Bat Interactions With Wind Turbines at the Buffalo Ridge, Minnesota Wind Resource Area

An Assessment of Bat Activity, Species Composition, and Collision Mortality

Technical Report

Bat Interactions With Wind Turbines at the Buffalo Ridge, Minnesota Wind Resource Area

An Assessment of Bat Activity, Species Composition, and Collision Mortality

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REPORT SUMMARY

During avian monitoring studies conducted from 1994-1999, several bat collision victims were found at wind turbines in the Buffalo Ridge Resource Area (WRA) in southwest Minnesota. This study further examined bat interactions with wind turbines at this site.

Background

Although development of renewable energy sources is generally considered environmentally friendly, wind power development has been associated with the deaths of birds colliding with turbines and other wind plant structures. Bats may also be affected. EPRI and Xcel Energy, Inc. sponsored a study of bat interactions at Xcel‘s 354 turbine 236 MW wind plant on Buffalo Ridge, located in southwest Minnesota. The wind development area currently consists of three major phases of development. Phase 1 was constructed in 1994 and consists of 73 Kenetech Model 33 M-VS 330 KW turbines. Turbines in Phase 1 are no longer being manufactured and are not representative of new-generation larger turbines; therefore, they were not included in this study. Phase 2 consists of 143 and Phase 3 consists of 138 newer-generation Zond Model Z-750 750 KW turbines.

Objectives

To evaluate the effect of existing wind plants on bats in the Buffalo Ridge WRA; to develop mitigation measures to reduce impacts on bats.

Approach

From mid June through mid September in 2001 and 2002, the breeding season and fall migration period for bats in the Buffalo Ridge study area, the project team surveyed bats using ultrasonic sensors that detect bat echolocation calls. In all, the team surveyed 216 turbines and many bat roosting and foraging sites and determined the relationship between bat activity and subsequent mortality by searching turbine plots for bat fatalities. The team also used mist nets to sample bat populations in the vicinity of the turbines and studied the relations between habitat and landscape features and bat activity and mortality patterns.

Results

The study estimates the relative abundance and composition of the bat population in the study area and the number of bat fatalities attributable to wind plant development. The estimated total number of bat collision fatalities for both wind plants combined was 849 in 2001 and 364 in 2002, for an overall average of 2.16/turbine/year. The 151 bat casualties actually recorded in the study comprised 115 hoary bats (*Lasiurus cinereus*), 21 eastern red bats (*Lasiurus borealis*), 8 big brown bats (*Eptesicus fuscus*), 4 silver-haired bats (*Lasionycteris noctivagans*), and 3 little brown bats (*Myotis lucifugus*). Most (82%) were found from mid July to the end of August. The species composition of bat casualties differed from that of the local bat population as estimated

from mist net sampling. Habitat variables did not correlate with the number of bat fatalities, and there was no statistical relationship between bat activity at turbines and the number of bat fatalities. Over all, collision fatalities are very rare given the amount of bat activity documented at turbines.

Both the bat detector and mist net data indicate there are relatively large breeding populations of bats in close proximity to the wind plant that experience little to no wind plant related collision mortality. Based on all available evidence, most bat mortality at Buffalo Ridge involves migrating bats. Data suggest that the number of bats migrating through the Buffalo Ridge area may be substantial and that wind plant-related mortality is apparently not large enough to cause large-scale population declines. Future research should concentrate on determining the causes of bat collisions and methods to reduce and/or mitigate the mortality.

EPRI Perspective

As wind power development proceeds in the United States, more is being learned about the effects that siting, construction, and operation of these facilities have on animal communities. Each wind resource area possesses unique characteristics. For example, at Buffalo Ridge birds are less impacted than bats, an observation that differs from studies of other sites. An emerging conclusion from the many diverse studies conducted in wind resource areas is that landscape ecologists must be brought in early on to assess the potential impact on existing and future animal populations that might use the area.

Keywords

Bats
Bat detector
Buffalo Ridge
Collision mortality
Minnesota
Wind turbine

ABSTRACT

EPRI and Xcel Energy, Inc. conducted a study to evaluate bat activity levels, species composition and collision mortality at a large wind plant in the Buffalo Ridge Wind Resource Area, Minnesota. Bat echolocation detectors recorded 3,718 bat passes at bat foraging and roosting areas within 2.25 miles of the wind plant ($\bar{x}$ = 48/detector-night) and 452 bat passes at wind turbines ($\bar{x}$ = 1.9/detector-night). Peak bat activity at turbines followed the same trend as bat mortality and occurred from mid July through the end of August. Over the 2-year study, 151 bat casualties were found, most of which were hoary bats (*Lasiurus cinereus*). Based on the timing of fall bat migration, most bat mortality apparently involved migrating bats. The study indicated that there were relatively large breeding populations of bats in close proximity to the wind plant when collision mortality was very low to non-existent. There was no significant relationship between bat activity or mortality at turbines and presence of FAA lighting on turbines. Mist nets were used to capture 103 bats comprised of five species in the study area. Big brown bats (*Eptesicus fuscus*) comprised most of the captures. Future research should concentrate on determining the causes of bat collisions and methods to reduce and/or mitigate the mortality.

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1

INTRODUCTION

Wind has been used to commercially produce energy in the U.S. since the early 1970s (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). To date, most wind power development in the U.S. has occurred in California and Texas, but greater than 90% of the wind power potential in the U.S. exists within the Midwestern and western states (Weinberg and Williams 1990).

Although development of renewable energy sources is generally considered environmentally friendly, wind power development has been associated with the deaths of birds colliding with turbines and other wind plant structures, especially in California (Erickson *et al*. 2001). As a result of these concerns, state and federal agencies have required monitoring of many new wind development areas to assess the extent of and potential for avian collision mortality.

In 1999, Xcel Energy, Inc. completed development of a 354 turbine 236-megawatt (MW) wind plant on Buffalo Ridge, located in southwestern Minnesota (Figure 1-1). Extensive research was conducted at this wind plant to assess potential for bird impacts and to measure actual impacts (Nelson 1993, Higgins *et al*. 1996, Leddy 1996, Hawrot and Hanowski 1997, Leddy *et al*. 1997, Usgaard *et al*. 1997, Osborn *et al*. 1998, Leddy *et al*. 1999, Johnson *et al.* 2000a, Osborn *et al.* 2000, Johnson *et al.* 2002a). An unexpected outcome of the avian monitoring studies was the discovery of bat collision fatalities near turbines. During the first two years of operation (1994 and 1995), researchers found 13 bat fatalities in association with turbines in the Phase 1 study area (Osborn *et al*. 1996). No further bat mortality was documented during searches conducted at the Phase 1 site in 1996 and 1997 (Johnson *et al*. 2000a). In 1998, however, two dead bats were found in the Phase 1 study area and 76 dead bats were collected in the Phase 2 study area, where the wind plant became operational in the summer of 1998. In 1999, 106 dead bats were found, including five in the Phase 1 wind plant, 57 in the Phase 2 wind plant, and 44 in the Phase 3 wind plant that became operational in the summer of 1999 (Johnson *et al*. 2003a).

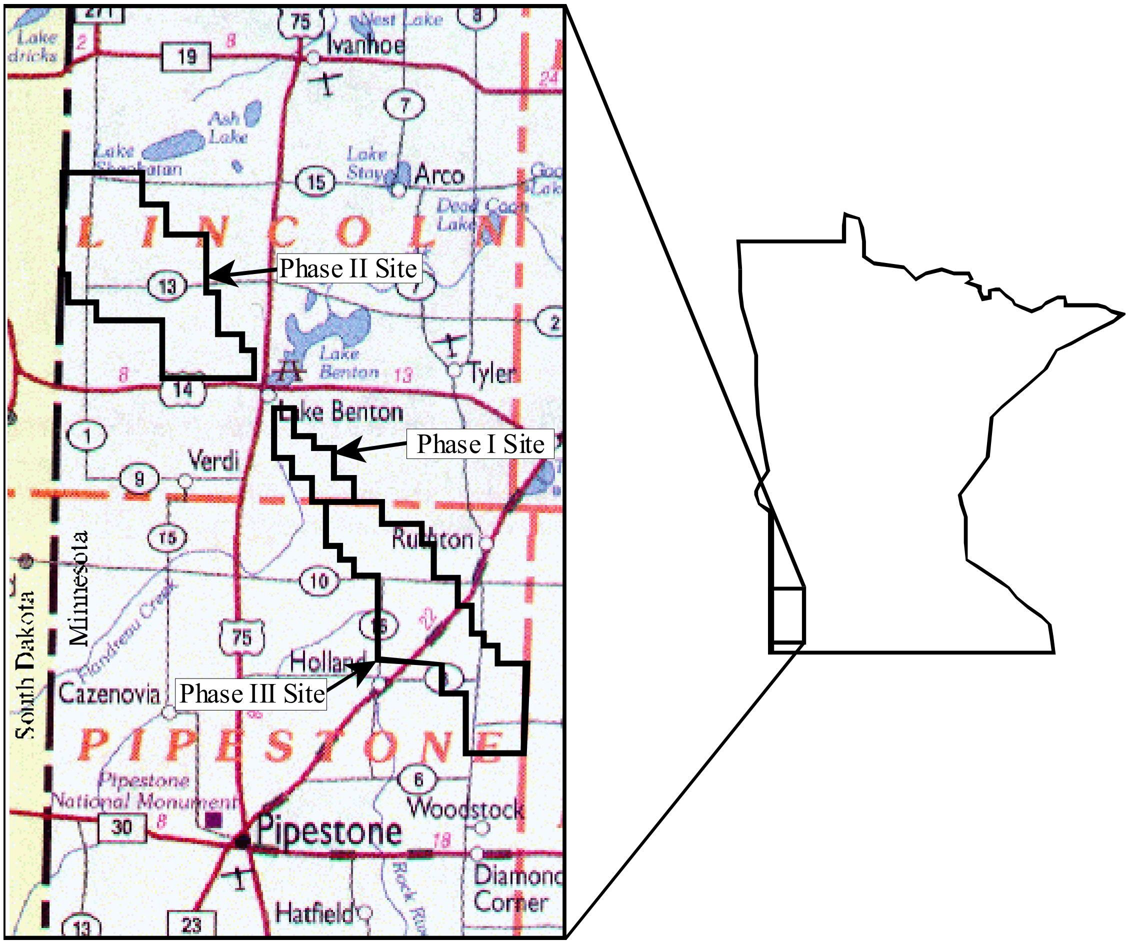

Figure 1-1
Location of the Buffalo Ridge Wind Resource Area and Individual Wind Plants in Southwest Minnesota

The primary objective of this study was to evaluate the effect of existing wind plants on bats in the Buffalo Ridge Wind Resource Area (WRA). The two necessary study components required to meet this objective included (1) estimating the relative abundance and composition of the bat population in the study area, and (2) estimating the number of bat fatalities attributable to wind plant development. Because the size of the affected population depends greatly on whether resident or migrant bats are being killed, we also attempted to address whether the mortality was occurring to resident breeders, migrants, or both. The study was conducted from June 15 to September 15, 2001 and 2002, which covers both the breeding season and fall migration periods for bats in the study area.

Secondary study objectives included (1) determining if species composition of the fatalities was similar to composition of the local or migrant bat population and (2) determining what physical (e.g., turbine characteristics) and biological (e.g., habitat) factors might be associated with bat collision mortality in the study area. The final objective was to develop mitigation measures that may be used to reduce bat mortality if the number of fatalities was found to be significant.

2
STUDY AREA

The study area was comprised of a large portion of Buffalo Ridge, a 100-km-long segment of the Bemis Moraine located in Lincoln and Pipestone Counties in southwest Minnesota and Brookings County, South Dakota (Figure 2-1). Buffalo Ridge is located in the Coteau des Prairies, a major physiographic landform consisting of terminal moraines and stream-dissected lands (Coffin and Pfannmuller 1988). The ridge runs diagonally from southeast to northwest and separates the Missouri and Mississippi River watersheds. Elevations in the study area range from 546 m to 610 m above sea level. The primary vegetation type in the study area is cultivated cropland, which comprised an average of 57.1% of the study area from 1996 through 1999 (Johnson *et al.* 2000a). The two most common crops were soybeans and corn. Pastures comprised 21.5% of the study area and Conservation Reserve Program (CRP) grasslands comprised 7.7%. Most CRP fields were planted to a mixture of smooth brome and alfalfa or to monocultures of switchgrass. Hayfields comprised 7.3% of the study area. Deciduous woodlots associated with farmsteads and wooded ravines comprised 4.8% of the study area, and wetlands comprised 1.5% of the area. Detailed descriptions of the study area have previously been presented in Johnson *et al.* (2000a), and descriptions of vegetation vertical density and height have previously been described for cropland, pasture, and CRP habitats occurring within the Buffalo Ridge study area (Leddy 1996).

The wind development area consisted of three major phases of development (Figure 1-1). Phase 1 was constructed in 1994 and consists of 73 Kenetech Model 33 M-VS 330 kilowatt (KW) turbines. The Kenetech turbine is no longer being manufactured and these small turbines are not representative of the larger, newer generation turbines currently being constructed at most wind plants. In addition, the number of bat fatalities at these turbines documented during avian studies was minor in comparison to other turbines in the WRA (Johnson *et al*. 2000a). For these reasons, we did not sample any turbines in the Phase 1 wind plant during this study. Phase 2, consisting of 143 newer-generation Zond Model Z-750 (750 KW) turbines capable of generating 107.25 MW of electricity, was completed in July 1998. Phase 2 consists of 26 strings of turbines, with 2 to 12 turbines per string spaced at intervals ranging from approximately 100 m to 200 m. The Zond turbine operates at wind speeds of 13 to 104 km/h, and is installed on top of a 50-m tubular tower. Two blade diameters are in use (46 m and 48 m). Therefore, the rotor-swept height of the turbine is either 26 m to 74 m or 27 m to 73 m above ground and the rotor-swept area is either 1661 m^2 or 1809 m^2. The Phase 2 facility has three turbines each at the north and south end of the wind plant (six total) with Federal Aviation Administration (FAA) airplane warning lights, consisting of non-pulsating red lights. Phase 3 facilities capable of generating an additional 103.5 MW with 138 Zond Model Z-750 turbines were completed in June 1999. Phase 3 consists of 36 strings of Turbines, with 2 to 13 Turbines per string spaced at intervals ranging from approximately 250 m to 500 m. Due to its proximity to the Pipestone, Minnesota airport, every other turbine within the Phase 3 wind plant has FAA lighting comprised of non-pulsating red lights. In addition to the 354 turbines within the three major developments, several small developments totaling an additional 55 turbines have recently been completed. The Buffalo Ridge wind power development is currently one of the largest in operation outside of California.

3
METHODS

Measuring Bat Activity Using Bat Echolocation Detectors

Bats can be surveyed using ultrasonic sensors that detect bat echolocation calls (Fenton 1988, Pye 1992). They are widely used to index and compare habitat use by bats (Fur longer *et al*. 1987, Thomas 1988, Hayes 1997, Racey 1998, Humes *et al*. 1999, Jung *et al*. 1999, Everette *et al*. 2001, Britzke *et al*. 2002, Swier 2003). We used Anabat® II bat detectors (Titley Electronics Pty Ltd., NSW, Australia). These detectors can easily be set up at multiple survey sites (Hayes and Hounihan 1994), do not require constant attention by the researcher (Murray *et al.* 1999), and are considered a valuable tool for comparing relative amounts of bat activity (Fenton 2000).

Anabat® II detectors record bat echolocation calls with a broadband microphone. The echolocation sounds are then translated into frequencies audible to humans by dividing the frequencies by a predetermined ratio. We used a division ratio of 16 that lowers the frequencies of western Minnesota bat species to less than 10 kHz, the upper limit for the Anabat® software. Bat echolocation detectors also detect other ultrasonic sounds made by insects, raindrops hitting vegetation, and other sources. We used a sensitivity level of 5-7 (usually 6) to reduce interference from these other sources of ultrasonic noise.

For most of the study, we used an Anabat® II delay switch and tape recorder to record bat calls. The delay switch activates the detector and recorder only when a bat call is detected. During the last month of the 2002 field season, we obtained ZCAIMs (zero crossings analysis interface module) recently introduced to the market by Titley Electronics. ZCAIMS use compact flash memory cards with large storage capacity, which eliminated the need for both the delay switches and tape recorders. The Anabat® detector and associated equipment were placed inside a plastic Tupperware® container and a hole was cut in the side of the container for the microphone to extend through. Although recording calls directly onto a laptop computer results in higher clarity recordings than use of a tape recorder (see Johnson *et al*. 2002b), it is usually cost prohibitive to use computers in the field with each detector during large scale studies such as this one (White and Gehrt 2001), and tape recorders have successfully been used in many bat echolocation studies (Hart *et al*. 1993, Hayes 1997, Jung *et al.* 1999, Gruver 2002). The most problematic group for species identifications are *Myotis* and *Pipistrellus* species due to their similar call structures (Rydell *et al*. 1994, Vaughan *et al*. 1997, Jung *et al*. 1999). Only three bats of these genera occur in Minnesota (Hazard 1982), the little brown bat (*Myotis lucifugus*), which is apparently fairly common in the study area as well as throughout Minnesota, Keen's myotis (*Myotis keenii*), which has a spotty distribution in Minnesota (Hazard 1982), and eastern pipistrelle (*Pipistrellus subflavus*), which has only recently been documented to occur west of St. Cloud, Minnesota (Osborn *et al*. 1996). Except for silver-haired (*Lasionycteris noctivagans*) and big brown bats (*Eptesicus fuscus*), which can have overlapping call characteristics (Betts 1998a), the other species likely encountered in southwest Minnesota can be readily differentiated and use of a computer to record calls is not as critical as in other locations in the U.S. where many species of *Myotis* may occur in the same area. Furthermore, White and Gehrt (2001) found no difference in the number of calls, passes, identifiable passes, or feeding buzzes/hour recorded simultaneously with tape recorders and computers. From this, they concluded that measures of general bat activity are relatively robust to types of recording devices.

We used four Anabat® II detectors during the study. Each survey night, three detectors were placed at turbines and one detector was placed at a potential bat roosting or foraging site (e.g., woodland or wetland) within the study area. Turbine locations were selected using a systematic design with a random start. Detectors were moved to different turbines each night. Over the two 3-month study periods, we used bat detectors to record bat activity at 216 turbines in the Phase 2 and Phase 3 wind plants. The detectors were placed near the base of turbines and the detector microphone was elevated to approximately 30°, which is commonly used in bat detector studies (Hayes 1997, Humes *et al*. 1999, Seidman and Zabel 2001). Bat detectors were not set out if rain was forecast as rain may damage the equipment.

For this study, bat passes were the units of activity (Hayes 1997). A pass is defined as a train of echolocation calls produced by an individual bat (Hickey *et al*. 1996), and consists of a continuous series of ≥ 2 call notes with no pauses between call notes of > 1 second (Thomas 1988, Everette *et al*. 2001, White and Gehrt 2001, Weller and Zabel 2002, Gannon *et al*. 2003). The number of bat passes was determined by listening to the audiotapes (Krusic *et al*. 1996, Grindal and Brigham 1999, Seidman and Zabel 2001). Data were expressed as the number of bat passes recorded per night per detector. The number of passes recorded per night was plotted over time and across space so that relative abundance of bats over the study period and across the study areas could be determined. Except at isolated roost locations such as caves, the absolute abundance of bats cannot be determined in most cases (Garcia 1998, O'Shea and Bogan 2000), and bat pass data represent levels of bat activity rather than numbers of individuals (Fenton 1970, Hickey and Neilson 1995). The relationship between bat activity recorded with the detector and the number of subsequent fatalities was determined by searching turbine plots for bat fatalities when the detectors were picked up each morning.

Bat call data were downloaded onto computers in the field office following methods in de Oliveira (1998). The calls are currently being identified by Matthew Perlik, a Minnesota State University, Mankato Graduate Student working on this project. Species identifications using the call data will be presented in Mr. Perlik's M.S. thesis.

Bat detectors were also used on 76 nights to sample likely bat foraging or roosting habits (*e.g.*, wetlands, woodlands) within 3.5 km of the wind plants. We used Anabat® recordings at these sites to monitor bat habitat use and changes in bat abundance over time as well as to determine appropriate locations for subsequent mist netting sessions. Much of this sampling occurred at Hole in the Mountain County Park, located within 0.8 km of the Phase 2 wind plant. This park was the largest contiguous tract of wooded area (324 ha) within several kilometers of the wind plant. Forty-one of the 76 Anabat®-nights occurred at this park, where bat activity was found to be the highest in the area. Other areas sampled included Norwegian Creek Park and Showboat Park along Lake Benton, several Minnesota DNR Wildlife Management Areas in Lincoln and Pipestone Counties, the Lake Benton cemetery, small ponds near the wind plants, woodlots at occupied farmsteads, and buildings/woodlots at abandoned farmsteads. All of these areas were within approximately 3.5 km of one of the Buffalo Ridge wind plants.

Proportion of each habitat within 100 m and distance to the nearest wetland and woodland were determined for each turbine randomly selected for sampling with bat detectors to determine any relationship between habitat and landscape features and level of bat activity. The relationships were examined using a Poisson regression model in which the number of passes was the response and habitat or landscape characteristic was the explanatory variable. A simple histogram of the bat activity data suggested that the distribution was not Poisson (there were both too many zeros and too many large values to fit any Poisson distribution). However, the assumptions behind other approaches, such as simple linear regression, were not well supported by the data either. Therefore, we fit Poisson regression models and made adjustments for over-dispersion (variance higher than expected) using the square root of the deviance divided by the model degrees of freedom. There was 1 degree of freedom for each chi-square test. In addition, a single outlying observation of 67 passes at one turbine in one night was deleted to avoid distortion of the regression relationships. To test for any significant difference in bat activity at turbines between study years, the variable "year" was included in the regression analyses.

At one study area in Ontario, Canada, both hoary and eastern red bats spent most of their foraging time in association with street lights (Hickey and Fenton 1990, Hickey 1992), where moth abundance is much higher than areas away from the lights (Hickey and Fenton 1990); such foraging behavior can provide significant energetic benefits to bats (de la Cueva Salcedo *et al*. 1993). Other studies have also shown high foraging activity around artificial lights by hoary, eastern red, big brown and other species of bats (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, Rydell 1990, Hutchinson and Lacki 1999); therefore, lights on turbines may increase the probability of bat collisions. A Poisson regression was also used to determine any relationship between bat activity at turbines and presence of FAA lighting on turbines.

Use of Mist Nets to Monitor Bat Abundance and Composition

Species identifications using both mist netting and bat detectors are recommended to survey bat populations (Kuenzi and Morrison 1998), as capturing bats allows for much more reliable species identifications (O'Farrel *et al*. 1999). Either an Anabat® detector or inexpensive hand-held detector (Belfrey® Bat Detector) was used to locate areas of bat activity for subsequent mist netting. Mist netting only where presence of bats was known allowed us to maximize our sample sizes for species composition estimates. Mist nets are frequently used to capture bats (Findley 1993). They are generally set up near ponds or known bat flyways (von Frenckell and Barclay 1987, Kunz and Kurta 1988). For this study, we set up mist nets primarily in woodlands and over ponds and other wetlands where bat activity is concentrated (Everette *et al*. 2001). Nets were set up to take advantage of vegetative and topographical features that channel bats into nets (Mills *et al.* 1996). Bats were trapped using mist nets specially made to catch bats by Avinet®, Inc. based on recommendations of Kunz and Kurta (1988). Nets were either 6 or 12 meters long, 2.6 meters high, and had 38 mm mesh with 4 panels made of nylon. These special bat nets have less "bag" than nets used for birds to minimize tangling. Both single as well as stacked nets totaling 5.2 m in height were used to trap bats, and some nets were elevated on poles to a top height of 6.1 m.

Each sampling occasion, up to 10 mist nets were set at sunset and checked regularly for 2.5- to 4-hour intervals each night (Kuenzi and Morrison 1998). Because capture success with mist nets often decreases greatly on consecutive nights (LaVal 1970, Kunz 1973, Kunz and Brock 1975), areas were trapped once and then were not retrapped for at least one week. Once in hand each bat was identified to species, aged, sexed, and weighed. Age (juvenile versus adult) was determined based on the degree of fusion of the distal epiphysis of the third metacarpal (fused = adult, nonfused = juvenile) (Buchler 1980, Anthony 1988). Bats were sexed based on external morphological indicators (Racey 1988). To obtain recordings of known bat calls, at least one individual bat of each species captured was marked with a chemiluminescent tag (Buchler 1976, Fenton and Bell 1981) so that its echolocation calls could be recorded when its presence was confirmed.

Mist net data were expressed as the number of bats captured by species per mist net hour. Over the 2-year study, 1,545 mist-net hours were spent over 61 nights attempting to capture bats. In addition, a funnel trap was used to capture bats from an attic in the Town of Lake Benton in 2001. This provided a unique opportunity to examine the composition of a colonial bat roost in the study area.

Fatality Searches

Mortality was measured by estimating the number of bat fatalities in the wind development areas. All bat fatalities located within search plots were recorded and a cause of death determined, if possible, based on field examination and necropsy results. An estimate of the total number of fatalities was made by adjusting for “length of stay” (scavenging) and searcher efficiency biases.

Objectives of fatality searches were to (1) estimate the number of fatalities attributable to wind turbine collisions for the Phase 2 and Phase 3 wind plants, and (2) relate the fatalities by species to the relative abundance of each species and other parameters such as turbine characteristics and habitat to aid in determining relative risk to that species.

Daily carcass searches were conducted at the three turbines where Anabat® detectors were placed the previous night to determine any relationships between bat activity at turbines and collision fatality levels. Another 80 turbines (2001) or 100 turbines (2002) were selected for additional fatality searches using a systematic design with a random start. Selected turbines were searched every two weeks throughout the study. With this design, 216 carcass searches were conducted in conjunction with Anabat® surveys and 1180 carcass searches were conducted at the randomly-selected turbines in the Phase 2 and Phase 3 areas during the study. Biologists trained in proper search techniques conducted the searches. During the avian monitoring study (Johnson *et al.* 2000a), only 1 of 184 bats was found greater than 30 m from a turbine, even though all areas within 50 m of each turbine were searched. Therefore, for this study we searched all areas within 30 m of each turbine. Proportion of each habitat within 100 m and distance to the nearest wetland and woodland were determined for each turbine randomly selected for carcass searching.

At other wind plants in the U.S. where both turbines and guyed meteorological (met) towers were searched for collision victims, no bats were found at the met towers even when significant numbers of fatalities were documented at turbines (Nicholson 2001, Young *et al.* 2002). This suggests that collision mortality is not completely random, and that something about turbines may be attracting bats (Johnson 2003). To test this theory at Buffalo Ridge, 13 meteorological towers in the Phase 2 and Phase 3 wind plants were searched for bat carcasses in July and August of 2002.

A square plot, rather than a circular one, was used to facilitate marking search boundaries and conducting the search. Transects were initially set at 6 m apart in the area to be searched, and the searcher initially walked at a rate of approximately 30-45 m/min along each transect searching both sides out to 3 m for casualties (Johnson *et al.* 1993). Transect width and search speeds were adjusted based on visibility within each habitat type. On average, approximately 20 to 25 minutes were spent searching each plot.

Searches of randomly-selected turbines were conducted once every two weeks to locate and collect any fatalities found under turbines. Casualties found at other times and places (e.g., those found on turbine pads while driving between search plots) were also collected. For all casualties found, data recorded included species, sex, age, date and time collected, location, distance to and direction from nearest turbine, condition, and any comments regarding possible causes of death. Sexing and aging of fatalities followed criteria in Kunz (1988). Inclement weather has been associated with migratory bat collisions with buildings and lighthouses (Van Gelder 1956). The estimated time since death and weather at the estimated time of death were recorded for each fatality. The condition of each fatality was recorded using the following condition categories:

- Injured – a live bat that cannot fly due to injury.
- Intact – a bat carcass that is completely intact, is not badly decomposed, and shows no sign of being fed upon by a predator or scavenger.
- Scavenged – an entire carcass that shows signs of being fed upon by a predator or scavenger or a portion(s) of a carcass in one location (*e.g.*, wings, skeletal remains, legs, pieces of skin, etc.).

Casualties were labeled with a unique number, bagged and frozen. A copy of the data sheet for each carcass was maintained with the carcass at all times. Field necropsies of all intact, suitable bat fatalities found associated with a turbine were conducted. No laboratory necropsies were conducted to determine cause of death, as data collected during the avian monitoring study indicated all bat fatalities were turbine-related (Johnson *et al.* 2000a).

The estimated average number of carcasses ($\bar{c}$) observed per turbine per year was calculated by:

$$\bar{c} = \frac{\sum_{i=1}^{n} c_i}{k}, \qquad \textbf{Eq. 3-1}$$

where c_i is the number of fatalities detected at turbine i for the period of study, and k is the number of turbines searched.

The final estimate of $\bar{c}$ and its standard error were calculated using bootstrapping (Manly 1997). Bootstrapping is a computer simulation technique that is useful for calculating point estimates, variances and confidence intervals for complicated test statistics. For each iteration of the bootstrap, the plots were sampled with replacement, and $\bar{c}$ was calculated. A total of 5000 bootstrap iterations were used. The reported estimate is the mean of the 5000 bootstrap estimates. The standard deviation of the bootstrap estimates of $\bar{c}$ is the estimated standard error of $\bar{c}$ (se($\bar{c}$)).

Fatality Search Biases

Estimation of Carcass Removal

Carcass removal trials were conducted to estimate the length of time bat fatalities remained in the search area over the 14-day interval between searches. The trials were conducted at randomly-selected turbine locations in the same areas and habitats where fatality searches occurred, but not within the same turbine plots to avoid potential for confusion of trial carcasses with collision victims. Each trial consisted of monitoring the fate of 10 to 15 bats. Bats used for the trials were intact fresh bats found dead during the study, and consisted of 42 hoary bats (*Lasiurus cinereus*), two eastern red bats (*Lasiurus borealis*), and two big brown bats.

To simulate bats that were killed or wounded by turbine collision, carcasses were (1) placed in an exposed location; (2) hidden to simulate a crippled bat (*e.g.*, placed beneath a tuft of grass); and (3) partially hidden. An equal proportion of carcasses was included in each of the above categories. Carcasses were checked daily the first seven days and then again on Day 14; all carcasses were removed at the end of the 14-day period. Estimates of carcass removal were used to adjust fatality counts for removal bias.

Carcass removal statistics were estimated by study site and habitat type. Because several bat carcasses remained at the end of 14 days, the mean length of stay was estimated using statistical methods appropriate for censored data (Barnard 2000) assuming an exponential model for removal time and the maximum likelihood estimate of the mean removal time.

The mean length of time a carcass remained in a plot before being removed ($\bar{t}$) was calculated by:

$$\bar{t} = \frac{\sum_{i=1}^{s} t_i}{s - s_c}. \qquad \textbf{Eq. 3-2}$$

where t_i is the time (days) each carcass remained in the study area before being removed, s is the number of carcasses used in removal trials, and s_c is the number of carcasses in removal trials that lasted 14 days or longer before being removed.

This estimator is the maximum likelihood estimator assuming the removal times follow an exponential distribution and there is right-censoring of data. In our application, any trial carcasses still remaining at 14 days were collected, yielding censored observations at 14 days.

If all trial carcasses are removed before the end of the trial, then s_c is 0, and $\bar{t}$ is just the arithmetic average of the removal times.

The final estimate of $\bar{t}$, the estimated standard error, and 90% confidence limits were calculated using bootstrapping. For each iteration of the bootstrap, the removal times for the trial bats were sampled with replacement, and $\bar{t}$ was calculated. A total of 5000 bootstrap iterations were used. The standard deviation of the bootstrap estimates of $\bar{t}$ is the estimated standard error of $\bar{t}$ (se ($\bar{t}$)).

Estimation of Searcher Efficiency

The objective of searcher efficiency trials was to estimate the percentage of bat fatalities found by searchers. Searcher efficiency trials were conducted in the same plots that fatality searches occurred. Searcher efficiency was estimated by major habitat (*i.e.*, turbine pad and "other" habitat [soybeans, corn, CRP, woodlot, fallow]). Estimates of searcher efficiency were used to adjust the number of carcasses found, correcting for detectability bias. In 2001, fresh bat fatalities found during the study were used to conduct the trials, and consisted of 54 hoary bats, 7 eastern red bats, 4 little brown bats, 2 big brown bats, and 1 silver-haired bat. In 2002, we used black plastic bats with approximately 13-cm wingspans for searcher efficiency trials. Use of the plastic bats allowed us to conduct searcher efficiency trials without waiting for a suitable number of bat carcasses to be found. Use of the bat substitutes also allowed us to save more carcasses for additional research being carried out by Minnesota State University, Mankato, including food habits analysis and preparation of museum specimens.

Personnel conducting searches did not know the location of searcher efficiency carcasses. All carcasses were placed at random locations within areas being searched for fatalities before the search on the same day. Carcasses were placed in a variety of postures to simulate a range of conditions as was described for carcass removal trials.

Each carcass was discreetly marked with black electrical tape on the feet so that it could be identified as a study carcass after being found. The number, location and habitat of the detectability carcasses found during fatality searches were recorded. Carcasses not found by the searcher were removed following the fatality search effort for that day.

Searcher efficiency was expressed as p, the estimated proportion of carcasses found by searchers. Results of searcher efficiency trials were used to evaluate effectiveness of the fatality search effort and to make adjustments for the final estimate of the total number of fatalities. The standard error of p and 90% confidence limits were calculated by bootstrapping. A total of 5000 bootstrap iterations were used. Observer detection rates were estimated by habitat and year. We assumed that no removal of carcasses by scavengers occurred between when they were placed and when the plot was searched later the same day.

Estimating the Total Number of Fatalities

The estimates of the total number of wind plant-related bat fatalities were based on: (1) observed number of carcasses found during standardized carcass searches; (2) searcher efficiency expressed as the proportion of planted carcasses found by searchers; and (3) non-removal rates expressed as the length of time a carcass is expected to remain in the study area and be available for detection by the searchers. To calculate the number of fatalities for the entire wind plant, values used for searcher efficiency and mean length of stay were weighted based on relative proportions of each habitat type within the search plots. We assumed equal distribution of bats throughout the 30 m radius search plot when weighting values based on habitat.

The estimators of the total number of wind plant-related fatalities adjust the observed number of fatalities by dividing by an estimate of the probability a casualty is available to be picked up during a fatality search (probability it is not removed by a scavenger), and is observed (probability of detection). The estimated total number of annual facility-related fatalities (m_1) was calculated by:

$$m_1 = \frac{N * \bar{c}}{\pi}. \qquad \textbf{Eq. 3-3}$$

where N is the total number of turbines in the facility, $\bar{c}$ is the average number of carcasses found per turbine per study period, and π is the estimated average probability a carcass is available to be found during a search and is found; π includes both observer detection and scavenging rates, with the assumption that the carcass removal times (t_i) follow an exponential distribution:

$$\pi = \frac{1}{\mathrm{I} * \mathrm{n_s}} \sum_{k=1}^{n_s} \sum_{i=1}^{I} \sum_{j=1}^{n_s-k+1} \left[\mathrm{P}(\mathrm{T} > \mathrm{j} * \mathrm{I} - (\mathrm{i} + 0.5)) * \mathrm{p}(1-\mathrm{p})^{\mathrm{j}-1} \right] \qquad \textbf{Eq. 3-4}$$

where T is an exponential random variable, $P(T>t)$ is the probability of the random variable T exceeding the value t, I is the average interval between searches in days, n_s is the number of searches at each turbine during the period of study, and p is the estimated proportion of detection trial carcasses found by searchers.

Relationships Between Habitat, Landscape Features, Turbine Lighting, Bat Activity, and Bat Fatalities

To determine the effects of habitat at the turbines and landscape features (distance to nearest wetland and woodland) on the number of bat collision fatalities at turbines, separate Poisson regression models were fit for distance to nearest wetland, distance to nearest woodlot, and proportion of each of 11 habitat types. For a single explanatory variable, X, the regression model was:

$$\log(Y) = \beta_0 + \beta_1 X \qquad \textbf{Eq. 3-5}$$

where Y is the number of fatalities and β_0 and β_1 are parameters to be estimated. There was 1 degree of freedom for each chi-square test. Goodness-of-fit tests indicated that all regressions met the assumptions of the general Poisson model.

Poisson regression was also used to examine the relationship between the number of fatalities and presence of FAA lighting on turbines. Separate analyses were conducted for Phase 3 (where every other turbine is lighted) and for Phase 2 and 3 combined. Poisson regression also was used to examine the relationship between bat activity at turbines and the number of fatalities. The number of passes was considered to be the explanatory variable and the number of fatalities was regarded as the response.

4
RESULTS

Fatality Searches

We found 151 bat casualties during the study (Table 4-1), including 80 in the P2 wind plant and 71 in the P3 wind plant. The casualties were comprised of 115 hoary bats, 21 eastern red bats, 8 big brown bats, 4 silver-haired bats, and 3 little brown bats. None of the bat fatalities are classified as endangered, threatened or sensitive species by the federal government or State of Minnesota (Minnesota Department of Natural Resources 1996). The hoary bat fatalities were comprised of 90% adults (50% male, 50% female) and 10% juveniles. The large percentage of adult male hoary bat fatalities at Buffalo Ridge is surprising. Hazard (1982) reports that in Minnesota most adult hoary bats are females because most males that migrate north concentrate in the western United States (Findley and Jones 1964). Eastern red bat fatalities were 93% adults (78% male, 22% female) and 7% juveniles. Sample sizes of the remaining three species of bats were too small to accurately characterize sex and age composition (Table 4-1).

Table 4-1
Sex and Age Composition of Bat Fatalities Found Associated with Turbines on Buffalo Ridge

Species	N	% Adult Females	% Adult Males	% Adults	% Juveniles
Hoary Bat	115	50	50	90	10
Eastern Red Bat	21	22	78	93	7
Big Brown Bat	8	33	67	83	17
Silver-haired Bat	4	NA[a]	NA	75	25
Little Brown Bat	3	NA[b]	NA	NA	100

[a] neither of the 3 adults found could be sexed due to decomposition.

[b] one of the 3 could not be aged or sexed due to decomposition; the other 2 were juveniles.

All bat fatalities were found associated with turbines. No bats were found while searching met towers, but dense vegetation under the towers would have made it extremely difficult to detect dead bats. Field necropsies revealed that injuries sustained by bats included fractured wings, legs, and necks; head wounds; abrasions and abdominal injuries. Bat fatalities were found during the period 19 June to 12 September; however, most (82%) were found from 16 July to 31 August (Figure 4-1). A total of 106 (70%) of the 151 bats were located on fatality search plots, 14 (9%) were located on plots searched in conjunction with Anabat® recordings, and 31 (21%) were incidental finds (*e.g.*, found at turbines while driving between fatality search plots). Only those fatalities found on the fatality search plots during scheduled searches were used to estimate mean number of fatalities per turbine and total wind plant mortality.

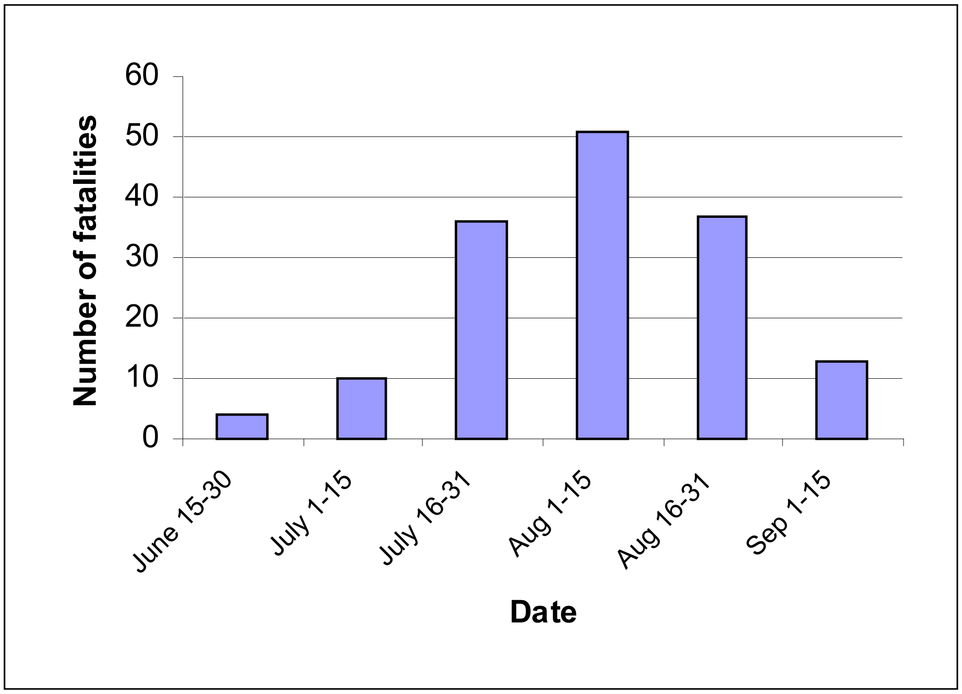

Figure 4-1
Timing of Bat Collision Mortality at Buffalo Ridge, Minnesota, 2001-2002

Bat fatalities were fairly widespread throughout the wind plants, and no patterns in location of the collision fatalities were evident. In 2001, dead bats were found at 23 (56%) of the 41 turbines randomly selected for fatality searches in the P2 study area and at 24 (62%) of the 39 turbines selected for sampling in the P3 study area. Incidental fatalities were found at an additional 10 turbines in P2 and 11 turbines in P3. In 2002, dead bats were found at 14 (28%) of the 50 turbine selected for fatality searches in the P2 study area and at 16 (32%) of the 50 turbines selected for sampling in the P3 study area. Incidental fatalities were found at an additional 11 turbines in P2 and 4 turbines in P3. The largest number of bats found at any one turbine was four at turbine #7 in the P2 wind plant during the 2002 field season (Appendix A). Fifty-six of the bats (37%) were intact, 93 (62%) were scavenged, and two (1%) were found alive but with injuries that prevented them from flying.

Several potential scavengers of bat carcasses were identified during this and previous studies at Buffalo Ridge (*i.e.*, Johnson *et al*. 2000a), including several species of raptor, American crow (*Corvus brachyrhynchos*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), domestic dog (*Canis familiaris*), domestic cat (*Felis catus*), raccoon (*Procyon lotor*), mink (*Mustela vison*), striped skunk (*Mephitis mephitis*), badger (*Taxidea taxus*), long-tailed weasel (*Mustela frenata*), least weasel (*Mustela nivalis*), and ground squirrels (*Spermophilus* spp.). However, virtually all scavenging of bat carcasses was done by insects, including maggots, carrion beetles, and crickets. Most of the carcasses classified as scavenged were intact (*i.e.*, still in one piece), but were heavily infested with maggots or had been partially consumed by carrion beetles and/or crickets which were often present when the carcass was found.

Most (74%) of the bats were found on the gravel pad surrounding turbines. These pads averaged approximately 24 m in diameter at P2 turbines and 36 m in diameter at P3 turbines. Distances bats were found from turbines ranged from <1m to 35 m, with an average of 11.1 m. Fifty percent of all bats were found ≤10 m from a turbine, 40% were found from 11-20 m, 9% were found from 21-30 m, and one (1%) was found >30 m from a turbine (35.0 m). The individual bat found 35 m from a turbine was the only bat not found within the 30-m search radius during the study. Based on distribution of bat fatalities surrounding turbines (Figure 4-2), the 60 mX 60 m search plot was adequate to detect virtually all bat fatalities associated with turbines (Gauthreaux 1996). Sixty percent of bat carcasses were found north (270-90 degrees) of the turbine, and 65% were found east (0-180 degrees) of the turbine. Significantly more were found northeast (0-90 degrees) of the turbine (42%) than any other quadrant (23% southeast, 18% southwest, 17% northwest).

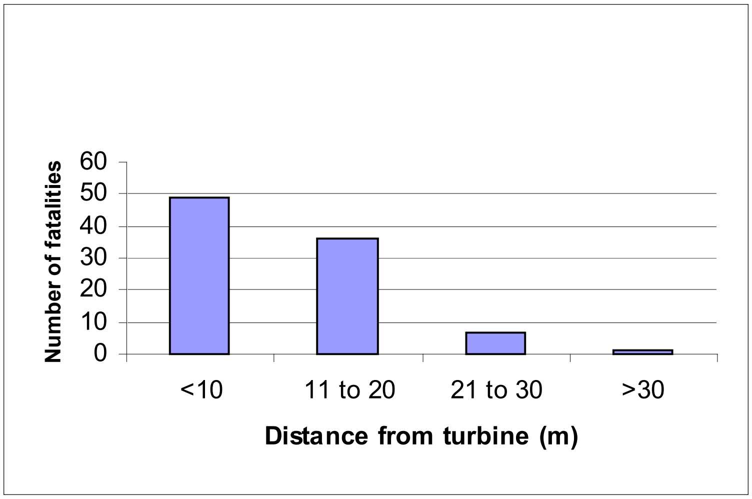

Figure 4-2
Distribution of Bat Fatalities as a Function of Distance from Turbine, Buffalo Ridge, Minnesota, 2001-2002

Inclement weather was possibly associated with up to 70% of the bat collision fatalities found on Buffalo Ridge in 1998 and 1999 (Johnson *et al.* 2000a), and up to 65% of fatalities at the Foote Creek Rim, Wyoming wind plant (Young *et al.* 2003). At Buffalo Mountain in Tennessee, bat collision fatalities also occurred during clear as well as inclement weather (Nicholson 2001, 2003). Weather conditions did not appear to be strongly related to the number of bat fatalities at Buffalo Ridge during this study. Of the 151 bats found, 95 appeared to have been dead for less than one week, which allowed weather at the approximate time of death to be estimated. Forty-four (46%) of these bats were found when severe weather was apparently not a factor and 51 (54%) were found when inclement weather could have possibly occurred at the time of the collision. Of these 51 bats, 75% were found following thunderstorms or rain and 25% were found following periods of fog or fog and rain mixed.

During this study, habitat within 100 m of the turbines was comprised primarily of cornfields, soybean fields, CRP grasslands, and pastures (Table 4-2). The mean distance from each turbine to the nearest woodland and wetland was 419 m and 547 m, respectively. The majority of dead bats were found near turbines placed in soybeans (44), followed by cornfields (37), CRP (26) and pasture (17). There was no significant relationship between the number of fatalities and habitat within 100 m of the turbine or distances to the nearest wetland or woodland (Table 4-3).

The best test of lighting effects can be made with fatality data from the P3 wind plant, where every other turbine is lighted. At that wind plant, 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 the number of bat fatalities and presence of lighting for Phase 3 alone ($p = 0.214$) or for Phase 2 and 3 combined ($p = 0.589$).

Table 4-2
Habitats within 100 m of all 281 Turbines within The Buffalo Ridge Phase 2 and Phase 3 Wind Plants

Habitat	Percentage By Year	
	2001	2002
Alfalfa	5.9	9.8
Corn	19.4	30.6
CRP	13.9	21.9
Fallow	9.7	0.7
Hayfield	2.3	0.0
Pasture	12.4	9.3
Woodlot	1.0	0.6
Soybeans	34.8	25.2
Small Grains	0.3	1.9
Wetland	0.2	0.0
TOTAL	100.0	100.0

Table 4-3
Relationship between Bat Collision Mortality and Landscape Features (Distance to Nearest Wetland and Woodland) and Habitat within 100 m of Turbines Based on Results of Individual Poisson Regression Models

Habitat Parameter	Estimate	SE	Chi-Square	Pr > ChiSq
Distance to Wetland	-0.2787	0.3542	0.62	0.431
Distance to Woodland	-0.2004	0.4632	0.19	0.665
% Alfalfa	-0.0055	0.0057	0.93	0.336
% Corn	0.0014	0.0023	0.40	0.525
% CRP	-0.0013	0.0031	0.17	0.678
% Fallow	0.0055	0.0040	1.92	0.166
% Hayfield	-0.2209	797.3411	0.00	1.000
% Pasture	0.0003	0.0032	0.01	0.931
% Wooded	-0.3207	0.0500	0.41	0.521
% Soybeans	-0.0007	0.0023	0.10	0.751
% Small Grains	-0.0066	0.0133	0.25	0.618
% Wetland	0.0146	0.0295	0.24	0.622

Fatality Search Biases

In 2001, 68 bats were placed for searcher efficiency trials. For the major habitats, detection rates were 81% on gravel pads surrounding turbines, 12% in CRP, and 25% in crop fields. The overall detection rate for all habitats combined was 53% (Table 4-4). In 2002, 74 plastic bats were placed for trials. Detection rates were 72% on turbine pads, 23% in CRP, 60% in pasture, and 12% in crop fields. The overall detection rate for all habitats combined was 41%.

For all data combined, searcher efficiency in the P2 wind plant weighted by proportion of each habitat in the search plot was estimated to be 44.1% in 2001 and 37.1% in 2002. In the P3 wind plant, weighted searcher efficiency was estimated to be 55.6% in 2001 and 45.0% in 2002. Searcher efficiency was higher in the P3 wind plant because the proportion of the search area comprised of gravel pad is much larger in the P3 wind plant, and searcher efficiency was substantially higher on the gravel pad than the other habitats.

Forty-six bat carcasses were used for scavenger removal trials during the study. Mean length of stay was 10.5 days for bat carcasses placed on turbine pads and 10.4 days for carcasses placed in other habitats, which included CRP fields, corn, soybeans, and pastures. The overall mean length of stay for all habitats was 10.4 days (Table 4-5). This is the same as the mean length of stay of 10.4 days determined for 40 bat carcasses at Buffalo Ridge in 1999 (Johnson *et al.* 2000a). Bat carcasses at Buffalo Ridge remained on search plots much longer than at Buffalo Mountain, Tennessee (2.4 – 4.3 days, Nicholson 2003), but did not last as long as bat carcasses placed in Wisconsin (20 days, n=2 bats) (Puzen 2002) or Wyoming (20 days, n=10 bats) (Young *et al*. 2003).

For combined bat scavenger data from 2001 and 2002, 48% of the carcasses still remained on Day 7 and 30% were still remaining on Day 14 (Figure 4-3). As was the case for collision fatalities, most scavenging of bat trial carcasses was done by insects. The combined probability that a dead bat was not removed by scavengers during the period between searches and was detected by searchers was 24.8% at the P2 wind plant and 27.5% at the P3 wind plant, and was 29.6% in 2001 and 25.3% in 2002.

Table 4-4
Percentage of Bats and Plastic Bats found During Searcher Efficiency Trials

Habitat	Number Placed	Number Found	Percent Found
Turbine Pad	66	51	77.3%
Corn	10	3	30.0%
CRP	30	5	16.7%
Soybeans	11	1	9.1%
Woodlot	3	0	0%
Fallow	3	0	0%
Pasture	10	6	60.0%
Small Grain	9	0	0%
Other Habitats	76	15	19.7%
All Habitats	142	66	46.5%

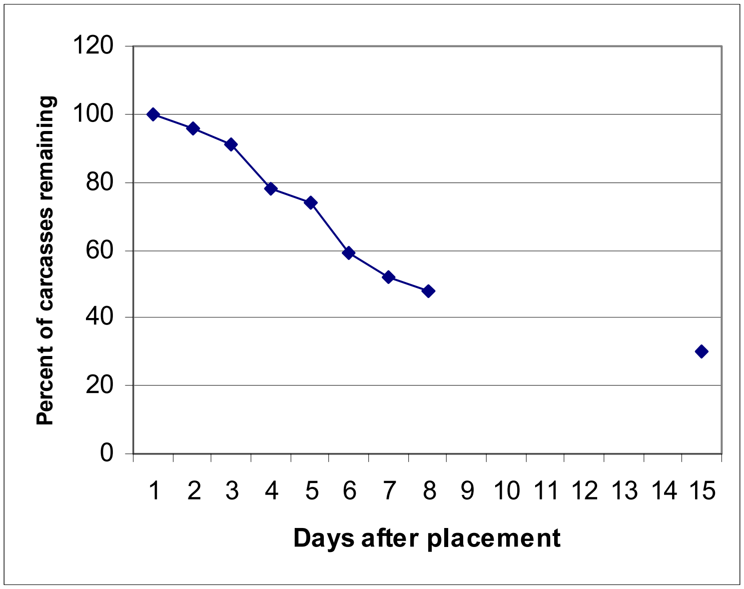

Figure 4-3
Mean Proportion of Bat Scavenger Trial Carcasses Available for Detection over the 14-day Interval between Carcass Searches

Table 4-5
Mean Length of Stay for Bat Carcasses Placed to Monitor Scavenger Removal Rates

Habitat	Number Placed	Mean Length of Stay (Days)
Turbine Pad	17	10.50
Other Habitats[a]	29	10.41
All Habitats	46	10.44

[a] Numbers of Bat Carcasses per Habitat Type were: Corn (5), Soybean (6), CRP (13) and Pasture (5).

Estimation of the Number of Turbine-Related Fatalities

The estimated total number of bat fatalities during 2001 was 467 in the P2 wind plant (90% CI = 322-640) and 383 in the P3 wind plant (90% CI = 270-512). For both the P2 and P3 wind plants, the total number of fatalities in 2001 was estimated to be 849 (90% CI = 640-1100). Mean number of bat fatalities per turbine in 2001 was estimated to be 3.26 in the P2 wind plant and 2.78 in the P3 wind plant (Table 4-6).

In 2002, the estimated total number of bat fatalities was 176 in the P2 wind plant (90% CI = 105-261) and 188 in the P3 wind plant (90% CI = 113-275), for a combined total of 364 (90% CI = 251-497). Mean number of bat fatalities per turbine in 2002 was estimated to be 1.23 in the P2 wind plant and 1.36 in the P3 wind plant (Table 4-6).

Table 4-6
Estimates of Turbine-Related Bat Mortality for the Buffalo Ridge Wind Resource Area

Study Area	Year	Number of Fatalities Found	Total Mortality Estimate[a]	90% Confidence Interval	No. Fatalities per Turbine per Year	90% Confidence Interval
P2	2001	47	467	322-640	3.26	2.25-4.48
P3	2001	46	383	270-512	2.78	1.96-3.71
2001 Total		93	849	640-1100	3.02	2.28-3.92
P2	2002	33	176	105-261	1.23	0.74-1.83
P3	2002	25	188	113-275	1.36	0.82-2.00
2002 Total		58	364	251-497	1.30	0.89-1.77

Bat Activity Based on Echolocation Detectors

During the study, we recorded 3,718 bat passes at bat foraging and roosting areas within the study area and 452 bat passes at turbines for a total of 4,170 recordings. Bat passes were detected at 64 (47%) of the 135 turbines sampled with Anabats® in 2001 and 31 (38%) of the 81 turbines sampled in 2002 (Appendix B). Where bat activity was documented at turbines, the number of passes ranged from 1 to 67 per night. For all turbines sampled, the mean number of bat passes per detector night over the 3-month study period was 2.2 per turbine in 2001 and 1.9 per turbine in 2002; the number of bat passes per turbine was not significantly different between years (*p*=0.679). The mean number of passes per turbine per night in 2001 was calculated using the extraordinary value of 67 passes recorded at turbine 5 in the P3 wind plant on June 24. If this one outlier is removed from the data, the mean number of passes per turbine in 2001 was 1.8, which is nearly identical to the 2002 mean. Some bat activity was documented at turbines throughout the entire study period. Peak bat activity at turbines based on Anabat® recordings occurred from mid July to mid August. During the last two weeks of July, 57% of the turbines sampled had bat activity (Figure 4-4) and 3.5 bat passes per turbine per night were documented (Figure 4-5). In the first two weeks of August, bat activity was recorded at 75% of the turbines sampled and the mean number of passes per turbine per night was 3.0.

The lowest activity occurred the first 2 weeks of September, when 17% of the turbines sampled had bat activity and the number of passes per turbine per night was 0.9. The only habitat variable significantly related to bat activity at turbines was distance to woodland (*p* = 0.006) (Table 4-7). The number of bat passes was negatively associated with distance to woodland, indicating that as distance increased, the number of passes decreased. At the Phase 3 wind plant, there was no significant difference in bat activity between lighted and unlighted turbines (*p*=0.138).

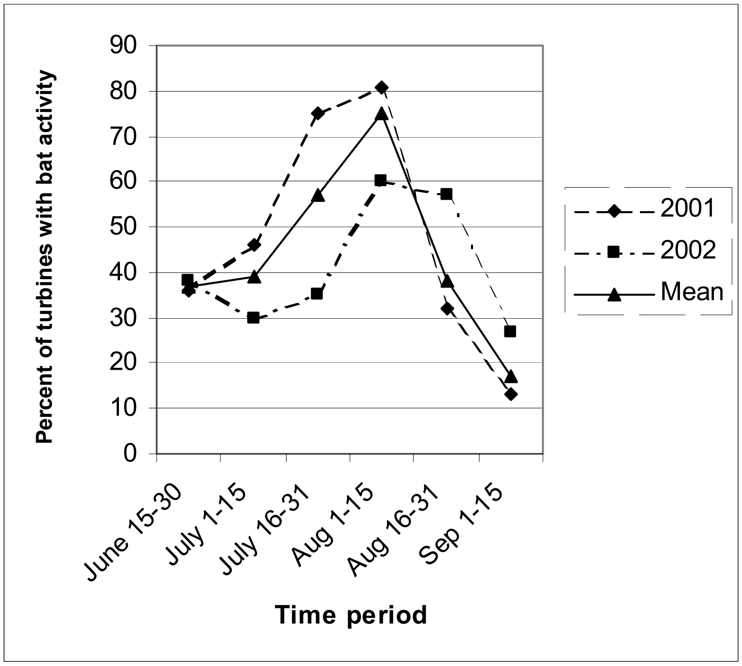

Figure 4-4
Bat Activity at Turbines (Proportion of Turbines with Bat Passes per Night) during the Mid-June to Mid-September Study Period, Buffalo Ridge, Minnesota, 2001-2002

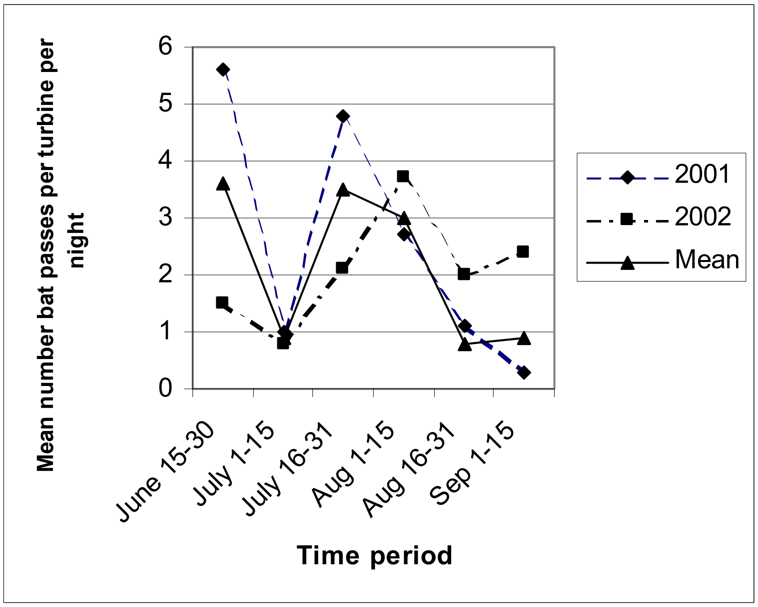

Figure 4-5
Bat Activity at Turbines (Mean Number Passes/Turbine/Night) During the Mid-June to Mid-September Study Period, Buffalo Ridge, Minnesota, 2001-2002

Table 4-7
Relationship between the Number of Bat passes at Turbines as a Function of Landscape Features (Distance to nearest Wetland and Woodland) and Composition of Habitats within 100 m of the Turbine Based on Individual Poisson Regression Models for Number of Bat Passes at Turbines as a Function of Each Habitat Characteristic

Parameter	Estimate	SE	Chi-Square	Pr > ChiSq
Year	0.1013	0.2445	0.17	0.679
Distance to Wetland	0.4045	0.3628	1.24	0.265
Distance to Woodland	-1.5533	0.5655	7.54	0.006
% Alfalfa	-0.0138	0.0083	2.75	0.097
% Corn	0.0049	0.0029	2.94	0.087
% CRP	-0.0034	0.0037	0.82	0.365
% Fallow	0.0024	0.0089	0.07	0.790
% Hayfield	-0.0137	0.0174	0.61	0.433
% Pasture	0.0012	0.0037	0.10	0.748
% Trees	0.0164	0.0119	1.90	0.168
% Soybeans	-0.0008	0.0029	0.07	0.784
% Small Grains	-0.0005	0.0156	0.00	0.976
% Wetland	-2.3672	22569.438	0.00	1.000

Anabats® were used to record bat activity at foraging and roosting areas within the study area 76 times. Fifty-two sessions occurred within upland habitats (*e.g.*, woodlots, farmsteads) and 24 occurred within aquatic habitats (*e.g.*, ponds, wetlands, streams). A mean of 48 bat passes were recorded per detector-night at these areas. The maximum number of passes recorded in one night on one detector each year was 191 on 25 June 2001 and 495 on 15 July 2002, both at Hole in the Mountain County Park (Appendix C). The mean number of bat passes recorded per detector-night in upland habitats (59.3) was over twice as high as the number of passes per detector-night recorded at aquatic habitats (26.4).

Bat activity within Hole in the Mountain Park was monitored throughout the entire study period so that trends in bat activity could be determined. Bat activity was documented throughout the entire 15 June – 15 September study period each year at that location. Based on 41 detector-nights at the park, peak bat activity occurred the first two weeks of August (137 passes/detector-night), followed by the second half of July (119) and first half of July (114) (Figure 4-6). There was a significant reduction in activity beginning in mid-August, as mean bat activity was 26 passes per detector-night from August 16-31 and 20 per detector-night the first two weeks of September.

Scavenger removal of bats found at Anabat® plots was assumed to be negligible because turbine plots were searched immediately following sampling with the detector the previous night. Adjusting the 14 fatalities found to account for searcher efficiency results in a total estimate of 34 bat fatalities at the 216 turbines sampled with Anabats® over the course of the study. The mean number of bat passes per detector night was 2.1 at turbines with no documented fatalities and 2.4 at turbines with fatalities. There was no significant relationship between bat activity and the number of bat fatalities at turbines (*p*=0.889). Only six bat fatalities were found during subsequent searches of the 95 turbine plots where bat activity was recorded the previous night. Eight bat fatalities were found while searching turbines where no bat activity had been recorded the previous night, and no fatalities were found at the seven turbines with the highest documented bat use (10 to 67 passes per night). Based on a mean of 1.9 bat passes per night at each of 281 turbines throughout the two annual 90-day study periods, a minimum of 96,102 bat passes occurred at turbines during this study, indicating that collision fatalities are very rare given the amount of bat activity documented at turbines.

Our estimate of 96,102 bat passes near turbines is certainly an underestimate of the true number of bat passes, as numerous bats were likely missed by the detectors. Hoary bats can be detected only up to 40 m away (Garcia 1998), and the maximum distance for detection of many other bat species is approximately 25 m due to differences in the frequency of their echolocation calls (Brigham *et al.* 1997a). Therefore, many of the bats flying within the turbine rotor-swept height (26 – 74 m) would not be detected by the Anabat®. Studies have also shown that detector orientation, height above ground and other factors influence the number of bats detected (Weller and Zabel 2002) because the receptivity of bat detectors is limited in both the horizontal and vertical planes (Waters and Walsh 1994, Larson and Hayes 2000). These biases associated with echolocation studies currently cannot be quantified (O'Shea and Bogan 2000), and the proportion of bats flying near turbines that were not detected by the Anabat® is unknown, but may have been substantial.

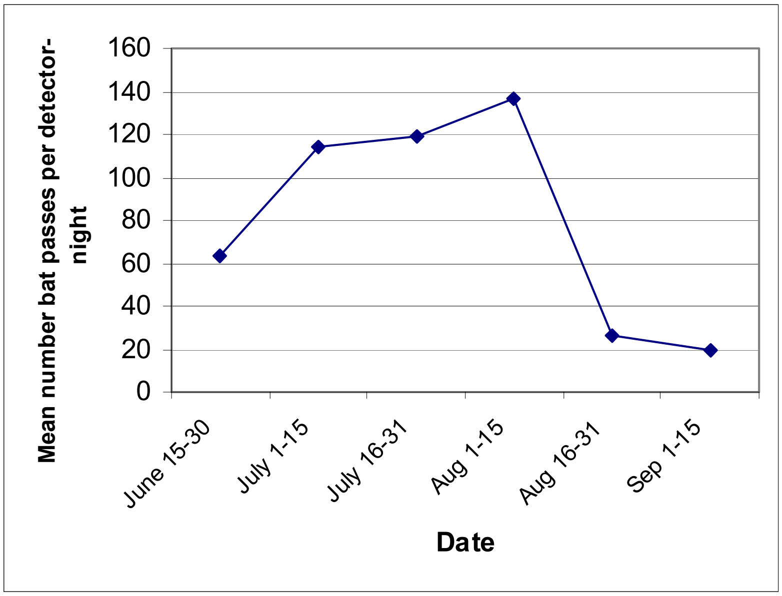

Figure 4-6
Bat activity at Hole in the Mountain Park, Mid-June to Mid-September, Buffalo Ridge, Minnesota, 2001-2002

Bat Activity and Composition Based on Mist Net Sampling

A total of 103 bats comprised of five species was captured in mist nets during the study. The species most commonly captured included big brown bat (64), silver-haired bat (17) and little brown bat (11). In addition, three hoary and eight eastern red bats were captured (Table 4-8). Composition of bats in the study area based on mist net sampling was not related to species composition of bat fatalities found within the wind plants.

Table 4-8
Sex and Age Composition of Bats Captured in Mist Nets During the Study

Species	N	% Adult Females	% Adult Males	% Adults	% Juvenile Females	% Juvenile Males	% Juveniles
Big Brown Bat	64	28	20	55	21	23	45
Little Brown Bat	11	22	78	100	0	0	0
Silver-haired Bat	17	18	24	41	29	29	59
Hoary Bat	3	0	0	0	100	0	100
Eastern Red Bat	8	29	43	71	14	14	29

Of the 64 big brown bats captured in mist nets, 55% were adults and 45% were juveniles. Twenty-two percent of the little brown bats captured were adult females and 78% were adult males. No juvenile little brown bats were captured in mist nets. Forty-one percent of the silver-haired bats were adults and 59% were juveniles; 71% of the eastern red bats were adults and 29% were juveniles. Two of the three hoary bats captured were juvenile females and the third escaped from the net before it could be examined.

Bats were captured on 24 days during the study (Appendix D). Capture success averaged nearly 20 mist-net hours per bat capture in 2001 and 12.4 mist-net hours per capture in 2002. Big brown bats were captured throughout the study period, and many gravid and lactating females were captured (Table 4-9). This species was likely the most common breeding bat in the study area (see below). Timing of captures indicate the little brown bat is also a breeding resident, as virtually all captures of this species occurred in early July. We also documented breeding populations of silver-haired bat in the study area. A gravid female was captured at Hole in the Mountain County Park on 19 June 2002, and six others were captured in early July prior to the known onset of migration for this species. The remaining 10 silver-haired bats were captured in late July and early August and these individuals could have been migrants. Four of the eight eastern red bats were caught in late June and early July, which again indicates breeding by this species in the study area. The remaining four were captured in late August and early September, and were probably migrants. Two of the three hoary bats were captured on 29 July 2002 and the third was captured on 31 July 2002; all three of these individuals were likely migrants. For all species combined, the number of bats captured per 100 mist net hours was highest the last two weeks of July (10.5) followed by the first two weeks of July (8.3). Capture success dropped off dramatically after mid August both years (Figure 4-7).

In addition to those bats caught in mist nets, a funnel trap was used to capture bats inhabiting an attic in the town of Lake Benton, located approximately 1.6 km from the Phase 2 wind plant. The colony was a maternal colony of big brown bats and the 29 bats caught were comprised of 59% adult females, 3% adult males, and 38% juveniles. Lake Benton is a small town (population = 693), and the presence of bat researchers in town did not go unnoticed. Study personnel were made aware of numerous additional big brown bat maternal colonies in attics within the town of Lake Benton.

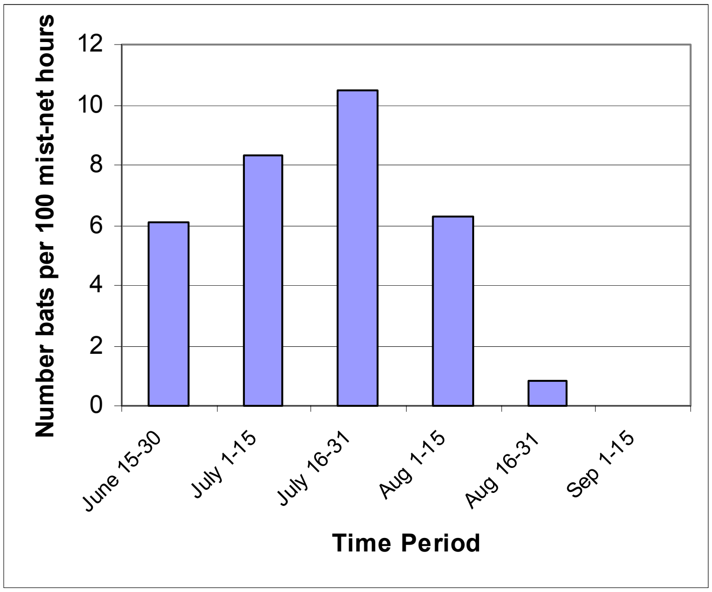

Figure 4-7
Bat Capture Rates in Mist Nets, Mid-June to Mid-September, Buffalo Ridge, Minnesota, 2001-2002

Table 4-9
Timing and Species Composition of Bats Captured in Mist Nets, Buffalo Ridge, Minnesota WRA, 2001-2002

Date	Species				
	Big Brown	Little Brown	Silver-Haired	Eastern Red	Hoary
June 15-30	5	0	1	1	0
July 1-15	12	10	6	3	0
July 16-31	28	1	8	3	3
August 1-15	13	0	2	0	0
August 16-31	1	0	0	1	0
September 1-15	0	0	0	0	0

5
DISCUSSION

A Review of Bat Collision Mortality

Bat collision mortality is not unique to wind plants or to Buffalo Ridge. Previous studies have documented bats colliding with other man-made structures. The first was by Saunders (1930), who reported that five bats comprised of three species (eastern red, hoary, and silver-haired) 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 bats have been killed by colliding with 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). 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). In Sweden, 17 dead bats of six species were collected at 160 turbines, of which half were migrant species (Ahlen 2002). Eleven species of bats have been documented as turbine fatalities in Germany, mostly migrant species (Bach 2001).

In the United States, large numbers of bat fatalities have been found at wind plants other than Buffalo Ridge, including 135 in Wyoming (Johnson *et al.* 2000b, Young *et al.* 2002, Gruver 2002, Young *et al*. 2003), 72 in Wisconsin (Howe *et al*. 2002), and 54 at a wind plant on the Washington/Oregon border (Erickson *et al*. 2002) (Table 5-1). Thirty-nine dead bats were found over a 4-year period at a wind plant in northern Colorado (Kerlinger *et al*. 2000, R. Ryder, Colorado State University, pers. commun.). Smaller numbers of dead bats have been found at wind plants in Oregon (Erickson *et al*. 2000, Johnson *et al*. 2003b), northern 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) 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 top of Buffalo Mountain in Tennessee, where 72 bats were found over a 2-year period (Tennessee Valley Authority 2002, Nicholson 2001, 2003).

Table 5-1
Bat Mortality Estimates at U.S. Wind Plants

Location	Year	Number of Bat Fatalities Found	Bat Fatalities per Turbine per year	Reference
Buffalo Ridge, MN Phase 173 Turbines	1994-1998	20	0.1	Osborn *et al*. 1996 Johnson *et al*. 2000a
Buffalo Ridge, MN Phase 2&3 281 Turbines	1998-2002	400	2.0	Johnson *et al*. 2003a, Krenz and McMillan 2000, this study
Northeastern Wisconsin 31 Turbines	1999-2001	72	4.3	Howe *et al*. 2002
Foote Creek Rim, WY 105 Turbines	1999-2002	135	1.3	Johnson *et al*. 2000b, Young *et al*. 2002, 2003, Gruver 2002
Buffalo Mountain, TN 3 Turbines	2001	72	28.5	Nicholson 2001, 2003
OR/WA border 399 Turbines	1999-2002	54	0.9	Erickson *et al*. 2002
Klondike, OR 16 Turbines	2002	6	1.2	Johnson *et al*. 2003b
Vansycle, OR 38 Turbines	1999	28	0.7	Erickson *et al*. 2000

Most bat fatalities documented at other wind plants were also migratory tree bats (Table 5-2). Of 774 bat wind plant collision victims identified to species, including 396 from Buffalo Ridge and 378 from other U.S. wind plants, hoary bats comprised 64.3%, eastern red bats comprised 19.3%, and silver-haired bats comprised 9.0%. The remaining fatalities were comprised of small numbers of big brown bat, little brown bat, and eastern pipistrelle. Of 45 species of bats in North America (Wilson and Ruff 1999), only six species comprise all known wind plant fatalities, despite that wind plants have been constructed in several regions and habitat types.

Most bat fatalities documented at U.S. wind plants were found in late summer and early fall. Data were available for 753 bat collision fatalities in the U.S. where the approximate date of the collision was reported (Table 5-3). Nearly 90% of the fatalities occurred from mid-July through mid-September, with over 50% occurring in August.

Table 5-2
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	Unid
Buffalo Ridge, MN	420	273	73	20	15	8	7	24
Buffalo Mountain, TN	72	10	48	1	2	0	11	0
Wisconsin	72	25	27	13	1	0	0	6
Vansycle, OR	10	5	0	3	0	1	0	1
Klondike, OR	6	3	0	1	0	0	0	2
Ponnequin, CO	39	36	0	2	0	0	0	1
Foote Creek Rim, WY	135	119	0	5	2	6	0	3
OR/WA border	54	25	0	25	2	1	0	1
Green Mountain, PA	1	0	0	0	0	1	0	0
California	6	2	1	0	0	0	0	3
Total Percent	815	498 61.1%	149 18.3%	70 8.6%	22 2.7%	17 2.1%	18 2.2%	41 5.0%

Table 5-3
Timing of Bat Collision Mortality at U.S. Wind Plants (Updated from Johnson 2003)

Date	Buffalo Ridge, MN	Vansycle OR	Klondike OR	Buffalo Mtn, TN	OR/WA border	Foote Creek Rim, WY	Northeast WI	Total (%)
May 1-15	0	0	0	2	0	0	3	5 (0.7%)
May 16-31	1	0	1	0	0	1	0	3 (0.4%)
June 1-15	0	0	0	3	0	1	0	4 (0.5%)
June 16-30	4	0	2	0	0	2	0	8 (1.1%)
July 1-15	16	0	0	8	0	3	0	27 (3.6%)
July 16-31	101	0	0	6	1	26	4	138 (18.3%)
Aug 1-15	144	0	0	15	1	23	1	184 (24.4%)
Aug 16-31	92	4	0	17	15	35	54	217 (28.8%)
Sep 1-15	55	4	1	14	7	25	5	111 (14.7%)
Sep 16-30	4	2	2	3	15	0	5	31 (4.1%)
Oct 1-15	1	0	0	2	11	3	0	17 (2.3%)
Oct 16-31	2	0	0	0	3	0	0	5 (0.7%)
Nov 1-15	0	0	0	2	1	0	0	3 (0.4%)

Resident Versus Migrant Bats

The most common bat fatality documented at Buffalo Ridge is the hoary bat, which comprised approximately 70% of the 420 casualties found on Buffalo Ridge from 1998 to 2002 (Johnson *et al.* 2003a, Krenz and McMillan 2000, this study). The hoary bat is a non-hibernating 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, are solitary tree roosting bats, and do not hibernate (Carter 1950, Shump and Shump 1982b, Hutchinson and Lacki 2000a). Anecdotal evidence indicates that historical populations of both hoary and eastern red bats were likely much greater than at present (Carter *et al.* 2003).

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 of silver-haired bats (Parsons *et al.* 1986, Betts 1996, Barclay *et al.* 1998, Betts 1998b, Vonhof 1999). The other two species found in the study area (little brown and big brown bat) may migrate short distances between summer and winter roosts (Griffin 1970) and are colonial species that roost in buildings, hollow trees, wood piles, and other structures (Fenton and Barclay 1980, Kurta and Baker 1990).

Potential habitat for resident breeding hoary and other tree bats does exist in and near the project area. The most likely tree bat habitats are riparian areas along Lake Benton, mature trees within the town of Lake Benton, state and local parks, Minnesota Department of Natural Resources wildlife management areas, farmstead woodlots, shelterbelts, and small native stands of trees. The amount of wooded area within the Buffalo Ridge wind plant boundaries is relatively insignificant, comprising only 4.8% of all habitats (Johnson *et al.* 2000a). However, most of the larger wooded habitats occur outside the defined wind plant boundaries, and bats are known to fly long distances to forage (*e.g.*, LaVal *et al.* 1977, Everette *et al.* 2001). We captured four eastern red and seven silver-haired bats in June and early July at Hole in the Mountain Park, suggesting that habitat there is suitable for breeding by these species. Eastern red bats occupied similar wooded park and riparian habitat intermingled with lawns and fields in Illinois (Mager and Nelson 2001). All three hoary bats were captured in late July and were likely migrants. The lack of hoary bat captures during the breeding season may suggest that the relatively small islands of wooded habitat surrounded by farmland and pasture may not provide suitable breeding habitat for this species. During a recent study to document bat abundance and composition in eastern South Dakota, the only location where hoary bats were captured was along the Missouri River, where there are extensive cottonwood gallery forests (Swier 2003).

A lack of suitable habitat in the Buffalo Ridge area could explain the absence of hoary bats during the breeding season; hoary bats may not occur or occur only at very low densities in the study area during this time period. Although low numbers of hoary bat captures could also be related to the relative difficulty in capturing this species in mist nets (Garcia 1998), several studies have shown that if they are present in any numbers at least some individuals are usually caught (e.g., Mumford 1963, Perkins and Cross 1988, Bogan *et al.* 1996, Koehler and Barclay 2000, Gruver 2002, Swier 2003). Identification of bat echolocation calls recorded during the study will shed more light on status of hoary bats in the study area during the breeding season.

If resident bats comprised the bulk of the collision fatalities, then the collisions would have to be occurring while these bats were commuting from roosting to foraging areas or were foraging within the wind plant. There appeared to be no pattern in the distribution of fatalities among turbines found in 1998 and 1999 (Johnson *et al.* 2000a), 2000 (Brock and McMillan 2000) or this study. Since 1998, dead bats have been found at all turbine strings in the P2 and P3 wind plants, and collision fatalities have been documented at 64% of the P2 and 50% of the P3 turbines. If the bulk of the collision victims were local bats commuting from roosting to foraging areas, defined flight corridors between woodlands or wetlands would be expected, and a widespread random distribution of fatalities would seem unlikely.

If foraging bats were involved, it seems unlikely that bats would spend significant amounts of time foraging within the wind plants at turbine rotor-swept heights. Most of the turbines are situated within the interiors of crop fields, pastures, and CRP fields. Silver-haired bats forage almost exclusively in forest habitat (Gannon *et al*. 2003). Although hoary bats have been known to rarely forage in agricultural areas when insect abundance at preferred feeding areas was low (Hickey and Fenton 1996), hoary bats as well as most other bat species prefer to forage near trees or water (*e.g.*, Carter *et al.* 1999, Verboom and Spoelstra 1999, Everette *et al*. 2001). Both hoary and eastern red bats prefer to forage over sites with woody vegetative cover and are positively associated with edge situations (Kunz 1973, Furlonger *et al.* 1987, Hart *et al.* 1993, Mager and Nelson 2001, Gannon *et al.* 2003), neither of which are present in areas where turbines are located.

Data collected during this study indicate that bats rarely, if ever, foraged in the areas where turbines were located. Although some bat activity was recorded within the wind plant (*i.e.*, 2.0 passes per night at turbines), it was very low compared to more suitable habitats such as woodlands and wetlands, where bat activity was 24 times higher (*i.e.*, 48.0 passes per night). Foraging bats locate their prey primarily through echolocation (Simmons *et al.* 1979). 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). No feeding buzzes were included among the 452 bat passes recorded at turbines during this study, indicating that bats were not foraging at the turbines.

Much of the bat activity recorded at turbines occurred at turbines located near woodlands, and regression analyses indicated that distance to the nearest woodland was the only habitat or landscape feature significantly associated with bat activity in the study area. The highest number of bat passes/night recorded at a turbine during the study (67) was at a turbine located within 100 m of a woodland.

There was no significant relationship between presence/absence of fatalities and any of the habitat variables in 2000 (Krenz and McMillan 2000) or during this study, again suggesting that collisions occurred randomly across space. If foraging bats comprised most of the collision victims, some relationship between habitat and bat fatality rates would be expected, as greater foraging activity would be expected at turbines closer to wetlands and woodlands or turbines with higher proportions of wetlands and woodlands within 100 m. Because there was no relationship between bat activity at turbines and the number of fatalities, it seems likely those bats which may have foraged within the wind plants were not highly susceptible to turbine collisions. At a small wind plant in Tennessee, bat activity at a pond near the turbines as measured with Anabats® was not correlated with the number of collision fatalities in 2001, but was in 2003 (Nicholson 2001, 2003).

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 m to 200 m (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 m to 30 m 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, and big brown bats forage from 7 m to 10 m above ground (Barclay 1984, Fitzgerald *et al*. 1994). Small numbers of little brown bat fatalities were found at turbines, and this species forages almost exclusively less than 5 m above the ground; much of their foraging is done from 1 m to 2 m above ground (Fenton and Bell 1979). It seems unlikely that foraging bats would routinely forage above 26 m, the lowest height of the blade on the Zond turbine.

Big brown bats typically forage from 1 to 2 km away from roost sites (Brigham and Fenton 1986, Kurta and Baker 1990, Brigham 1991), although studies have found that they will commute up to 10 times this distance to forage (Brigham 1989, Everette *et al*. 2001). The apparent relatively large big brown bat populations at Hole in the Mountain Park and the Town of Lake Benton are well within typical foraging range of the P2 wind plant. Big brown and hoary bats prefer to forage in similar habitats (Hazard 1982) although big brown bats prefer beetles while hoary bats specialize in moths (Black 1972, Hickey and Fenton 1990, Acharya and Fenton 1992). A study in Ontario, Canada found that big brown bats spent significantly less time feeding in farmland than in residential and over-water areas (Geggie and Fenton 1985). The low bat activity at turbines and absence of feeding buzzes among recorded calls indicate that big brown bats as well as most other species apparently rarely foraged within the wind plants, and similar foraging behavior would be expected of any resident hoary bats in the study area. From 1998 to 1999, approximately 66% of the bat collision fatalities at Buffalo Ridge possibly occurred in association with rain or fog, and up to 54% of collision fatalities documented in 2001 and 2002 may have occurred during rain or fog. Bats are not expected to be foraging under these conditions because foraging activity of bats is greatly depressed during rain and fog (Grindal *et al.* 1992, Hickey and Neilson 1995).

At Delta Marsh, Manitoba, hoary bats gave birth from 9 to 20 June, and fledging ran from 5 to 20 July over the 3-year study (Koehler and Barclay 2000). In Ontario, Canada, lactating hoary bat females were captured as early as 10 June (Hickey and Fenton 1996), and a female hoary bat with young was found on 1 June 1 1998 in Mitchell, South Dakota (Mullican 1999). If mortality involved resident breeding bats, some collision fatalities would be expected in June and early July, a time period when hoary and other bat species should be breeding in Minnesota (Hazard 1982), yet this rarely occurred. Adults of some species of bats have been shown to change foraging patterns and locations once juveniles become volant, 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, eastern red or silver-haired bat. Therefore, the late summer increase in the number of fatalities is not likely explained by a concurrent shift in diet or habitat use of resident adult bats. Recently fledged juvenile bats 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 (Audet

1990, Rolseth *et al.* 1994), thereby possibly making them more susceptible to turbine collision over time. The increase in the number of fatalities at Buffalo Ridge 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 became volant. Ninety percent of the hoary bats and 88% of all bat collision victims found during this study were adults.

Both the Anabat® and mist net data indicate that there were relatively large breeding populations of bats in close proximity to the wind plant when collision mortality was virtually non-existent. Although most of these bats were big brown and little brown bats, we also captured four eastern red bats and seven silver-haired bats during June and early July at Hole in the Mountain Park. Eastern red bats have been documented in eastern South Dakota during this same time period (Jones and Genoways 1967, Swier 2003), and the large number of silver-haired bats captured in June and early July at Hole in the Mountain Park (including a gravid female on 6-19-02) supports the conclusion by Swier (2003) that this species is a summer resident in the region.

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 fatalities 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 72 bat fatalities documented the first two years of operation (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 a wind plant near Condon, Oregon, considerable bat activity was recorded at nearby (0.4 – 0.8 km) 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 research wind turbines and met towers. During a recent study of the NWTC, 216 bats (representing as many as 6 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 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.

Based on all available evidence, it does not appear that bat mortality occurring at Buffalo Ridge involves resident bats foraging within the wind plant or commuting between foraging and roosting areas. In virtually all other cases of bat collision mortality documented at other structures, the timing suggested that migrant bats were involved (*e.g.*, Van Gelder 1956, Zin and

Baker 1979, Crawford and Baker 1981). Data collected at other wind plants in the U.S. (Johnson 2003, Keeley *et al.* 2001), Sweden (Ahlen 2002), and Germany (Bach 2001) also suggest that migrants comprise most of the bat collision fatalities. We believe that most bat mortality at Buffalo Ridge also involves migrating bats. 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. 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).

At Delta Marsh along the southern end of Lake Manitoba, Canada, hoary bats began migrating in mid July (Koehler and Barclay 2000, C. Koehler, personal communication), and all resident juvenile hoary bats had migrated out of the study area by 2 August. During an earlier study at Delta Marsh, all hoary bats had migrated out of the area by 3 September (Barclay 1984). Delta Marsh is located approximately 560 km (350 miles) almost due north of Buffalo Ridge. The hoary bat is a strong flyer and can attain speeds of 21 km/hr (Hayward and Davis 1964). At this speed, hoary bats migrating from large forested tracts in northern Minnesota and southern Canada could easily reach Buffalo Ridge within a few days, and the timing of fall hoary bat migration documented by Koehler and Barclay (2000) is similar to the timing of hoary bat collision mortality at Buffalo Ridge.

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), Iowa (McClure 1942), Illinois (Izor 1979) and Canada (Banfield 1974, Collister 1995) in August or September. At Delta Marsh, Manitoba, both eastern red and silver-haired bats began migrating through the area in mid July (C. Koehler, personal communication), 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). Both big and little brown bats spend the winter in hibernacula, but the little brown bat may migrate several hundred kilometers to hibernate (Davis and Hitchcock 1965, Griffin 1970, Humphrey and Cope 1976, Smith 1995), and the big brown bat may migrate up to 80 km to hibernate (Mills *et al.* 1975). Autumn dispersal 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 big brown bats also occurs as early as August (Barbour and Davis 1979). The timing of migratory or dispersal movements by species other than hoary bat also corresponds to the timing of collision mortality at Buffalo Ridge. Based on this, plotting the number of fatalities by date should provide a reasonable estimate of the timing of fall bat migration and dispersal in southwest Minnesota (Figure 5-1).

Based on the timing of spring migration (Koehler and Barclay 2000), hoary bats should be migrating north through the Buffalo Ridge area in mid to late May, and eastern red bats migrate into South Dakota in April (Findley 1956). However, very few collision fatalities have been found in April or May at Buffalo Ridge (Higgins *et al.* 1996, Johnson *et al.* 2000a) or other wind plants (*e.g.*, Erickson *et al.* 2000, Johnson *et al.* 2000b). 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).

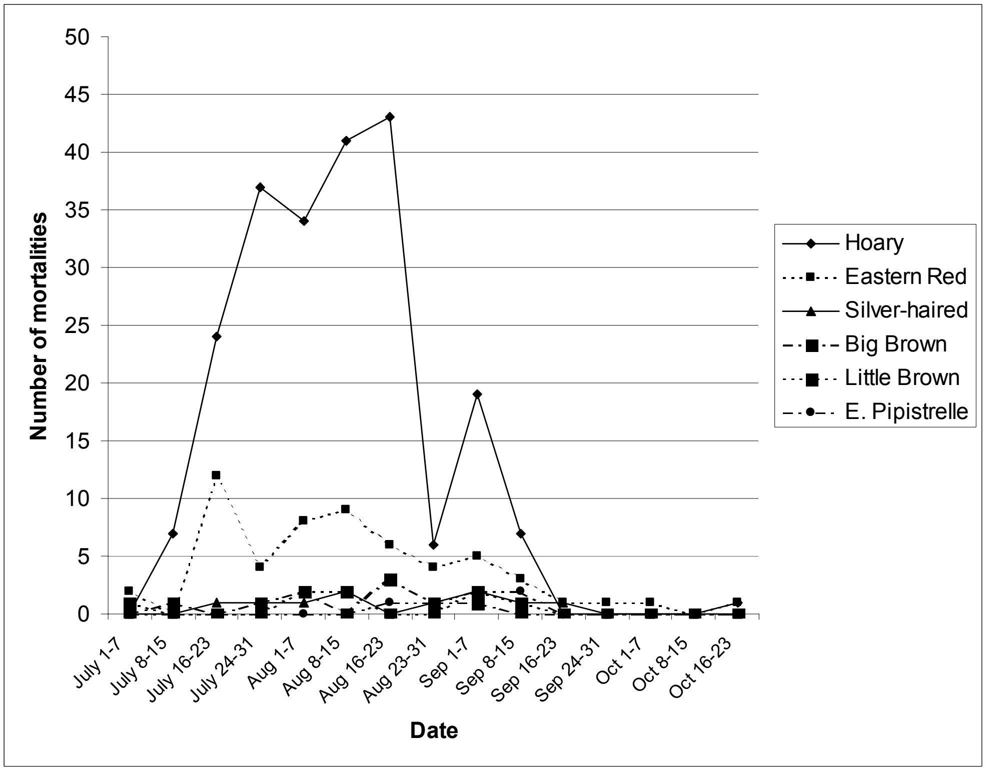

Figure 5-1
Timing of Fall Bat Migration and Dispersal in Southwest Minnesota Based on Timing of Collision Mortality at Buffalo Ridge (Data from Johnson *et al.* 2003a and this Study)

Why collision mortality in the spring is only a fraction of that in the fall is not clear. Plots of museum occurrence records of hoary bats indicate extremely low densities of this species in Minnesota in May, with much higher densities in July and August. A similar pattern occurs for eastern red bat, whereas silver-haired bat abundance is fairly similar from mid May through mid September in Minnesota (Cryan, in press). At a wind plant in northeastern Wisconsin, bat activity based on echolocation data was far greater in the fall than in the spring (Puzen 2002). These data indicate that hoary and eastern red bats may use different migration corridors in the spring and fall, as do several species of birds (*e.g.*, Cooke 1915, Lincoln 1950, Richardson 1974, Richardson 1976). Behavioral differences between migrating hoary bats in the spring and fall may also be related to mortality patterns. Such differences have been reported; in Florida, autumn migration of hoary bats occurred in waves whereas the spring migration appeared to be far more scattered and less organized (Zinn and Baker 1979).

Food items were present in 17 bat carcasses collected at Buffalo Ridge in 1999, indicating the bats had been feeding before colliding with turbines (Johnson *et al.* 2000a). When and where these bats previously foraged is not known, although based on typical bat foraging behavior, they likely fed soon after leaving their daytime roost earlier in the evening. Little information is available on foraging habits of migrating bats. Unlike most songbirds, which are night migrants, swallows and swifts (also aerial insectivores) migrate during the day and forage on insects along the way (Welty 1982); therefore, it seems plausible that migrating bats could also forage on insects while migrating.

Potential Causes of Collision Mortality

The cause of bat collisions with wind turbines or other man-made structures is not well understood (Johnson 2003). Bats have the ability to navigate through constructed clutter zones made of staggered vertical strands of twine 3 mm in diameter spaced 1 m apart (Mackey and Barclay 1989, Brigham *et al.* 1997a). Bats are also able to detect large landscape and background features by echolocation out to 100 m (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 one meter of an operating wind turbine in Germany, yet no collision fatalities were 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 fatalities were 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 inclement weather and avian collision fatalities. 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 fatalities (Crawford and Baker 1981), and there appeared to be no relationship in the number of bat and bird fatalities found during previous studies of Buffalo Ridge (Osborn *et al.* 1996, Johnson *et al.* 2000a) or other wind plants in the U.S. (Johnson *et al.* 2000b, Erickson *et al.* 2000, Young *et al.* 2002, 2003).

Even though echolocation in flying bats does not require additional energy expenditures (Speakman and Racey 1991), anecdotal evidence suggests that migrating bats may 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 fatality data indicated numerous hoary bats were apparently migrating over the wind plant during the study (Gruver 2002).

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 to 100 m) over which echolocation is effective (Griffin 1970, Fenton 1982). If bats are flying through wind farms on Buffalo Ridge primarily by sight, then causes of bat mortality could be similar to causes of avian nocturnal migrant collision mortality at wind plants.

Data we collected at Buffalo Ridge indicate that migrating bats likely do echolocate, at least to some extent. During this study, bat activity at turbines based on echolocation calls peaked in late July and August, which corresponds to the time that many of the fatalities occurred (see Figures 4-4 and 5-1). 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.

Is there something about turbines that attracts bats? Hayes and Waldien (2000) speculated that noise generated by wind turbines could attract or repel bats, jam their echolocation signals, or have other effects not currently predictable. Anabats® placed at turbines during this study did not pick up any ultrasonic sounds, indicating that the turbines do not emit any ultrasonic noises that might confuse or attract bats.

We did not find that FAA lighting on turbines leads to increased numbers of fatalities. During an earlier 4-year avian monitoring study 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). In addition, mortality at the P2 wind plant, with only 6 of 143 turbines lighted, was similar to the P3 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*. 2003b). 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 (WEST, Inc., unpublished data).

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. We do not believe insects swarmed at turbines on Buffalo Ridge based on the absence of "feeding buzzes" among the 452 bat echolocation passes recorded at turbines.

Although not documented, Osborn *et al*. (1996) suggested that bats may possibly roost temporarily on the catwalk or other external turbine structures present on turbines in P1. The turbines in the P2 and P3 wind plants do not have any external structures suitable for bat roosting, and bats have never been observed on turbines by wind plant maintenance personnel (Jim Mikel, Enron Wind, pers. commun.). Dalquest (1943) reported that migrating hoary bats often seem to select the nearest available tree as a daytime hiding 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.

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 generally nearly as high as the turbines and are supported by thin guy wires, theoretically making them more hazardous to bats then 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. Although six dead bats were found at 16 turbines within a wind plant in Oregon, none were found at a met tower searched with the same intensity as turbines (Johnson *et al*. 2003c). Similarly, 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). In 2002, we searched 13 met towers at Buffalo Ridge and did not find any dead bats, but dense vegetation underneath the towers would have made it difficult to detect any bat carcasses present. Only one study has attempted to address behavior of migrant 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 (Puzen 2002).

Because most of the fatalities are apparently 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 migrate at elevations above the rotor-swept area of commercial wind turbines (see Kerlinger 1995). There is little information on flight heights of migrating bats. Some groups of bats are known to migrate much higher than 100 m in altitude (Altringham 1996). Bats migrating during the day over Washington, D.C. were reported flying from 46 to 140 m 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 (*Tadarida brasiliensis*) are capable of flying from 180 to 3050 m above ground in pursuit of migrating moths (McCracken 1996).

We do not know if Buffalo Ridge has higher than normal concentrations of migrating bats. Many species of bats make extensive use of linear features in the landscape while commuting (Limpens and Kapteyn 1991) and migrating (Strelkov 1969, Humphrey and Cope 1976, Timm 1989), and perhaps some linear feature such as the Red River along much of the Minnesota and North and South Dakota border is followed by migrating bats which would direct them over Buffalo Ridge in higher than average numbers. However, similar linear features do not occur at all wind plants where bat fatalities frequently occur (e.g., Erickson *et al.* 2000, Johnson *et al.* 2000b, 2003b).

Impacts to Bats

Population consequences associated with wind power-related mortality cannot be quantified with available data. Most bats produce few young each year (Kurta and Kunz 1987) and therefore have very slow population growth rates for a small mammal (Hill and Smith 1984, Fitzgerald *et al.* 1994). As a result, high mortality rates should result in population declines (Humphrey and Cope 1976, Keeley *et al.* 2001, Kuenzi and Morrison 2003). If bat collision mortality associated with wind power development at Buffalo Ridge has significantly impacted the affected bat “population”, then one might expect lower numbers of fatalities each subsequent year simply because there would be fewer bats present to collide with turbines. Estimates of the total number of bat fatalities at Buffalo Ridge did not decline between 1998 and 2001 (Figure 5-2). Although the combined number of bat fatalities was lower in 2002 than during previous years, the estimated number of fatalities at P2 in 2002 (176) was similar to 2000 (189). The 2002 estimate of the number of bat fatalities in P3 is lower than previous years. Whether the reduced number of fatalities in 2002 was caused by natural variation in bat migration rates or a drop in the population is not known. Although fewer dead bats were found in 2002, many of the turbine pads were allowed to become overgrown with weeds in 2002, which reduced visibility. In previous years all of the pads were maintained with herbicides and visibility on the pad was substantially higher. Therefore it is likely that more bats were missed in 2002, but the difference in searcher efficiency on pads between years does not totally account for the reduced fatality estimates in 2002.

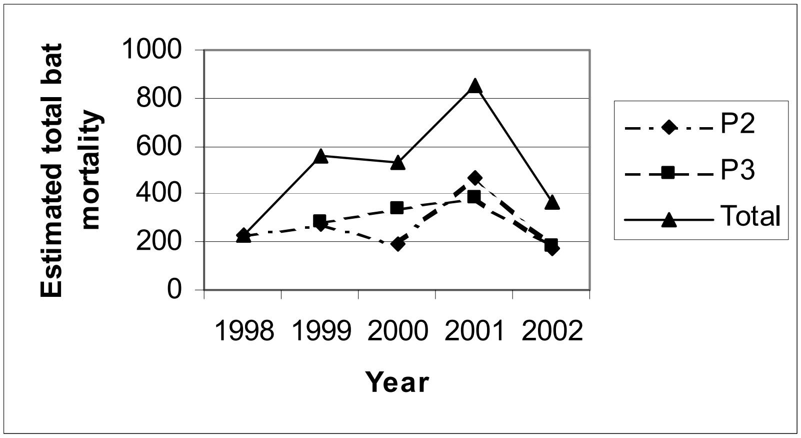

Figure 5-2
Estimated Total Numbers of Bat Fatalities at the P2 and P3 Wind Plants from 1998 to 2002 (Data from 1998-99 are from Johnson *et al.* 2000a; Data from 2000 are from Krenz and McMillan 2000; Data from 2001-02 are from this Study)

Although the estimated number of fatalities was lower in 2002, there was no significant difference in bat activity at turbines within the wind plant between 2001 and 2002. Although the mean in 2001 (2.2) was slightly higher than the mean in 2002 (1.9), the mean number of passes per turbine per night in 2001 was calculated using the extraordinary value of 67 passes recorded at turbine 5 in the P3 wind plant on June 24. If this one outlier is removed from the data, the mean number of passes per turbine in 2001 was 1.8, or nearly identical to the 2002 mean. The 67 passes at turbine 5 also occurred in June well before the onset of migration, and indicated one to several resident bats were flying in the vicinity of this turbine. When bat activity at Turbines was examined for the period July 15 to August 31, when peak mortality (and presumably peak migration) was occurring, the mean number of passes per turbine per night was similar (2.7 in 2001 vs. 2.5 in 2002). Because bat activity at turbines during the peak migration period did not decline from 2001 to 2002, it is likely that the population of migratory bats also did not decline. Preliminary data indicate that many of the bat passes recorded at turbines during migration were hoary bats.

Data collected at Buffalo Ridge since 1998 suggest that the number of bats migrating through the WRA area is substantial, and that wind plant-related mortality to date may not be large enough to cause significant, large-scale population declines. However, the potential effects on populations of sustained collision mortality at these levels over several years are not known.

Mitigation and Future Research

Mitigation measures are usually recommended when impacts to a resource are considered "significant." In the case of bat collision at wind plants, defining a significant impact is difficult (*e.g.*, Johnson and Strickland 2003). For avian collision mortality at wind plants, the death of individuals is not considered a significant impact as long as the mortality does not result in population declines (Kerlinger 2001), and no avian population impacts have been demonstrated or suspected at U.S. wind plants (Erickson *et al.* 2001, 2002). If this criterion were applied to bat mortality at Buffalo Ridge, mitigation would not be warranted because we did not definitively document a significant population impact. Although lower numbers of fatalities were observed in 2002, bat activity levels in the wind plant during the migration period did not decrease from 2001 to 2002, suggesting no large-scale population effects.

Determining whether or not mitigation is required and the form of any mitigation is the responsibility of state and federal regulators working in conjunction with wind plant developers. Here we provide an overview of mitigation measures potentially relevant for impacts associated with bats and wind power. Numerous mitigation strategies have been developed to reduce avian collision fatalities at wind plants, although most have not been experimentally tested on a large-scale basis (Johnson *et al.* 2003c). Mitigation for wind plant impacts can include (1) modifications of turbines to eliminate or reduce collision fatalities, (2) changing operation of the wind plant to reduce the number of collision fatalities, (3) modifying the sitting of entire wind plants as well as placement of individual turbines within wind plants to reduce impacts, and (4) off-site modifications of habitats to benefit impacted wildlife (Johnson *et al.* 2003c).

An example of turbine modification might include placing an electronic device on turbines to repel bats. Attempts have been made to repel bats from buildings with high-frequency sounds. Although success has been reported in some instances (see Greenhall 1982), it is the consensus of most bat researchers and control specialists that these devices are ineffective (William Rainey, University of California, Berkeley; Gareth Jones, Bat Ecology and Bioacoustics Laboratory, University of Bristol, London; Barbara French, Bat Conservation International, Austin, Texas; Brian McGuckin, Four Seasons Bat Control, Inc., Owosso, Michigan, personal communication). Efforts to repel bats using taped bat distress calls are also ineffective, as the distress calls tend to attract rather then repel bats (Gareth Jones, University of Bristol, London, personal communication).

At a wind plant in Wisconsin, the number of bat fatalities at one set of turbines was 30% lower in 2000 than it was in 1999, whereas the number of fatalities at a nearby set of turbines was similar both years. The only difference between the two sets of turbines was that turbines in the set with lowered bat mortality were shut down during low wind conditions beginning in early July 2000, which may have been responsible for reducing bat mortality (Howe *et al.* 2002). This is an example of how modifying operation of the wind plant might be used to reduce mortality.

Bat mortality levels were not found to be related to distance to woodlands or wetlands or any other habitat variable during this study. As a result, no recommendations to reduce the number of bat collision fatalities through turbine sitting can be provided based on available data.

In the absence of proven methods to reduce the number of bat fatalities through modifying turbines, changing operation of the wind plant, or through changes in future siting of turbines and wind plants, one form of mitigation might include off-site habitat protection or improvement. Several studies have examined habitat use of forest bats, and have made recommendations to maintain or enhance bat habitat (Brigham *et al.* 1997b, Kalcounis and Brigham 1998, Ormsbee and McComb 1998, Rabe *et al.* 1998, Jung *et al.* 1999, Hutchinson and Lacki 2000b, Krusac and Mighton 2002). Such forest management practices could be considered to improve bat habitat on a regional level to mitigate impacts associated with wind power development. Forest management practices in the Lake Benton area itself would not benefit hoary bats because this is apparently not a breeding species in the area.

Another example is use of artificial bat roosts to enhance habitat where roost sites might be limited due to alteration or removal of forested habitats (e.g., Fenton 1997, Chambers *et al.* 2002). In Thetford Forest, England, the population of brown long-eared bats (*Plecotus auritus*) doubled after 10 years when artificial bat boxes were added (Boyd and Stebbings 1989). This example would not be appropriate for most wind power related impacts, as the species comprising most of the fatalities are solitary foliage roosters that would not use artificial roosts. To mitigate impacts associated with wind power development in Washington State, the Washington Department of Fish and Wildlife is requesting that developers pay into a fund set up by the state to purchase wildlife habitat. The current fee for this fund is $75 per turbine per year (e.g., Klickitat County, Washington Planning Department 2002). Although this is being done primarily to mitigate impacts to birds, similar measures might also work for bats. Another potential form of mitigation might involve making contributions to organizations such as Bat Conservation International, the Organization for Bat Conservation, or the recently-formed North American Bat Conservation Partnership (see Arnett and Haufler 2003, Keeley *et al.* 2003) that can be used to fund bat conservation throughout North America.

Although substantial research has been conducted on bats, there is still a basic lack of information on geographic distributions, habitat associations, and population status of most bat species (Fenton 1997, Menzel *et al.* 1998, Fenton 2003, Hayes 2003, Keeley *et al.* 2003, Sherwin *et al.* 2003), which hinders the development of management procedures to protect bat populations (Kuenzi and Morrison 2003). This study as well as several other recent studies of bat/wind power interactions have greatly improved our knowledge of the species, timing and extent of bat mortality in the U.S. These studies have also established that wind power development primarily impacts migrating bats, with minor impact to resident breeding bat populations. Additional funding for future research on bats may also be considered a form of mitigation. This could include research that is not directly tied to wind power impacts, but that may be useful for understanding bat migrations or bat population dynamics. The next logical area for investigation of bat/wind power interactions is development and testing of methods that might reduce or eliminate bat collision mortality at wind plants. Before it is possible to develop procedures to modify turbines, future research should be conducted to determine if turbines attract bats, and, if so, to find out what mechanisms might be responsible for this. A simple study involving placement of bat detectors at turbines and in nearby areas of similar habitat without turbines could possibly address whether turbines attract bats. Additional research with thermal imaging or night vision devices that would allow the study of bat behavior near turbines would also be useful.

The measures identified above may not be applicable or even warranted for the Buffalo Ridge wind plant. Bat collision mortality at wind plants occurs throughout the U.S., and the entire wind industry should be involved in finding solutions to the problem. Some of the potential mitigation measures for bats would be most beneficial if implemented regionally rather than on a small-scale basis associated with one wind plant. Suggested ideas for future research are not necessarily appropriate for Buffalo Ridge. The ability to conduct meaningful research is greatly improved as sample sizes increase, and better data might be collected where bat fatality rates (and presumably bat passage rates) are much higher (See Table 5-1).

6
CONCLUSIONS

Based on results of this study, the following conclusions can be made:

- Bat collision mortality during the breeding season was virtually non-existent, despite the fact that relatively large populations of bats, including two species known to be susceptible to turbine collisions (eastern red and silver-haired), apparently breed in close proximity to the wind plant. Data we collected and similar data collected at other U.S. wind plants indicate that wind plants do not pose major threats to local breeding bat populations.
- All available evidence indicates that most of the fatalities at Buffalo Ridge and other U.S. wind plants are migrating or dispersing bats in the fall.
- The Anabat® and fatality data indicate that only a small fraction of bat passes near turbines result in collisions. The actual number of bats passing by turbines for each fatality is likely much higher than documented by bat detectors during this study.
- FAA lighting on turbines does not lead to increased bat activity around the turbine or to increased fatality rates; however, available evidence indicates that turbines may somehow attract bats or that bats cannot detect turbines as well as stationary tall structures.
- Fatality estimates at Buffalo Ridge indicate that the population of bats susceptible to turbine collisions is large, and that the observed number of fatalities is possibly not sufficient to cause significant, large-scale population declines. However, the potential effects on populations of sustained collision mortality at these levels over several years are not known.
- Future research should concentrate on determining the causes of bat collisions and methods to reduce and/or mitigate the mortality.

Acknowledgements

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7

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A

BAT FATALITIES FOUND AT THE BUFFALO RIDGE, MINNESOTA WIND RESOURCE AREA, 2001-2002

Phase	Species	Age	Sex	Turbine	Found During Search?	Habitat Bat Found In	Date	Condition	Distance from Turbine (m)	Direction from Turbine (°)
2	Hoary	A	F	2	Yes	Turbine Pad	6-20-01	Intact	7	10
2	Hoary	A	M	65	No	Corn	7-16-01	Intact	35	5
2	Hoary	A	M	78	Yes	Soybean	7-17-01	Intact	12	40
2	Hoary	A	U	49	No	Turbine Pad	7-18-01	Scavenged	4	40
2	Hoary	A	M	141	Yes	Turbine Pad	7-20-01	Intact	9	150
2	Hoary	A	F	143	No	Turbine Pad	7-20-01	Intact	11	90
2	Hoary	J	U	142	No	Turbine Pad	7-20-01	Scavenged	7	20
2	Hoary	U	U	17	No	Turbine Pad	7-30-01	Scavenged	2	10
2	Hoary	A	U	9	Yes	Turbine Pad	7-30-01	Scavenged	4	110
2	Hoary	A	F	2	Yes	Turbine Pad	7-30-01	Intact	3	5
2	Hoary	A	U	61	Yes	Soybean	7-31-01	Scavenged	15	80
2	Hoary	A	M	40	Yes	Turbine Pad	7-31-01	Scavenged	4	10
2	Big Brown	J	U	134	Yes	Turbine Pad	8-1-01	Scavenged	3	60
2	Hoary	A	U	134	Yes	Turbine Pad	8-1-01	Scavenged	1	20
2	Hoary	U	U	131	Yes	Turbine Pad	8-1-01	Scavenged	1	200
2	Hoary	U	U	96	Yes	Turbine Pad	8-1-01	Scavenged	4	75
2	Eastern Red	A	M	128	No	Turbine Pad	8-2-01	Intact	4	5
2	Hoary	U	U	129	No	Turbine Pad	8-2-01	Scavenged	10	80

Phase	Species	Age	Sex	Turbine	Found During Search?	Habitat Bat Found In	Date	Condition	Distance from Turbine (m)	Direction from Turbine (°)
2	Silver-haired	A	U	143	No	Corn	8-2-01	Scavenged	20	350
2	Hoary	A	U	16	Yes	Soybean	8-2-01	Scavenged	19	280
2	Hoary	U	U	16	Yes	Turbine Pad	8-2-01	Scavenged	7	190
2	Hoary	A	U	18	No	Turbine Pad	8-2-01	Scavenged	6	95
2	Hoary	U	U	58	Yes	Soybean	8-2-01	Scavenged	17	5
2	Hoary	U	U	71	Yes	Soybean	8-2-01	Scavenged	19	70
2	Eastern Red	U	U	71	Yes	Turbine Pad	8-2-01	Scavenged	7	10
2	Hoary	U	U	104	No	Turbine Pad	8-2-01	Scavenged	4	85
2	Hoary	U	U	110	Yes	CRP	8-2-01	Scavenged	13	190
2	Hoary	A	U	40	Yes	Turbine Pad	8-13-01	Scavenged	1	90
2	Hoary	U	U	2	Yes	Turbine Pad	8-13-01	Scavenged	5	100
2	Hoary	A	U	5	Yes	Turbine Pad	8-13-01	Scavenged	11	210
2	Hoary	A	M	117	Yes	Pasture	8-14-01	Intact	14	50
2	Eastern Red	A	M	47	Yes	Turbine Pad	8-14-01	Scavenged	9	300
2	Hoary	U	U	47	Yes	Corn	8-14-01	Scavenged	12	70
2	Hoary	A	U	134	Yes	Turbine Pad	8-14-01	Scavenged	7	180
2	Hoary	U	U	26	Yes	Turbine Pad	8-15-01	Scavenged	2	350
2	Eastern Red	A	M	127	Yes	Turbine Pad	8-16-01	Scavenged	5	100
2	Hoary	J	M	141	Yes	Turbine Pad	8-16-01	Scavenged	8	50
2	Hoary	U	U	85	Yes	Turbine Pad	8-16-01	Scavenged	11	330
2	Eastern Red	A	M	123	No	Pasture	8-28-01	Intact	14	250
2	Hoary	A	U	96	Yes	Turbine Pad	8-28-01	Scavenged	11	160
2	Hoary	A	F	78	Yes	Soybean	8-29-01	Intact	12	290
2	Big Brown	A	M	19	Yes	Pasture	8-30-01	Scavenged	18	300

Phase	Species	Age	Sex	Turbine	Found During Search?	Habitat Bat Found In	Date	Condition	Distance from Turbine (m)	Direction from Turbine (°)
2	Silver-haired	A	U	138	Yes	Turbine Pad	8-31-01	Scavenged	10	275
2	Hoary	J	U	85	Yes	Turbine Pad	9-10-01	Scavenged	6	25
2	Silver-haired	J	U	64	Yes	Corn	9-10-01	Scavenged	16	275
2	Hoary	A	M	127	Yes	Turbine Pad	9-12-01	Intact	1	250
2	Hoary	J	U	120	Yes	Turbine Pad	9-12-01	Scavenged	4	200
3	Eastern Red	A	U	79	Yes	Pasture	6-26-01	Scavenged	20	45
3	Hoary	A	M	89	Yes	Turbine Pad	6-27-01	Intact	11	270
3	Hoary	A	U	82	Yes	Turbine Pad	7-11-01	Scavenged	12	170
3	Hoary	A	U	68	Yes	Corn	7-11-01	Scavenged	18	45
3	Hoary	A	U	68	Yes	Corn	7-11-01	Scavenged	24	80
3	Hoary	A	M	132	Yes	Turbine Pad	7-23-01	Intact	1	5
3	Eastern Red	A	F	128	Yes	Turbine Pad	7-23-01	Scavenged	2	200
3	Hoary	A	F	124	No	Turbine Pad	7-23-01	Intact	12	45
3	Hoary	A	F	4	Yes	Turbine Pad	7-24-01	Intact	7	90
3	Hoary	A	U	98	No	Turbine Pad	7-25-01	Scavenged	12	125
3	Hoary	A	F	89	Yes	Turbine Pad	7-25-01	Intact	12	10
3	Hoary	A	U	33	Yes	Alfalfa	7-25-01	Scavenged	21	40
3	Hoary	A	F	72	Yes	Turbine Pad	7-25-01	Intact	9	250
3	Hoary	A	M	65	Yes	Corn	7-26-01	Intact	18	200
3	Hoary	A	F	54	Yes	Turbine Pad	7-26-01	Intact	11	80
3	Hoary	A	M	40	Yes	Soybean	7-27-01	Intact	22	270
3	Hoary	A	F	19	Yes	Turbine Pad	7-27-01	Intact	11	30
3	Hoary	A	F	47	Yes	Turbine Pad	8-6-01	Intact	14	0
3	Eastern Red	U	U	12	Yes	CRP	8-6-01	Scavenged	18	190

Phase	Species	Age	Sex	Turbine	Found During Search?	Habitat Bat Found In	Date	Condition	Distance from Turbine (m)	Direction from Turbine (°)
3	Hoary	U	U	22	Yes	Turbine Pad	8-7-01	Scavenged	5	160
3	Big Brown	A	M	64	No	Corn	8-7-01	Intact	25	260
3	Eastern Red	A	M	33	Yes	Alfalfa	8-7-01	Injured	25	90
3	Hoary	A	F	79	Yes	Turbine Pad	8-8-01	Intact	9	85
3	Hoary	A	U	96	Yes	Turbine Pad	8-8-01	Scavenged	11	350
3	Little Brown	J	U	100	Yes	Turbine Pad	8-9-01	Intact	16	275
3	Hoary	A	F	128	Yes	Soybean	8-10-01	Intact	24	170
3	Eastern Red	A	U	135	Yes	Turbine Pad	8-10-01	Scavenged	3	100
3	Hoary	A	F	121	Yes	Turbine Pad	8-10-01	Intact	5	90
3	Hoary	A	U	47	Yes	Turbine Pad	8-19-01	Scavenged	10	120
3	Hoary	A	M	35	No	Corn	8-19-01	Intact	22	150
3	Hoary	A	F	39	No	Turbine Pad	8-19-01	Intact	15	80
3	Hoary	A	M	26	Yes	Turbine Pad	8-19-01	Intact	10	85
3	Hoary	A	U	4	Yes	Turbine Pad	8-19-01	Scavenged	13	345
3	Hoary	A	U	2	No	Turbine Pad	8-21-01	Scavenged	12	15
3	Hoary	A	M	16	No	Turbine Pad	8-22-01	Intact	7	5
3	Hoary	A	F	30	No	Soybean	8-22-01	Intact	18	95
3	Hoary	A	U	68	Yes	Turbine Pad	8-22-01	Scavenged	5	270
3	Hoary	A	F	99	No	Turbine Pad	8-23-01	Intact	7	125
3	Big Brown	A	U	121	Yes	Turbine Pad	8-23-01	Scavenged	5	180
3	Eastern Red	A	M	128	Yes	Turbine Pad	8-23-01	Intact	11	340
3	Hoary	U	U	129	No	Turbine Pad	9-1-01	Scavenged	1	2
3	Hoary	A	U	133	No	Turbine Pad	9-1-01	Scavenged	10	95

Phase	Species	Age	Sex	Turbine	Found During Search?	Habitat Bat Found In	Date	Condition	Distance from Turbine (m)	Direction from Turbine (°)
3	Eastern Red	J	U	43	Yes	Turbine Pad	9-4-01	Scavenged	1	70
3	Big Brown	A	F	29	Yes	Turbine Pad	9-4-01	Intact	4	25
3	Hoary	A	F	26	Yes	Turbine Pad	9-4-01	Intact	5	170
3	Little Brown	J	M	111	Yes	Turbine Pad	9-6-01	Intact	9	150
2	Hoary	A	U	84	Yes	Corn	6-19-02	Scavenged	20	350
2	Little Brown	U	U	134	No	Turbine Pad	7-1-02	Scavenged	5	345
2	Eastern Red	U	U	67	Yes	Corn	7-2-02	Scavenged	11	0
2	Eastern Red	U	U	9	Yes	Turbine Pad	7-4-02	Scavenged	20	260
2	Hoary	A	M	12	Yes	Turbine Pad	7-19-02	Scavenged	16	270
2	Hoary	A	U	7	No	Turbine Pad	7-19-02	Scavenged	6	180
2	Hoary	A	U	3	No	Turbine Pad	7-19-02	Intact	9	270
2	Hoary	U	U	143	No	Turbine Pad	7-29-02	Intact	5	110
2	Hoary	J	M	134	No	Turbine Pad	7-29-02	Scavenged	4	90
2	Hoary	A	M	24	Yes	Turbine Pad	8-1-02	Intact	10	280
2	Hoary	A	U	18	Yes	Pasture	8-2-02	Scavenged	22	270
2	Hoary	U	U	7	No	Turbine Pad	8-2-02	Scavenged	6	90
2	Eastern Red	U	U	7	No	Turbine Pad	8-2-02	Scavenged	3	350
2	Hoary	U	U	6	Yes	Turbine Pad	8-2-02	Scavenged	10	170
2	Hoary	U	U	1	Yes	Turbine Pad	8-2-02	Scavenged	10	83
2	Hoary	A	U	140	No	Turbine Pad	8-12-02	Scavenged	6	2
2	Hoary	A	F	72	Yes	Turbine Pad	8-13-02	Intact	8	80
2	Hoary	A	M	101	Yes	CRP	8-13-02	Intact	23	100
2	Hoary	A	U	32	Yes	Turbine Pad	8-15-02	Injured	17	80

Phase	Species	Age	Sex	Turbine	Found During Search?	Habitat Bat Found In	Date	Condition	Distance from Turbine (m)	Direction from Turbine (°)
2	Hoary	A	M	36	No	Turbine Pad	8-15-02	Intact	21	170
2	Silver-haired	U	U	26	Yes	Turbine Pad	8-15-02	Scavenged	1	270
2	Hoary	A	F	58	Yes	Soybean	8-15-02	Intact	20	95
2	Hoary	U	U	133	No	Turbine Pad	8-15-02	Scavenged	2	95
2	Eastern Red	U	U	9	Yes	Turbine Pad	8-16-02	Scavenged	1	270
2	Big Brown	U	U	16	No	Turbine Pad	8-16-02	Scavenged	29	100
2	Hoary	A	U	8	No	Turbine Pad	8-16-02	Intact	6	100
2	Hoary	A	U	7	No	Turbine Pad	8-16-02	Intact	14	130
2	Big Brown	A	U	6	Yes	Turbine Pad	8-16-02	Scavenged	3	200
2	Hoary	U	U	3	No	Turbine Pad	8-16-02	Scavenged	5	170
2	Eastern Red	A	F	5	No	Turbine Pad	8-16-02	Intact	7	10
2	Eastern Red	A	U	86	Yes	Turbine Pad	8-28-02	Scavenged	17	295
2	Hoary	U	U	132	Yes	Turbine Pad	9-7-02	Scavenged	13	5
2	Eastern Red	A	M	3	No	Turbine Pad	9-10-02	Intact	16	90
3	Hoary	A	M	93	Yes	Turbine Pad	7-10-02	Scavenged	23	320
3	Big Brown	U	U	60	Yes	Turbine Pad	7-11-02	Scavenged	19	230
3	Hoary	A	F	107	Yes	Turbine Pad	7-11-02	Intact	10	290
3	Hoary	A	M	137	Yes	Turbine Pad	7-12-02	Intact	12	270
3	Hoary	J	M	13	Yes	Turbine Pad	7-22-02	Intact	2	220
3	Hoary	J	F	28	No	Turbine Pad	7-22-02	Intact	14	180
3	Hoary	J	M	45	No	Turbine Pad	7-23-02	Intact	15	225
3	Hoary	A	U	57	Yes	Soybean	7-23-02	Scavenged	20	90
3	Eastern Red	A	U	79	Yes	Turbine Pad	7-24-02	Intact	24	30

Phase	Species	Age	Sex	Turbine	Found During Search?	Habitat Bat Found In	Date	Condition	Distance from Turbine (m)	Direction from Turbine (°)
3	Hoary	A	U	118	Yes	Turbine Pad	7-26-02	Scavenged	5	270
3	Hoary	J	U	132	Yes	Turbine Pad	7-26-02	Scavenged	19	300
3	Hoary	A	U	137	Yes	Turbine Pad	7-26-02	Scavenged	4	80
3	Hoary	U	U	121	Yes	Turbine Pad	8-9-02	Scavenged	1	340
3	Hoary	U	U	121	Yes	Corn	8-9-02	Scavenged	22	330
3	Hoary	A	U	132	Yes	Turbine Pad	8-12-02	Scavenged	15	40
3	Hoary	A	U	16	Yes	Turbine Pad	8-19-02	Scavenged	13	10
3	Hoary	U	U	71	Yes	Turbine Pad	8-21-02	Scavenged	20	15
3	Hoary	A	U	79	Yes	Turbine Pad	8-21-02	Scavenged	17	20
3	Hoary	A	U	102	Yes	Turbine Pad	8-22-02	Scavenged	14	105
3	Hoary	A	U	112	No	Turbine Pad	8-22-02	Scavenged	10	150
3	Hoary	U	U	113	Yes	Turbine Pad	8-22-02	Scavenged	15	15
3	Hoary	A	U	137	Yes	Turbine Pad	8-23-02	Scavenged	11	45
3	Hoary	A	M	57	Yes	Turbine Pad	8-24-02	Intact	14	45
3	Eastern Red	A	U	110	Yes	CRP	8-24-02	Scavenged	10	340
3	Hoary	A	M	2	Yes	Turbine Pad	9-3-02	Intact	15	45

B

NUMBER OF BAT PASSES RECORDED WITH BAT DETECTORS AND BAT COLLISION FATALITIES AT TURBINES IN THE PHASE 2 AND 3 WIND PLANTS, BUFFALO RIDGE, MINNESOTA, 2001-2002

Study Area	Turbine	Date	Number Passes	Number Fatalities	Species
2	140	6/18/01	0	0	NA
2	138	6/20/01	0	0	NA
2	143	6/20/01	0	0	NA
2	133	6/21/01	0	0	NA
2	125	6/21/01	0	0	NA
2	3	6/23/01	0	0	NA
3	5	6/24/01	67	0	NA
3	70	6/26/01	0	0	NA
3	35	6/26/01	1	0	NA
3	25	6/26/01	0	0	NA
3	28	6/26/01	9	0	NA
3	7	6/27/01	0	0	NA
3	84	6/27/01	1	0	NA
3	94	6/27/01	1	0	NA
3	41	7/02/01	0	0	NA
2	73	7/02/01	1	0	NA
2	119	7/03/01	0	0	NA
2	48	7/03/01	0	0	NA
2	45	7/03/01	0	0	NA
2	8	7/04/01	0	0	NA

Number of Bat Passes Recorded with Bat Detectors and Bat Collision Fatalities at Turbines in the Phase 2 and 3 Wind Plants, Buffalo Ridge, Minnesota, 2001-2002

Study Area	Turbine	Date	Number Passes	Number Fatalities	Species
2	122	7/07/01	1	0	NA
2	108	7/07/01	2	0	NA
2	95	7/07/01	0	0	NA
2	55	7/07/01	0	0	NA
2	77	7/08/01	2	0	NA
2	38	7/08/01	4	0	NA
2	34	7/08/01	1	0	NA
3	5	7/08/01	2	0	NA
3	11	7/09/01	1	0	NA
3	13	7/09/01	3	0	NA
3	49	7/09/01	0	0	NA
3	21	7/11/01	0	0	NA
3	45	7/11/01	0	0	NA
3	54	7/11/01	0	0	NA
3	71	7/12/01	0	0	NA
3	74	7/12/01	0	0	NA
3	34	7/12/01	1	0	NA
2	4	7/15/01	7	0	NA
2	11	7/15/01	1	0	NA
2	25	7/15/01	0	0	NA
2	135	7/17/01	10	0	NA
2	132	7/17/01	14	0	NA
2	130	7/17/01	6	0	NA
2	116	7/17/01	8	0	NA
2	126	7/18/01	9	0	NA
2	139	7/18/01	14	0	NA
2	86	7/19/01	4	0	NA
2	79	7/19/01	0	0	NA
2	53	7/19/01	2	0	NA

Study Area	Turbine	Date	Number Passes	Number Fatalities	Species
3	123	7/22/01	6	0	NA
3	115	7/22/01	3	0	NA
3	108	7/24/01	0	0	NA
3	98	7/24/01	3	1	Hoary Bat
3	134	7/26/01	3	0	NA
3	131	7/26/01	1	0	NA
3	124	7/26/01	0	0	NA
2	17	7/29/01	0	1	Hoary Bat
2	13	7/29/01	5	0	NA
2	60	7/30/01	0	0	NA
2	66	7/30/01	7	0	NA
2	142	8/01/01	10	0	NA
2	128	8/01/01	4	1	Eastern Red Bat
2	129	8/01/01	7	1	Hoary Bat
2	72	8/02/01	7	0	NA
2	118	8/02/01	5	0	NA
3	17	8/05/01	1	0	NA
3	24	8/05/01	1	0	NA
3	37	8/05/01	3	0	NA
3	56	8/07/01	1	0	NA
3	69	8/07/01	1	0	NA
3	64	8/07/01	2	0	NA
3	85	8/07/01	2	0	NA
3	101	8/08/01	0	0	NA
3	113	8/08/01	3	0	NA
3	6	8/09/01	3	0	NA
3	3	8/09/01	3	0	NA
2	69	8/12/01	5	0	NA
2	67	8/12/01	1	0	NA

Number of Bat Passes Recorded with Bat Detectors and Bat Collision Fatalities at Turbines in the Phase 2 and 3 Wind Plants, Buffalo Ridge, Minnesota, 2001-2002

Study Area	Turbine	Date	Number Passes	Number Fatalities	Species
2	84	8/12/01	0	0	NA
2	81	8/12/01	1	0	NA
2	21	8/13/01	0	0	NA
2	27	8/13/01	0	0	NA
2	56	8/13/01	2	0	NA
2	137	8/15/01	4	0	NA
2	121	8/15/01	0	0	NA
2	109	8/15/01	3	0	NA
2	102	8/16/01	0	0	NA
2	105	8/16/01	0	0	NA
3	2	8/20/01	2	1	Hoary Bat
3	9	8/20/01	0	0	NA
3	20	8/20/01	4	0	NA
3	23	8/20/01	1	0	NA
3	14	8/21/01	1	0	NA
3	16	8/21/01	0	1	Hoary Bat
3	30	8/21/01	0	1	Hoary Bat
3	31	8/21/01	0	0	NA
3	111	8/22/01	6	0	NA
2	87	8/25/01	0	0	NA
2	80	8/25/01	1	0	NA
2	136	8/27/01	0	0	NA
2	123	8/27/01	0	1	Eastern Red Bat
2	76	8/28/01	0	0	NA
2	39	8/28/01	9	0	NA
2	46	8/28/01	0	0	NA
2	100	8/30/01	3	0	NA
2	105	8/30/01	0	0	NA
2	104	8/30/01	0	0	NA

Study Area	Turbine	Date	Number Passes	Number Fatalities	Species
3	136	8/31/01	0	0	NA
3	130	8/31/01	0	0	NA
3	133	8/31/01	0	1	Hoary Bat
3	129	8/31/01	0	1	Hoary Bat
3	90	9/01/01	0	0	NA
3	120	9/01/01	3	0	NA
3	116	9/01/01	0	0	NA
3	90	9/01/01	0	0	NA
3	41	9/02/01	0	0	NA
3	48	9/02/01	0	0	NA
3	10	9/03/01	0	0	NA
3	8	9/03/01	0	0	NA
3	18	9/03/01	0	0	NA
3	32	9/04/01	0	0	NA
3	76	9/04/01	0	0	NA
3	67	9/04/01	0	0	NA
3	62	9/04/01	0	0	NA
2	97	9/08/01	0	0	NA
2	93	9/08/01	2	0	NA
2	98	9/08/01	1	0	NA
2	114	9/08/01	0	0	NA
2	74	9/09/01	0	0	NA
2	70	9/09/01	0	0	NA
2	88	9/09/01	0	0	NA
2	10	9/10/01	0	0	NA
2	15	9/10/01	0	0	NA
2	107	9/11/01	0	0	NA
2	141	9/11/01	0	0	NA
3	11	6/26/02	2	0	NA

Number of Bat Passes Recorded with Bat Detectors and Bat Collision Fatalities at Turbines in the Phase 2 and 3 Wind Plants, Buffalo Ridge, Minnesota, 2001-2002

Study Area	Turbine	Date	Number Passes	Number Fatalities	Species
3	28	6/26/02	5	0	NA
3	29	6/26/02	0	0	NA
3	25	6/27/02	2	0	NA
3	18	6/27/02	1	0	NA
3	15	6/27/02	0	0	NA
3	7	6/27/02	0	0	NA
3	14	6/28/02	0	0	NA
3	36	6/28/02	0	0	NA
3	40	6/28/02	0	0	NA
2	125	6/30/02	0	0	NA
2	134	6/30/02	0	0	NA
2	142	6/30/02	9	1	Little Brown Bat
2	116	7/01/02	0	0	NA
2	108	7/01/02	0	0	NA
2	97	7/01/02	0	0	NA
2	73	7/03/02	0	0	NA
2	119	7/03/02	2	0	NA
2	77	7/03/02	2	0	NA
2	66	7/04/02	0	0	NA
2	48	7/04/02	0	0	NA
2	40	7/04/02	4	0	NA
2	136	7/05/02	0	0	NA
2	140	7/05/02	1	0	NA
3	48	7/08/02	1	0	NA
3	76	7/08/02	0	0	NA
3	64	7/08/02	3	0	NA
3	7	7/11/02	0	0	NA
3	18	7/11/02	0	0	NA
3	40	7/11/02	0	0	NA

Study Area	Turbine	Date	Number Passes	Number Fatalities	Species
3	25	7/11/02	0	0	NA
3	84	7/12/02	0	0	NA
3	73	7/12/02	0	0	NA
2	107	7/15/02	0	0	NA
2	109	7/15/02	0	0	NA
2	93	7/15/02	6	0	NA
2	118	7/16/02	0	0	NA
2	120	7/16/02	3	0	NA
2	47	7/16/02	0	0	NA
2	38	7/16/02	0	0	NA
2	35	7/18/02	0	0	NA
2	6	7/18/02	3	0	NA
2	18	7/18/02	0	0	NA
2	15	7/18/02	2	0	NA
3	52	7/22/02	0	0	NA
3	55	7/22/02	1	0	NA
3	35	7/22/02	0	0	NA
3	118	7/25/02	8	1	Hoary Bat
3	132	7/25/02	0	0	NA
3	129	7/25/02	18	0	NA
2	101	7/29/02	0	0	NA
2	95	7/29/02	0	0	NA
2	92	7/29/02	0	0	NA
2	41	8/01/02	8	0	NA
2	15	8/01/02	4	0	NA
2	18	8/01/02	0	1	Hoary Bat
2	78	8/13/02	7	0	NA
2	60	8/13/02	0	0	NA
2	81	8/13/02	9	0	NA

Number of Bat Passes Recorded with Bat Detectors and Bat Collision Fatalities at Turbines in the Phase 2 and 3 Wind Plants, Buffalo Ridge, Minnesota, 2001-2002

Study Area	Turbine	Date	Number Passes	Number Fatalities	Species
2	86	8/13/02	0	0	NA
2	9	8/15/02	0	1	Eastern Red Bat
2	12	8/15/02	2	0	NA
2	4	8/15/02	7	0	NA
2	137	8/17/02	0	0	NA
2	128	8/17/02	2	0	NA
2	130	8/17/02	0	0	NA
3	9	8/19/02	4	0	NA
3	11	8/19/02	0	0	NA
3	5	8/19/02	5	0	NA
3	13	8/19/02	3	0	NA
3	38	9/03/02	5	0	NA
3	46	9/03/02	20	0	NA
3	49	9/03/02	0	0	NA
3	55	9/03/02	0	0	NA
2	52	9/06/02	0	0	NA
2	55	9/06/02	1	0	NA
2	105	9/06/02	0	0	NA
2	121	9/10/02	0	0	NA
2	127	9/10/02	0	0	NA
2	135	9/10/02	0	0	NA
2	142	9/10/02	0	0	NA

C

NUMBER OF BAT PASSES RECORDED AT BAT FORAGING AND ROOSTING AREAS IN THE BUFFALO RIDGE, MINNESOTA STUDY AREA, 2001-2002

Date	Location	Habitat	No. Passes Recorded
6-18-01	Hole in the Mountain Park	Deciduous Woodland	82
6-18-01	Norwegian Creek Park	Brushy Field	19
6-19-01	Hole in the Mountain Park	Deciduous Woodland	20
6-20-01	Wildlife Management Area at P2	Pond	29
6-21-01	Hole in the Mountain Park	Deciduous Woodland	2
6-21-01	Wildlife Management Area at P2	Pond	1
6-24-01	Coteau Marsh Wildlife Management Area	Deciduous Woodland	1
6-24-01	Norwegian Creek Park	Swamp	43
6-25-01	Hole in the Mountain Park	Deciduous Woodland	191
6-25-01	Lake Benton Cemetery	Coniferous Woodland	9
6-27-01	Norwegian Creek Park	Swamp	15
7-2-01	Hole in the Mountain Park	Deciduous Woodland	16
7-3-01	Norwegian Creek Park	Swamp	41
7-4-01	Hole in the Mountain Park	Deciduous Woodland	11
7-9-01	Health Food Store (Lake Benton)	Ponds & Wetlands	121
7-10-01	Health Food Store (Lake Benton)	Ponds & Wetlands	110
7-11-01	Dekam Pond	Pond	0
7-12-01	Hole in the Mountain Park	Deciduous Woodland	22
7-16-01	Picnic Point County Park	Deciduous Woodland	67
7-18-01	Paul’s Pond	Pond	8
7-18-01	Old Barn	Abandoned Farmstead	5

Number of Bat Passes Recorded at Bat Foraging and Roosting Areas in the Buffalo Ridge, Minnesota Study Area, 2001-2002

Date	Location	Habitat	No. Passes Recorded
7-22-01	Hole in the Mountain Park	Deciduous Woodland	69
7-22-01	Woodstock Wildlife Management Area	Swamp	2
7-23-01	Dave Swenson's Farm House	Deciduous Woodland	40
7-23-01	Hole in the Mountain Park	Deciduous Woodland	119
7-25-01	Hole in the Mountain Park	Deciduous Woodland	155
7-29-01	Collinson Wildlife Management Area	Deciduous Woodland &Wetland	145
7-30-01	Collinson Wildlife Management Area	Deciduous Woodland &Wetland	10
8-10-01	Coteau Marsh Wildlife Management Area	Deciduous Woodland	8
8-15-01	Hole in the Mountain Park	Deciduous Woodland	7
8-22-01	Lake Benton Cemetery	Coniferous Woodland	15
8-22-01	Klinger Wildlife Management Area	CRP	0
8-22-01	Holland Wildlife Management Area	CRP & Stream	12
8-23-01	Hole in the Mountain Park	Deciduous Woodland	2
8-25-01	Collinson Wildlife Management Area	Deciduous Woodland &Wetland	1
8-27-01	Hole in the Mountain Park	Deciduous Woodland	4
8-27-01	Hole in the Mountain Park	Deciduous Woodland	17
8-28-01	Hole in the Mountain Park	Deciduous Woodland	13
8-30-01	Hole in the Mountain Park	Deciduous Woodland	6
9-5-01	Health Food Store (Lake Benton)	Ponds & Wetlands	46
9-5-01	Hole in the Mountain Park	Deciduous Woodland	113
9-5-01	Showboat Park	Lake	14
9-5-01	Hole in the Mountain Park	Deciduous Woodland	4
9-7-01	Hole in the Mountain Park	Deciduous Woodland	0
9-7-01	Hole in the Mountain Park	Deciduous Woodland	7
9-7-01	Norwegian Creek Park	Brushy Field	0
9-12-01	Hole in the Mountain Park	Deciduous Woodland	0
9-12-01	Hole in the Mountain Park	Deciduous Woodland	2
9-12-01	Hole in the Mountain Park	Deciduous Woodland	0

Date	Location	Habitat	No. Passes Recorded
6-17-02	Hole in the Mountain Park	Deciduous Woodland	98
6-19-02	Hole in the Mountain Park	Deciduous Woodland	9
6-19-02	Hole in the Mountain Park	Deciduous Woodland	40
6-19-02	Hole in the Mountain Park	Deciduous Woodland	95
6-21-02	Hole in the Mountain Park	Deciduous Woodland	33
6-30-02	Collinson Wildlife Management Area	Deciduous Woodland, Wetland, & CRP	13
7-01-02	Hole in the Mountain Park	Deciduous Woodland	29
7-04-02	Phase 2 Stock Pond	Stock Pond in Pasture	3
7-10-02	Picnic Point County Park	Deciduous Woodland	1
7-12-02	Coteau Marsh Wildlife Management Area	Wetland & Water	6
7-12-02	Hole in the Mountain Park	Deciduous Woodland	111
7-15-02	Hole in the Mountain Park	Deciduous Woodland	495
7-17-02	Phase 2 Stock Pond	Stock Pond in Pasture	10
7-17-02	Picnic Point County Park	Deciduous Woodland	41
7-19-02	Hole in the Mountain Park	Deciduous Woodland	70
7-25-02	Coteau Marsh Wildlife Management Area	Wetland & Water	4
7-29-02	Hole in the Mountain Park	Deciduous Woodland	128
7-31-02	Phase 2 Stock Pond	Stock Pond in Pasture	0
7-31-02	Phase 2 Stock Pond	Stock Pond in Pasture	0
7-31-02	Phase 2 Stock Pond	Stock Pond in Pasture	0
7-31-02	Hole in the Mountain Park	Deciduous Woodland	174
8-02-02	Hole in the Mountain Park	Deciduous Woodland	75
8-12-02	Hole in the Mountain Park	Deciduous Woodland	85
8-14-02	Hole in the Mountain Park	Deciduous Woodland	379
8-17-02	Hole in the Mountain Park	Deciduous Woodland	17
8-21-02	Hole in the Mountain Park	Deciduous Woodland	104
8-24-02	Hole in the Mountain Park	Deciduous Woodland	43
9-06-02	Hole in the Mountain Park	Deciduous Woodland	31

D

TRAPPING EFFORT AND BATS CAPTURED IN THE BUFFALO RIDGE, MINNESOTA STUDY AREA, 2001-2002

Date	Location	Habitat	Mist Net Hours	Species Captured	Number Captured
6-19-01	Hole in the Mtn. Park	Deciduous Woodland	15	none	
6-20-01	Hole in the Mtn. Park	Deciduous Woodland	15	big brown bat	1
6-21-01	P2 Wildlife Mgmt Area	Pond	15	none	
6-24-01	Hole in the Mtn. Park	Deciduous Woodland	16	none	
6-25-01	Hole in the Mtn. Park	Deciduous Woodland	18	big brown bat	8
6-26-01	P3 Turbine 28	Deciduous Forest/CRP	14	none	
6-27-01	Norwegian Creek Park	Young Spruce Forest	19	none	
7-2-01	Hole in the Mtn. Park	Deciduous Woodland	24	big brown bat	1
7-3-01	Norwegian Creek Park	Pond	18	none	
7-4-01	Hole in the Mtn. Park	Deciduous Woodland	37	none	
7-8-01	P3 Turbine 5	Tree Row/Cornfield	23	none	
7-10-01	W. side Lake Benton	Ponds	18	none	
7-11-01	Dekam Pond	Pond	15	none	
7-12-01	Hole in the Mtn. Park	Deciduous Woodland	20	little brown bat	1
7-15-01	Hole in the Mtn. Park	Deciduous Woodland	27	big brown bat little brown bat silver-haired bat	3 9 2
7-16-01	Picnic Point County Park	Woodland Wetland	27	none	
7-18-01	P2 Turbine 139	Crp	20	none	

Trapping Effort and Bats Captured in the Buffalo Ridge, Minnesota Study Area, 2001-2002

Date	Location	Habitat	Mist Net Hours	Species Captured	Number Captured
7-19-01	W. side Lake Benton	Ponds	27	none	
7-22-01	Hole in the Mtn. Park	Deciduous Woodland	20	none	
7-23-01	Hole in the Mtn. Park	Deciduous Woodland	30	eastern red bat	2
7-25-01	Hole in the Mtn. Park	Deciduous Woodland	20	none	
7-26-01	Hole in the Mtn. Park	Deciduous Woodland	28	big brown bat little brown bat	7 1
7-29-01	Picnic Point County Park	Deciduous Woodland	22	none	
7-30-01	Collinson Wildlife Mgmt Area	Mixed Woodland	18	none	
8-1-01	Hole in the Mtn. Park	Deciduous Woodland	24	big brown bat	1
8-7-01	Hole in the Mtn. Park	Deciduous Woodland	19	none	
8-9-01	Swenson's place	Residential Woodlot	21	none	
8-10-01	Coteau Marsh WMA	Deciduous Woodland/Ponds	21	none	
8-14-01	City of Lake Benton	Near House	2	big brown bat	2
8-15-01	Hole in the Mtn. Park	Deciduous Woodland	21	none	
8-22-01	Holland Wildlife Mgmt Area	Ponds	16	none	
8-25-01	Collinson Wildlife Mgmt Area	Mixed Woodland	18	none	
8-23-01	Hole in the Mtn. Park	Deciduous Woodland	24	none	
8-30-01	Hole in the Mtn. Park	Deciduous Woodland	18	none	
9-7-01	Hole in the Mtn. Park	Deciduous Woodland	26	none	
6-17-02	Hole in the Mtn. Park	Deciduous Woodland	24	big brown bat	2
6-19-02	Hole in the Mtn. Park	Deciduous Woodland	29	silver-haired bat big brown bat	1 1
6-21-02	Hole in the Mtn. Park	Deciduous Woodland	26	None	
6-26-02	West end Lake Benton	Wetlands, Ponds	18	None	

Date	Location	Habitat	Mist Net Hours	Species Captured	Number Captured
6-28-02	Hole in the Mtn. Park	Deciduous Woodland	39	eastern red bat	1
7-1-02	Hole in the Mtn. Park	Deciduous Woodland	32	big brown bat	1
7-3-02	Collinson Wildlife Mgmt Area	Mixed Woodland	25	None	
7-8-02	Hole in the Mtn. Park	Deciduous Woodland	32	eastern red bat silver-haired bat	2 1
7-10-02	Picnic Point County Park	Deciduous Woodland	30	None	
7-12-02	Hole in the Mtn. Park	Deciduous Woodland	32	big brown bat silver-haired bat	2 2
7-15-02	Hole in the Mtn. Park	Deciduous Woodland	45	big brown bat silver-haired bat eastern red bat	5 1 1
7-17-02	Picnic Point County Park	Deciduous Woodland	32	None	
7-19-02	Hole in the Mtn. Park	Deciduous Woodland	33	silver-haired bat big brown bat	5 9
7-22-02	Hole in the Mtn. Park	Deciduous Woodland	28	big brown bat	4
7-25-02	Hole in the Mtn. Park	Deciduous Woodland	35	None	
7-29-02	Hole in the Mtn. Park	Deciduous Woodland	36	Hoary bat big brown bat eastern red bat silver-haired bat	2 3 1 2
7-31-02	Hole in the Mtn. Park	Deciduous Woodland	37	Hoary bat big brown bat silver-haired bat	1 5 1
8-2-02	Hole in the Mtn. Park	Deciduous Woodland	44	big brown bat silver-haired bat	3 2
8-12-02	Hole in the Mtn. Park	Deciduous Woodland	32	big brown bat	2
8-14-02	Hole in the Mtn. Park	Deciduous Woodland	48	big brown bat	5
8-17-02	Hole in the Mtn. Park	Deciduous Woodland	35	big brown bat	1
8-21-02	Hole in the Mtn. Park	Deciduous Woodland	62	eastern red bat	1
8-24-02	Hole in the Mtn. Park	Deciduous Woodland	33	None	

Trapping Effort and Bats Captured in the Buffalo Ridge, Minnesota Study Area, 2001-2002

Date	Location	Habitat	Mist Net Hours	Species Captured	Number Captured
9-6-02	Hole in the Mtn. Park	Deciduous Woodland	24	None	
9-11-02	Hole in the Mtn. Park	Deciduous Woodland	18	None	
TOTAL			1545	Big Brown Bat	64
				Little Brown Bat	11
				Silver-Haired Bat	17
				Hoary Bat	3
				Eastern Red Bat	8
				TOTAL	103

Program:

Rights-of-Way Environmental Issues in Siting, Development, and Management

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