season for bats provides additional evidence that high-elevation ridges in West Virginia do not support breeding bat populations.
7. Indiana bats apparently exist in extremely low densities throughout most of West Virginia, and the Virginia big-eared bat cave roost near the project site is very small, containing only 7 individuals in 1999.
8. Bat collision mortality at existing wind plants during the breeding season is virtually non-existent, despite the fact that relatively large numbers of some bat species have been documented in close proximity to wind plants, many of which are related *Myotis* species.
9. Indiana bats do not routinely forage in open areas, and Virginia big-eared bats seldom use linear features such as logging roads in forested habitats, which minimizes the probability either species would forage among the turbines or use the turbine strings as travel corridors.
10. Indiana bats are known to restrict their foraging to areas below 30 m (98 feet), and Virginia big-eared bats do not typically forage above tree-top level. Neither species would therefore be expected to forage within the turbine rotor-swept heights, which greatly reduces the risk of collision mortality.
11. No Indiana bat or Virginia big-eared bat fatalities have been documented at the nearby Backbone Mountain wind project, indicating little risk to these species of wind power development on high-elevation ridges in the region.
12. No Indiana bat fatalities have been documented at other wind plants constructed within the range of the species. Likewise, no Indiana or Virginia big-eared bats have been killed at other tall structures, many of which are within the range of the species. This information indicates that these species are not highly susceptible to collision with tall structures.
13. Nearly 90% of bat mortality in the U.S. involves non-hibernating, migratory, foliage roosting bats, namely the hoary bat, eastern red bat, and silver-haired bat.
14. No members of the genus *Corynorhinus* have been killed at windplants, and only three species in the genus *Myotis* have been killed at windplants, including little brown bat, which comprised 49 (4.6%) of 1044 wind plant casualties identified to species, long-eared bat (one fatality in California), and northern myotis (one fatality in West Virginia). The little brown bat is an abundant, widespread species across most of the U.S. (Fenton and Barclay 1980).

15. The Virginia big-eared bat is considered non-migratory, although it will move between caves.
16. Although considered to be migratory, movements of Indiana bat in the eastern U.S. between summer habitats and hibernacula more closely resemble dispersal movements of several bat species that have very low or no mortality at windplants than they do the long-distance migrations of hoary, eastern red, and silver-haired bats.
17. Available data indicate that FAA airplane warning lights on turbines do not result in increased bat activity or mortality at turbines.

The determination of no take as defined by Section 3 of the Endangered Species Act was made based on available evidence indicating very low potential for indirect effects through habitat loss/modification and direct impacts through collision mortality. Our conclusions were based on published and unpublished literature regarding the ecology and behavior of the listed bats, data on bat use of the area, past and current studies of bat interactions with wind turbines, interviews with persons knowledgeable of Indiana and Virginia big-eared bats, and habitat conditions at the project site and within 3.2 km (2 miles) of the project site.

Although site-specific bat surveys were not conducted for this assessment, our review indicates that it is extremely unlikely Indiana bats or Virginia big-eared bats would use the project area. Although the southern end of the project site is considered to be within essential habitat of Virginia big-eared bat (Jeffrey Towner, USFWS, letter to Potesta & Associates dated 8-3-02), actual habitat where turbines will be constructed is much less suitable than other habitats available to the colony.

The utility of conducting pre-construction studies of bat use of wind resource areas to predict collision risk appears limited due to the lack of correlation between bat activity and collision mortality. Efforts were made to estimate bat use of the Stateline Wind Plant on the Oregon/Washington border (Hayes and Waldien 2000b) and the Condon, Oregon wind development area (Hayes and Waldien 2000a) prior to development. Limited surveying with mist nets and bat echolocation detectors did not detect any bat activity at the Stateline project area, yet several dead bats were found at this facility after development (Erickson *et al*. 2003a). In contrast, at the Condon site, bat activity was documented at upland sites within the development area, consisting of nine bat passes recorded during 10 detector nights in September. In addition, there was considerable bat activity recorded at nearby (0.4-0.8 km [0.25 - 0.5 miles]) stream and pond sites, where bat activity was nearly continual for portions of the night when bat activity was monitored. Despite documented activity by bats, no bat mortalities were found during one full year of post-construction mortality monitoring (Steve Steinhour, SeaWest Energy, pers. commun.). As discussed in the literature review above, several studies have shown the presence of relatively large populations of bats near existing wind plants in the absence of collision mortality. Many other studies have also noted a lack of correlation between bat activity and collision mortality within the wind plants themselves. Based on the above factors, we do not feel that conducting surveys would add significant information useful for predicting either direct or indirect impacts to bats.

LITERATURE CITED

Adam, M.D., M.J. Lacki, and T.G. Barnes. 1994. Foraging areas and habitat use of the Virginia big-eared bat in Kentucky. Journal of Wildlife Management 58:462-469.

Adams, R.A. 1996. Size specific resource use in juvenile little brown bats, *Myotis lucifugus* (Chiroptera: Vespertilionidae): Is there an ontogenetic shift? Canadian Journal of Zoology 74:1204-1210.

Adams, R.A. 1997. Onset of volancy and foraging patterns of juvenile little brown bats, *Myotis lucifugus*. Journal of Mammalogy 78:239-246.

Ahlen, I. 2002. Fladdermoss och faglar dodade av vindkraftverk. (Bats and birds killed by wind power turbines). Fauna och flora 97:14-21.

Aldridge, H.D.J.N. and I.L. Rautenbach. 1987. Morphology, echolocation and resource partitioning in insectivorous bats. Journal of Animal Ecology 56:763-778.

Allen, G.M. 1939. Bats. Dover Publications, Inc., New York, New York. 358pp.

Altringham, J.D. 1996. Bats: Biology and Behaviour. Oxford University Press, Inc., New York. 262 pp.

American Wind Energy Association (AWEA). 1995. Avian interactions with wind energy facilities: a summary. Prepared by Colson & Associates for AWEA, Washington, D.C., 62 pp.

American Wind Energy Association. 2001. Wind energy's costs hit new low, position wind as clean solution to energy crisis, trade group says. American Wind Energy Association News Release, AWEA, Washington, D.C., 4 p.

American Wind Energy Association. 2002a. U.S. wind industry ends most productive year, more than doubling previous record for new installations. American Wind Energy Association News Release, AWEA, Washington, D.C., 2 p.

American Wind Energy Association. 2002b. Wind power: U.S. installed capacity (megawatts), 1981-2001. American Wind Energy Association, Washington, D.C., 2 p.

American Wind Energy Association. 2002c. AWEA projects record market for wind power in 2003. American Wind Energy Association, Washington, D.C.

Anderson, R., M. Morrison, K. Sinclair, and D. Strickland. 1999. Studying wind energy/bird interactions: A guidance document. National Wind Coordinating Committee, Washington, D.C., 87pp.

Anderson, R.L., D. Strickland, J. Tom, N. Neumann, W. Erickson, J. Cleckler, G. Mayorga, G. Nuhn, A. Leuders, J. Schneider, L. Backus, P. Becker and N. Flagg. 2000. Avian monitoring and risk assessment at Tehachapi Pass and San Gorgonio Pass wind resource areas, California: Phase 1 preliminary results. Proceedings of the National Avian-Wind Power Planning Meeting 3:31-46. National Wind Coordinating Committee, Washington, D.C.

Anderson, R.L., W.P. Erickson, M.D. Strickland, M. Bourassa, K.J. Bay, and K.J. Sernka. 2003a. Avian monitoring and risk assessment at the San Gorgonio Wind Resource Area. National Renewable Energy Laboratory, Golden, Colorado. In Press.

Anderson, R.L., W.P. Erickson, M.D. Strickland, M. Bourassa, K.J. Bay, and K.J. Sernka. 2003b. Avian monitoring and risk assessment at the Tehachapi Pass Wind Resource Area. National Renewable Energy Laboratory, Golden, Colorado. In Press.

Angus, N.B., P. Clem, and M. Hamilton. 2001a. Appalachian Corridor H Davis to Bismarck Project: mist net report for Myotis sodalis. West Virginia Department of Transportation.

Angus, N.B., P. Clem, and M. Hamilton. 2001a. Appalachian Corridor H Bismarck to Forman Project: mist net report for Myotis sodalis. West Virginia Department of Transportation.

Anonymous. 1961. Large bird kills at TV towers. Bluebird 28:9.

Avery, M. and T. Clement. 1972. Bird mortality at four towers in eastern North Dakota: Fall 1972. Prairie Naturalist 4:87-95.

Bach, L. 2001. Fledermause und Windenergienutzung – reale Probleme oder Einbildung? (Bats and wind turbines – real problems or only fancies?). Vogelkdl. Ber. Niedersachs. 33:119-124.

Bach, L., R. Brinkman, H.J.G.A. Limpens, U. Rahmel, M. Reichenbach, and A. Roschen. 1999. Bewertung und planerische Umsetzung von Fledermausdaten im Rahmen der Windkraftplanung. - Bremer Beitraege fuer Naturkunde und Naturschutz, Band 4. Themenheft "Voegel und Windkraft":163-170.

Bagley, F.M. 1984. A recovery plan for the Ozark big-eared bat and the Virginia big-eared bat. U.S. Fish and Wildlife Service, Twin Cities, MN.

Banfield, A.W.F. 1974. The mammals of Canada. University of Toronto Press, Toronto. 438pp.

Barbour, R.A. and W.H. Davis. 1969. Bats of America. Univ. Kentucky, Lexington.

Barclay, R.M.R. 1984. Observations on the migration, ecology and behaviour of bats at Delta Marsh, Manitoba. Canadian Field-Naturalist 98:331-336.

Barclay, R.M.R. 1985. Long- versus short-range foraging strategies of hoary (*Lasiurus cinereus*) and silver-haired (*Lasionycteris noctivagans*) bats and the consequences for prey selection. Canadian Journal of Zoology 63:2507-2515.

Barclay, R.M.R. 1986. The echolocation calls of hoary (*Lasiurus cinereus*) and silver-haired (*Lasionycteris noctivagans*) bats as adaptations for long- versus short-range foraging strategies and the consequences for prey selection. Canadian Journal of Zoology 64:2700-2705.

Barclay, R.M.R., P.A. Faure, and D.R. Farr. 1988. Roosting behavior and roost selection by migrating silver-haired bats (*Lasionycteris noctivagans*). Journal of Mammalogy 69:821-825.

Bell, G.P. 1985. The sensory basis of prey location by the California leaf-nosed bat, *Macrotus californicus* (Chiroptera: Phyllostomidae). Behavioral Ecology and Sociobiology 16:343-347.

Belwood, J.J. and J.H. Fullard. 1984. Echolocation and foraging behaviour in the Hawaiian hoary bat, *Lasiurus cinereus semotus*. Canadian Journal of Zoology 62:2113-2120.

Betts, B.J. 1996. Roosting behaviour of silver-haired bats (*Lasionycteris noctivagans*) and big brown bats (*Eptesicus fuscus*) in northeast Oregon. Pages 55-61 in Bats and Forests Symposium, R.M.R. Barclay and R.M. Brigham, eds. British Columbia Ministry of Forests, Victoria, B.C., Canada.

Bogan, M.A., J.G. Osborne, and J.A. Clarke. 1996. Observations on bats at Badlands National Park, South Dakota. Prairie Naturalist 28:115-123.

Brack, V.W., Jr. 1983. The nonhibernating ecology of bats in Indiana with emphasis on the endangered Indiana bat, *Myotis sodalis*. Ph.D. Dissertation. Purdue University, West Lafayette, IN. 280pp.

Brack, V. and R.K. LaVal. 1095. Food habits of the Indiana bat in Missouri. Journal of Mammalogy 66:308-315.

Brack, V., Jr., C.W. Stihler, R.J. Reynolds, C.M. Butchkoski, and C.S. Hobson. 2002. Effect of climate and elevation on distribution and abundance in the mideastern United States. Pages 21-28 *in* The Indiana bat: biology and management of an endangered species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Brigham, R.M., S.D. Grindal, M.C. Firman, and J.L. Morissette. 1997. The influence of structural clutter on activity patterns of insectivorous bats. Canadian Journal of Zoology 75:131-136.

Buckelew, A. R., Jr. and G. A. Hall. 1994. West Virginia Breeding Bird Atlas. University of Pittsburgh Press, Pittsburgh, Pennsylvania. 215 pp.

Buchler, E.R. 1980. The development of flight, foraging, and echolocation in the little brown bat (*Myotis lucifugus*). Behavioral Ecology and Sociobiology 6:211-218.

Burford, L.S. and M.J. Lacki. 1995. Habitat use by Corynorhinus townsendii virginianus in the Daniel Boone National Forest. American Midland Naturalist 134:340-345.

Butchkoski, C.M. and J.D. Hassinger. 2002. Ecology of a maternity colony roosting in a building. Pages 130-142 *in* The Indiana bat: biology and management of an endangered species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Callahan, E.V., R.D. Drobney, and R.L. Clawson. 1997. Selection of summer roosting sites by Indiana bats (*Myotis sodalis*) in Missouri. Journal of Mammalogy 78:818-825.

Canterbury, R. A. 2002. Phase 1 Avian Risk Assessment for a Proposed Wind Farm in Grant County, West Virginia. Tech. Rpt. prepared for Potesta & Associates, Inc., Charleston, West Virginia. 33 pp.

Carter, T.C., S.K. Carroll, J.E. Hofmann, J.E. Gardner, and G.A. Feldhamer. 2002. Landscape analysis of roosting habitat in Illinois. Pages 160-164 *in* The Indiana bat: biology and management of an endangered species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Carter, T.D. 1950. On the migration of the red bat, *Lasiurus borealis borealis*. Journal of Mammalogy 31:349-350.

Carter, T.C., M.A. Menzel, B.R. Chapman, K.V. Miller, and J.R. Lee. 1999. A new method to study bat activity patterns. Wildlife Society Bulletin 27:598-602.

Clark, B.K., J.B. Bowles, and B.S. Clark. 1987. Summer habitat of the endangered Indiana bat in Iowa. American Midland Naturalist 118:32-39.

Clark, T.W. and M.R. Stromberg. 1987. Mammals in Wyoming. Univ. of Kansas Museum of Natural History. 314pp.

Clawson, R.L. 2002. Trends in population size and current status. Pages 2-8 *in* The Indiana bat: biology and management of an endangered species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Constantine, D.G. 1966. Ecological observations on lasiurine bats in Iowa. Journal of Mammalogy 47:34-41.

Cope, J.B., A.R. Richter, and R.S. Mills. 1974. A summer concentration of the Indiana bat, *Myotis sodalis*, in Wayne County, Indiana. Proceedings of the Indiana Academy of Science 83:482-484.

Cooke, W.W. 1915. Bird migration. U.S. Department of Agriculture Bulletin 185:1-47.

Crawford, R.L. and W.W. Baker. 1981. Bats killed at a north Florida television tower: a 25-year record. Journal of Mammalogy 62:651-652.

Cryan, P.M., M.A. Bogan, and J.S. Altenbach. 2000. Effects of elevation on the distribution of female bats in the Black Hills, South Dakota. Journal of Mammalogy 81:719-725.

Dalquest, W.W. 1943. Seasonal distribution of the hoary bat along the Pacific coast. Murrelet 24:21-24.

Dalton, V.M., V.W. Brack, Jr., and P.M. McTeer. 1986. Food habits of the big-eared bat, *Plecotus townsendii virginianus*, in Virginia. Virginia Journal of Science 37:248-254.

Davis, W.H. and H.B. Hitchcock. 1965. Biology and migration of the bat, *Myotis lucifugus*, in New England. Journal of Mammalogy 46:296-313.

DeBlase, A.F. and J.B. Cope. 1967. An Indiana bat impaled on barbed wire. American Midland Naturalist 77:238.

Dedon, M., S. Byrne, J. Aycrigg, and P. Hartman. 1989. Bird mortality in relation to the Mare Island 115-kV transmission line: progress report 1988/1989. Department of the Navy, Western Division, Naval Facilities Engineering Command, Office of Environmental Management, San Bruno, California. Report 443-89.3. 150pp.

Denys, G.A. 1972. Hoary bat impaled on barbed wire. Jack-Pine Warbler 50:63.

Erickson, W.P., G.D. Johnson, M.D. Strickland, and K. Kronner. 2000. Avian and bat mortality associated with the Vansycle Wind Project, Umatilla County, Oregon: 1999 study year. Technical Report prepared by WEST, Inc. for Umatilla County Department of Resource Services and Development, Pendleton, Oregon. 21pp.

Erickson, W.P., G.D. Johnson, M.D. Strickland, D.P. Young, Jr., K.J. Sernka and R.E. Good. 2001. Avian collisions with wind turbines: A summary of existing studies and comparisons to other sources of collision mortality in the United States. National Wind Coordinating Committee (NWCC) Resource Document. August 2001. NWCC, Washington, D.C. 62pp.

Erickson, W., G. Johnson, D. Young, D. Strickland, R. Good, M. Bourassa, K. Bay and K. Sernka. 2002. Synthesis and comparison of baseline avian and bat use, raptor nesting and mortality information from proposed and existing wind developments. Bonneville Power Administration, Portland, Oregon.

Erickson, W.P., J. Jeffrey, K. Kronner, and K. Bay. 2003a. Stateline Wind Project Wildlife Monitoring Annual Report, Results for the Period July 2001 – December 2002. Technical report submitted to FPL Energy, the Oregon Office of Energy, and the Stateline Technical Advisory Committee.

Erickson, W.P., B. Gritski, and K. Kronner, 2003b. Nine Canyon Wind Power Project Avian and Bat Monitoring Annual Report. Technical report submitted to Energy Northwest and the Nine Canyon Technical Advisory Committee.

Everette, A.L., T.J. O'Shea, L.E. Ellison, L.A. Stone, and J.L. McCance. 2001. Bat use of a high-plains urban wildlife refuge. Wildlife Society Bulletin 29:967-973.

Farmer, A., B.S. Cade, and D.F. Staufer. 2002. Evaluation of a habitat suitability index model. Pages 172-181 *in* The Indiana bat: biology and management of an endangered species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Farney, J. and E.D. Fleharty. 1969. Aspect ratio, loading, wing span, and membrane areas of bats. Journal of Mammalogy 50:362-367.

Fenton, M.B. 1982. Echolocation, insect hearing, and feeding ecology of insectivorous bats. Pages 261-286 *In* T.H. Kunz (ed.). Ecology of Bats. Plenum Press, New York.

Fenton, M.B. 2001. Bats, Revised Edition. Checkmark Books, New York, NY. 224 pp.

Fenton, M.B. and R.M.R. Barclay. 1980. *Myotis lucifugus*. Mammalian Species 142:1-8.

Fenton, M.B. and G.P. Bell. 1979. Echolocation and feeding behaviour in four species of *Myotis* (Chiroptera). Canadian Journal of Zoology 57:1271-1277.

Fenton, M.B., H.G. Merriam, and G.L. Holryod. 1983. Bats of Kootenay, Glacier, and Mount Revelstoke national parks in Canada: identification by echolocation calls, distribution, and biology. Canadian Journal of Zoology 61:2503-2508.

Fenton, M.B., C.G. vanZyll de Jong, G.P. Bell, D.B. Campbell, and M. LaPlante. 1980. Distribution, parturition dates, and feeding of bats in south-central British Columbia. Canadian Field-Naturalist 94:416-420.

Findley, J.S. and C. Jones. 1964. Seasonal distribution of the hoary bat. Journal of Mammalogy 45:461-470.

Fitzgerald, J.P., C.A. Meaney, and D.M. Armstrong. 1994. Mammals of Colorado. University Press of Colorado, Niwot, CO. 467pp.

Fullard, J.H. 1989. Echolocation survey of the distribution of the Hawaiian hoary bat (*Lasiurus cinereus semotus*) on the island of Kaua'i. Journal of Mammalogy 70:424-426.

Furlonger, C.L., H.J. Dewar, and M.B. Fenton. 1987. Habitat use by foraging insectivorous bats. Canadian Journal of Zoology 65:284-288.

Ganier, A.F. 1962. Bird casualties at a Nashville TV tower. Migrant 33:58-60.

Gardner, J.E. and E.A. Cook. 2002. Seasonal and geographic distribution and quantification of potential summer habitat. Pages 9-20 *in* The Indiana bat: biology and management of an endangered species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Gardner, J.E., J.D. Gardner, and J.E. Hofmann. 1991. Summer roost selection and roosting behavior of *Myotis sodalis* (Indiana bat) in Illinois. Final Report, Champaign, IL, Illinois Natural History Survey and Illinois Department of Conservation. 56 pp.

Geggie, J.F. and M.B. Fenton. 1985. A comparison of foraging by *Eptesicus fuscus* (Chiroptera: Vespertilionidae) in urban and rural environments. Canadian Journal of Zoology 63:263-267.

Gollop, M.A. 1965. Bird migration collision casualties at Saskatoon. Blue Jay 23:15-17.

Gould, E. 1955. The feeding efficiency of insectivorous bats. Ibid 36:399-407.

Griffin, D.R. 1970. Migrations and homing of bats. Pages 233-264 *in* W.A. Wimsatt, ed. Biology of bats. Vol. 1. Academic Press, New York. 406pp.

Griffin, D.R., F.A. Webster, and C.R. Michael. 1960. The echolocation of flying insects by bats. Animal Behavior 8:141-154.

Gruver, J.C. 2002. Assessment of bat community structure and roosting habitat preferences for the hoary bat (*Lasiurus cinereus*) near Foote Creek Rim, Wyoming. M.S. Thesis, University of Wyoming, Laramie. 149pp.

Gumbert, M.W., J.M. O'Keefe, and J.R. MacGregor. 2002. Roost fidelity in Kentucky. Pages 143-152 *in* The Indiana bat: biology and management of an endangered species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Hall, L.S. and G.C. Richards. 1972. Notes on *Tadarida australis* (Chiroptera:molossidae). Australian Mammalogy 1:46.

Hallman, R.C. 1968. Hoary bat (*Lasiurus cinereus*) in Bay County, Florida. Florida Naturalist 41:36.

Hamilton, W.J., Jr. and J.O. Whitaker, Jr. 1979. Mammals of the eastern United States. Cornell Univ. Press, Ithaca, NY. 346pp.

Hansen, P., B. Grand, and N. Lange. 1992. Power to spare in the Upper Midwest. Izaak Walton League of America. Minneapolis, MN, 30 pp.

Harvey, M.J. 2002. Status and ecology in the southern United States. Pages 29-34 *in* The Indiana bat: biology and management of an endangered species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Hayes, J.P. and D.L. Waldien. 2000a. Potential influences of the proposed Condon Wind Project on bats. Unpublished report prepared for CH2MHILL, Portland, Oregon. 14pp.

Hayes, J.P. and D.L. Waldien. 2000b. Potential influences of the Stateline wind project on bats. Unpublished report prepared for CH2MHILL, Portland, Oregon.

Hickey, M.B.C. 1992. Effect of radiotransmitters on the attack success of hoary bats, *Lasiurus cinereus*. Journal of Mammalogy 73:344-346.

Hickey, M.B.C. and M.B. Fenton. 1990. Foraging by red bats (*Lasiurus borealis*): do intraspecific chases mean territoriality? Canadian Journal of Zoology 68:2477-2482.

Hickey, M.B.C. and M.B. Fenton. 1996. Behavioural and thermoregulatory responses of female hoary bats, *Lasiurus cinereus* (Chiroptera: Vespertilionidae), to variations in prey availability. Ecoscience 3:414-422.

Hitchcock, H.B. 1965. Twenty-three years of bat banding in Ontario and Quebec. Canadian Field-Naturalist 79:4-14.

Howe, R.W., W. Evans, and A.T. Wolf. 2002. Effects of wind turbines on birds and bats in northeastern Wisconsin. Wisconsin Public Service Corporation, Madison, Wisconsin.

Howell, J.A. 1997. Bird mortality at rotor swept area equivalents, Altamont Pass and Montezuma Hills, California. Transactions of the Western Section of the Wildlife Society 33:24-29.

Howell, J.A. and J.E. Didonato. 1991. Assessment of avian use and mortality related to wind turbine operations, Altamont Pass, Alameda and Contra Costa Counties, California, September 1998 through August 1989. Final report submitted to U.S. Wind power, Inc.

Hubbard, E.A. 1963. Another hoary bat found hanging on a fence. Journal of Mammalogy 4:265.

Humphrey, S.R. and J.B. Cope. 1976. Population ecology of the little brown bat, *Myotis lucifugus*, in Indiana and north-central Kentucky. American Society of Mammalogists Special Publication No. 4. 81pp.

Humphrey, S.R. and T.H. Kunz. 1976. Ecology of a Pleistocene relict, the western big-eared bat (*Plecotus townsendii*), in the southern Great Plains. Journal of Mammalogy 57:470-494.

Humphrey, S.R., A.R. Richter, and J.B. Cope. 1977. Summer habitat and ecology of the endangered Indiana bat, *Myotis sodalis*. Journal of Mammalogy 58:334-346.

Hutchinson, J.T. and M.J. Lacki. 1999. Foraging behavior and habitat use of red bats in mixed mesophytic forests of the Cumberland Plateau, Kentucky. Pages 171-177 *in* Stringer, J.W. and D.L. Loftis (eds.), Proceedings, 12th Central Hardwood Forest Conference. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.

Hutchinson, J.T. and M.J. Lacki. 2000. Roosting behavior and foraging activity of a female red bat with nonvolant young. Bat Research News 41:36-38.

Iwen, F.A. 1958. Hoary bat the victim of a barbed wire fence. Journal of Mammalogy 39:438.

Izor, R.J. 1979. Winter range of the silver-haired bat. Journal of Mammalogy 69:641-643.

Jen, P.H.-S. and J.K. McCarty. 1978. Bats avoid moving objects more successfully than stationary ones. Nature 275:743-744.

Johnson, G.D. 2003. What is known and not known about bat collision mortality at wind plants? In R.L. Carlton, editor. Avian interactions with wind power structures. Proceedings of a workshop in Jackson Hole, Wyoming, USA, October 16-17, 2002. Electric Power Research Institute Technical Report, Concord, CA (in press).

Johnson, G.D., W.P. Erickson, M.D. Strickland, M.F. Shepherd and D.A. Shepherd. 2000a. Avian Monitoring Studies at the Buffalo Ridge Wind Resource Area, Minnesota: Results of a 4-year study. Technical report prepared for Northern States Power Co., Minneapolis, MN. 212pp.

Johnson, G.D., D.P. Young, Jr., W.P. Erickson, M.D. Strickland, R.E. Good and P. Becker. 2000b. Avian and bat mortality associated with the initial phase of the Foote Creek Rim Wind power Project, Carbon County, Wyoming: November 3, 1998 - October 31, 1999. Tech. Rept. prepared for SeaWest Energy Corporation and Bureau of Land Management. 32pp.

Johnson, G.D., W.P. Erickson, M.D. Strickland, M.F. Shepherd, D.A. Shepherd, and S.A. Sarappo. 2002. Collision mortality of local and migrant birds at a large-scale wind power development on Buffalo Ridge, Minnesota. Wildlife Society Bulletin 30:879-887.

Johnson, G.D., W.P. Erickson, M.D. Strickland, M.F. Shepherd, D.A. Shepherd, and S.A. Sarappo. 2003a. Mortality of bats at a large-scale wind power development at Buffalo Ridge, Minnesota. American Midland Naturalist 150:332-342.

Johnson, G.D., M.K. Perlik, W.P. Erickson, M.D. Strickland, D.A. Shepherd, and P. Sutherland, Jr. 2003b. Bat interactions with wind turbines at the Buffalo Ridge, Minnesota Wind Resource Area: An assessment of bat activity, species composition, and collision mortality. Electric Power Research Institute, Palo Alto, California, and Xcel Energy, Minneapolis, Minnesota. In Press.

Johnson, G.D., W.P. Erickson, and J. White. 2003b. Avian and bat mortality at the Klondike, Oregon Phase I Wind Plant. Technical report prepared for Northwestern Wind Power by WEST, Inc.

Johnson, P.B. 1933. Accidents to bats. Journal of Mammalogy 14:156-157.

Kerlinger, P. 1995. How birds migrate. Stackpole, Mechanicsburg, Pennsylvania.

Kerlinger, P., R. Curry, and R. Ryder. 2000. Ponnequin wind energy project avian studies, Weld County, Colorado: Summary of activities during 2000. Prepared for Public Service Company of Colorado, Denver, Colorado.

Kiefer, A., H. Merz, W. Rackow, H. Roer, and D. Schlegel. 1995. Bats as traffic casualties in Germany. Myotis 32-33:215-220.

Koehler, C.E. and R.M.R. Barclay. 2000. Post-natal growth and breeding biology of the hoary bat (*Lasiurus cinereus*). Journal of Mammalogy 81:234-244.

Krenz, J.D., and B.R. McMillan. 2000. Final Report: Wind-turbine related bat mortality in southwestern Minnesota. Minnesota Department of Natural Resources, St. Paul.

Krusac, D.L. and S.R. Mighton. 2002. Conservation of the Indiana bat in national forests: where we have been and where we should be going. Pages 55-65 in A. Kurta and J. Kennedy (eds.), The Indiana Bat: Biology and Management of an Endangered Species. Bat Conservation International, Austin, Texas.

Kunz, T.H. 1971. Reproduction of some Vespertilionid bats in central Iowa. American Midland Naturalist 86:477-486.

Kunz, T.H. 1982. *Lasionycteris noctivagans*. Mammalian Species 172:1-5.

Kunz, T.H. and R.A. Martin. 1982. *Plecotus townsendii*. Mammalian Species 175:1-6.

Kurta, A. and R.H. Baker. 1990. *Eptesicus fuscus*. Mammalian Species 356:1-10.

Kurta, A. and J.O. Whitaker. 1998. Diet of the endangered Indiana bat (*Myotis sodalis*) on the northern edge of its range. American Midland Naturalist 140:280-286.

Kurta, A., S.W. Murray, and D.H. Miller. 2002. Roost selection and movements across the summer landscape. Pages 118-129 *in* The Indiana bat: biology and management of an endangered species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Kurta, A., D. King, J.A. Teramino, J.M. Stribley, and K.J. Williams. 1993. Summer roosts of the endangered Indiana bat (*Myotis sodalis*) on the northern edge of its range. American Midland Naturalist 129:132-138.

Kurta, A., K.J. Williams, and R. Miles. 1996. Ecological, behavioural, and thermal observations of a peripheral population of Indiana bats (*Myotis sodalis*). Pages 102-117 in Bats and Forests Symposium, R.M.R. Barclay and R.M. Brigham (eds.). Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia, Canada.

Lacki, M.J., M.D. Adam, and L.G. Shoemaker. 1993. Characteristics of feeding roosts of Virginia big-eared bats in Daniel Boone National Forest. Journal of Wildlife Management 57:539-543.

LaVal, R.K. and M.L. LaVal. 1980. Ecological studies and management of Missouri bats, with emphasis on cave-dwelling species. Missouri Department of Conservation, Terrestrial Series 8:1-52.

LaVal, R.K. and M.L. LaVal. 1979. Notes on reproduction, behavior, and abundance of the red bat, *Lasiurus borealis*. Journal of Mammalogy 60:209-212.

LaVal, R.K., R.L. Clawson, M.L. LaVal, and W. Caire. 1977. Foraging behavior and nocturnal activity patterns of Missouri bats, with emphasis on the endangered species *Myotis grisescens* and *Myotis sodalis*. Journal of Mammalogy 58:592-599.

Leddy, K.L., K.F. Higgins, and D.E. Naugle. 1999. Effects of wind turbines on upland nesting birds in Conservation Reserve Program grasslands. Wilson Bulletin 111:100-104.

Lewis, T. 1970. Patterns of distributions of insects near a wind break of tall trees. Annals of Applied Biology 65:213-220.

Limpens, H.J.G.A. and K. Kapteyn. 1991. Bats, their behaviour and linear landscape elements. Myotis 29:39-47.

Lincoln, F.C. 1950. Migration of birds. U.S. Fish and Wildlife Service, Circular No. 16, Washington, D.C.

Mackey, R.L. and R.M.R. Barclay. 1989. The influence of physical clutter and noise on the activity of bats over water. Canadian Journal of Zoology 67:1167-1170.

Manville, R.H. 1963. Accidental mortality in bats. Mammalia 27:361-366.

Manville, A. M. 2001. The ABCs of avoiding bird collisions at communication towers: the next steps. Proceedings of the Avian Interactions Workshop, December 2, 1999, Charleston, South Carolina. Electric Power Research Institute, Washington, D.C., USA.

McCracken, G.F. 1996. Bats aloft: a study of high-altitude feeding. BATS 14:7-10.

Miller, N.E., R.D. Drobney, R.L. Clawson, and E.V. Callahan. 2002. Summer habitat in northern Missouri. Pages 165-171 *in* The Indiana bat: biology and management of an endangered species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Mills, R.S., G.W. Barrett, and M.P. Farrell. 1975. Population dynamics of the big brown bat (*Eptesicus fuscus*) in southwestern Ohio. Journal of Mammalogy 56:591-604.

Mueller, H.C. 1968. The role of vision in vespertilionid bats. American Midland Naturalist 79:524-525.

Mumford, R.E. and J.O. Whitaker, Jr. 1982. Mammals of Indiana. Indian Univ. Press, Bloomington, IN. 537pp.

Nicholson, C.P. 2003. Buffalo Mountain Windfarm bird and bat mortality monitoring report: October 2001 - September 2002. Tennessee Valley Authority, Knoxville.

Nicholson, C.P. 2001. Buffalo Mountain Windfarm bird and bat mortality monitoring report: October 2000 - September 2001. Tennessee Valley Authority, Knoxville.

Norberg, U.M. and J.M.V. Rayner. 1987. Ecological, morphology and flight in bats (Mammalia: Chiroptera): wing adaptations, flight performance, foraging strategy and echolocation. Philosophical Transactions Royal Society London 316:335-427.

Nordquist, G.E. 1997. Bats in Minnesota. James Ford Bell Museum of Natural History Natural History Leaflet. Univ. of Minnesota.

Obrist, M.K. 1995. Flexible bat echolocation: the influence of individual, habitat and conspecifics on sonar signal design. Behavioral Ecology and Sociobiology 36:207-219.

Orloff, S. and A. Flannery. 1992. Wind turbine effects on avian activity, habitat use, and mortality in Altamont Pass and Solano County Wind Resource Areas, 1989-1991. Final Report to Alameda, Costra Costa and Solano Counties and the California Energy Commission by Biosystems Analysis, Inc., Tiburon, CA.

Osborn, R.G., K.F. Higgins, C.D. Dieter, and R.E. Usgaard. 1996. Bat collisions with wind turbines in southwestern Minnesota. Bat Research News 37:105-108.

Owen, S.F., M.A. Menzel, W.M. Ford, B.R. Chapman, K.V. Miller, J.W. Edwards, and P.B. Wood. 2001. First summer record of a female Indiana bat, *Myotis sodalis*, in West Virginia. Journal of the Elisha Mitchell Scientific Society 117:132-134.

Puzen, S.C. 2002. Bat interactions with wind turbines in northeastern Wisconsin. Wisconsin Public Servcie Commission, Madison, Wisconsin.

Racey, P.A. and S.M. Swift. 1985. Feeding ecology of *Pipistrellus pipistrellus* (Chiroptera: Vespertilionidae) during pregnancy and lactation. I. Foraging behaviour. Journal of Animal Ecology 54:205-215.

Richardson, W.J. 1974. Spring migration over Puerto Rico and the western Atlantic: a radar study. Ibis 116:172-193.

Richardson, W.J. 1976. Autumn migration over Puerto Rico and the western Atlantic: a radar study. Ibis 118:309-332.

Rolseth, S.L., C.E. Koehler, and R.M.R. Barclay. 1994. Differences in the diets of juvenile and adult hoary bats, *Lasiurus cinereus*. Journal of Mammalogy 75:394-398.

Sample, B.E. and R.C. Whitmore. 1993. Food habits of the endangered Virginia big-eared bat in West Virginia. Journal of Mammalogy 74:428-435.

Saunders, W.E. 1930. Bats in migration. Journal of Mammalogy 11:225.

Schmidt, E., A.J. Piaggio, C.E. Bock, and D.M. Armstrong. 2003. National Wind Technology Center site environmental assessment: bird and bat use and fatalities – final report NREL/SR-500-32981, National Renewable Energy Laboratory, Golden, Colorado. 21pp.

Schnitzler, H.U. 1987. Echoes of fluttering insects: information for echolocating bats. Pages 226-243 *In* Fenton, M.B., P.A. Racey, and J.V.M. Rayner (eds.). Recent Advances in the Study of Bats. Cambridge University Press, Cambridge, UK.

Schnitzler, H.U. and E.K.V. Kalko. 1998. How echolocating bats search and find food. Pages 183-196 In T.H. Kunz and P.A. Racey (eds.). Bat Biology and Conservation. Smithsonian Institution Press, Washington, D.C.

Shump, K.A., Jr. and A.U. Shump. 1982a. *Lasiurus cinereus*. Mammalian Species 185:1-5.

Shump, K.A., Jr. and A.U. Shump. 1982b. *Lasiurus borealis*. Mammalian Species 183:1-6

Simmons, J.A., M.B. Fenton, and M.J. O'Farrell. 1979. Echolocation and the pursuit of prey by bats. Science 203:16-21.

Simmons, J.A. and R.A. Stein. 1980. Acoustic imaging in bat sonar: echolocation signals and the evolution of echolocation. Journal of Comparative Physiology 135:61-84.

Speakman, J.R. and P.A. Racey. 1991. No cost of echolocation for bats in flight. Nature 350:421-423.

Studier, E.H. and M.J. O'Farrell. 1972. Biology of *Myotis thysanodes* and *M. lucifugus* (Chiroptera: Vespertilionidae) – I. Thermoregulation. Comparitive Biochemistry and Physiology 41A:567-595.

Stihler, C.W. 1994. Radio telemetry studies of the endangered Virginia big-eared bat (*Plecotus townsendii virginianus*) at Cave Mountain Cave, Pendleton County, West Virginia. West Virginia Division of Natural Resources Endangered Species Program report.

Stihler, C.W. 1995. A radio telemetry study of female Virginia big-eared bats (*Corynorhinus* (=*Plecotus*) *townsendii virginianus*) at a maternity colony in Cave Mountain Cave, Pendleton County, West Virginia, June-July 1994. West Virginia Division of Natural Resources Nongame Wildlife and Natural Heritage Program.

Stihler, C.W. and V. Brack, Jr. 1992. A survey of hibernating bats in Hellhole Cave, Pendleton County, WV. Proceedings of the West Virginia Academy of Science 64:97-103.

Suthers, R.A. 1970. Vision, olfaction, and taste. Pages 265-309 *in* W.A. Wimsatt, ed. Biology of bats. Vol. 2. Academic Press, New York. 477pp.

Suthers, R.A. 1966. Optomotor responses by echolocating bats. Science 152:1102-1104.

Taylor, W.K. and B.H. Anderson. 1973. Nocturnal migrants killed at a central Florida TV tower: autumns 1969-1971. Wilson Bulletin 85:42-51.

Tenaza, R.H. 1966. Migration of hoary bats on South Farallon Island, California. Journal of Mammalogy 47:533-535.

Tennessee Valley Authority. 2002. Draft Environmental Assessment - 20-MW Windfarm and Associated Energy Storage Facility. Tennessee Valley Authority, Knoxville, Tennessee.

Terres, J.K. 1956. Migration records of the red bat, *Lasiurus borealis*. Journal of Mammalogy 37:442.

Thelander, C.G. and L. Rugge. 2000. Bird risk behaviors and fatalities at the Altamont Wind Resource Area. Pp. 5-14 *in* Proceedings of the National Avian-Wind Power Planning Meeting III. National Wind Coordinating Committee/RESOLVE. Washington, D.C.

Thomas, D.W. 1988. The distribution of bats in different ages of Douglas-fir forests. Journal of Wildlife Management 52:619-626.

Timm, R.M. 1989. Migration and molt patterns of red bats. Illinois Bull. Chicago Academy of Science.

U.S. Department of Energy. 2002. Draft Site-Wide Environmental Assessment of National Renewable Energy Laboratory's National Wind Technology Center. U.S. Department of Energy, Golden, Colorado.

U.S. Fish and Wildlife Service. 1999. Agency draft. Indiana bat (*Myotis sodalis*) revised recovery plan. U.S. Fish and Wildlife Service, Fort Snelling, Minnesota.

Van Gelder, R.G. 1956. Echo-location failure in migratory bats. Transactions of the Kansas Academy of Science 59:220-222.

Whitaker, J.O., Jr., and V. Brack, Jr. 2002. Distribution and summer ecology in Indiana. Pages 48-54 *in* The Indiana bat: biology and management of an endangered species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Williams, T.C. and J.M. Williams. 1970. Radio tracking of homing and feeding flights of a neotropical bat. Animal Behavior 18:302-309.

Wilson, D.E. and S. Ruff, eds. 1999. The Smithsonian book of North American Mammals. Smithsonian Institution Press, Washington, D.C. 750 pp.

Wilson, N. 1965. Red bats attracted to insect light traps. Journal of Mammalogy 46:704-705.

Wisely, A.N. 1978. Bat dies on barbed wire fence. Blue Jay 36:53.

Young, D.P., Jr., W.P. Erickson, R.E. Good, M.D. Strickland, and G.D. Johnson. 2003. Avian and bat mortality associated with the initial phase of the Foote Creek Rim wind power project, Carbon County, Wyoming: November 1998 – June 2002. Tech. Rept. prepared for SeaWest Energy Corporation and Bureau of Land Management.

Young, D.P., Jr., W.P. Erickson, M.D. Strickland, and R.E. Good. 2002. Comparison of avian effects from UV light reflective paint applied to wind turbines: Foote Creek Rim Wind Plant, Carbon County, Wyoming. National Renewable Energy Laboratory, Golden, Colorado.

Zinn, T.L. and W.W. Baker. 1979. Seasonal migration of the hoary bat, *Lasiurus cinereus*, through Florida. Journal of Mammalogy 60:634-635.